BIOLOGY OF LICHENS

Roderick Westgarth Rogers **BSc(Hons) PhD (Adelaide)**

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Statements

Except where indicated in the list of cited publications and attributions this thesis contains no work which has been accepted for the award of any diploma or degree in any university, and, to the best of my knowledge and belief the thesis contains no material previously published or written by another person except where due reference is made.

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Roderick W. Rogers BSc(Hons) PhD (Adelaide)

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ABSTRACT

Lichens are a group of organisms that make a significant contribution to biodiversity and ecosystem function in many environments. This account of studies undertaken over a thirty-year period includes studies on lichens in mediterranean and subtropical arid lands, subtropical woodlands and rainforests. Substrata examined include soil surfaces, leaves, bark, palm-trunks and calcareous concretions on a coral cay.

The systematics of lichenised fungi has undergone dramatic change in the last fifty years, with the role of secondary chemical products, ascocarp ontogeny and the structure of the ascus being given great weight. These issues are examined in terms of revisional studies of Australian taxa and the development of systems of classification for the Australian Lichen flora, necessitating creation of new taxa at species, genus and family level.

The ecology and biogeography of lichens follows patterns which are similar to those exhibited by plants. The lichens are shown to be extreme stress tolerators when compared with flowering plants. Within the lichens different ecological strategies can be determined that relate to both systematics and environment. The nature of succession in lichen communities varies with nature of the community and the scale of study.

The first and last papers in the series relate to lichens on arid-zone soil surfaces. Lichens are economically and environmentally important in these fragile land systems where they stabilise the soil surface and are associated with nitrogen fixation.

The work presented here documents both my intellectual development and the transition of Australian lichenology from an intellectual backwater to its current prominent place in the global lichenological community.

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BIOLOGY OF LICHENS

INTRODUCTION

I commenced postgraduate studies in The University of Adelaide in 1966. To that date only a handful of papers written in Australia during the 20th century referred to lichens, and little attention had been paid to Australian lichens elsewhere. No account of the lichens of Australia was available for use, not even a catalogue.

During the 1960's the environment movement was awakening. In South Australia the sustainability of grazing in the semi-arid rangelands was a concern, with nitrogen balance attracting attention. In this context I visited the rangelands of South Australia and found vast areas covered with a dense, species-rich carpet of lichens. Because some lichens were known to fix nitrogen it was suspected that fixation might be associated with these crusts too. Nitrogen fixation was demonstrated, and this discovery resulted in my first publication (1) and launched me into the study of lichens.

The study of the biology of lichens has been intertwined with my broader botanical interests, which have revolved around issues of diversity and sustainability.

My studies in lichen biology are conveniently treated in two inter-related and inter-dependent fields, Ecology and Systematics.

ECOLOGY

LICHENS IN SEMI-ARID RANGELANDS: ECOLOGY, ECOPHYSIOLOGY AND BIOGEOGRAPHY

The semi-arid chenopod shrublands of southern Australia have been subject to grazing by stock since the middle of the nineteenth century. Despite a history of ecological study of these rangelands, only passing mention had been made of the often continuous cover of lichens on the soils. The soil surface crusts were shown to be rich in lichen species (2), and numerical analysis demonstrated that the lichen associations could be distinguished (3). The lichen flora was richest in areas with a marked winter rainfall pattern, and calcareous (alkaline but not strongly sodic) soils (4). On a smaller scale, lichens were distributed in an inverse relationship to intensity of stocking within a paddock (5).

The lichen *Chondropsis semiviridis* was selected for detailed ecophysiological study because its distribution pattern epitomised that of a large group of species, it was readily available, lived unattached on the soil surface and was beautiful. The distribution of *C. semiviridis* could be related to its sensitivity to heat when wet and its capacity to survive drought, linking biogeographical patterns to ecophysiological tolerance (6).

The contrasting subtropical semi-arid grasslands of central Queensland have also been subject to prolonged grazing. These grasslands have a predominance of summer rainfall and acid soils, and the soil surface is not crusted extensively by lichens. However, lichen species occur scattered along with Bryophytes and Cyanobacteria amongst the perennial grasses. Stocking has influenced these crusts and their lichens in a manner similar to that reported for those in southern Australia (7).

A review of the ecology and biogeography of the lichens from the world's hot arid and semi-arid lands (8) highlighted their significance, and was followed up in a symposium at the 1981 International Botanical Congress (9,10). Lichen crusts and their associated cyanobacteria play an important role in the ecology of arid lands. They fix nitrogen, prevent erosion and influence soil moisture retention. Loss of these crusts must, therefore, have an effect on other components on the system.

COMPARATIVE ECOLOGY: TACTICS AND STRATEGIES

Lichen communities in the vicinity of Brisbane offered opportunities to develop ecological strategy theory while gaining insight into lichen biology.

Two contrasting populations were selected for study, lichens growing on the trunks of palms in an urban environment, and those on leaves of shrubs in a sub-tropical rainforest. Treating a palm trunk as a vertical chronosequence allowed a study of the effect of age and aspect, thus examining the interactions between diverse species, succession, competition and environmentally induced stress in terms of ecological strategy theory (11). The populations of lichens on rainforest leaves were interesting in that they occupied small naturally defined spaces (leaves) with a finite, probably short, life span (12). The life span of the leaves, however, proved to be much longer than expected (6.8 years) (13,14).

The successional patterns of lichens on rainforest leaves fitted a 'tolerance' model if individual leaves were considered, or a 'chronic disturbance' model if the leaf population was considered (15,16). Lichen colonisation rates on the leaves were species and time dependent

(16). The species of host plant and leaf area were also implicated in colonisation patterns (14).

When selected attributes of the lichens on palms and on leaves were collated with other available records, Grime's CSR strategy theory could be applied (17). Ecological strategies could be related to family level taxonomy, to lichen growth form and diversity of secondary chemistry. Grouping lichens in a common quantitative CSR ordination with vascular plants confirmed that lichens are extreme stress tolerators (17).

SYSTEMATICS

REVISIONAL STUDIES

Field studies brought to notice lichen taxa that were apparently undescribed, and a series of revisional studies were undertaken. The genus *Haematomma* had not been monographed since 1804, and collections posed problems. Revisions of *Haematomma* for Australia (18,19) and New Zealand (20), used apothecial ontogeny and secondary chemistry as major taxonomic features. Several new species were recognised, and many synonyms identified. These studies suggested that the genus *Haematomma* was heterogenous, a view confirmed by studies of ascus tip morphology (21). *Haematomma* was consequently split and the genus *Ophioparma* reinstated to accommodate some arctic-alpine species from Europe and North America, and for which the family Ophioparmataceae R.W.Rogers & Hafellner was created.

The characteristically subtropical genus *Pyxine* was revised for Australia (22, 23), recognising a number of new taxa and reducing a number to synonymy. As with *Haematomma,* the practice of requiring that chemical differences be correlated with morphological variation before recognising species was followed.

Revision of the *Usnea baileyi* complex (*Usnea* subgenus *Eumitria*) in Australia was undertaken in an attempt to unravel a particularly difficult group in a notoriously difficult genus. Fourteen taxa were reduced to synonymy with this species (24). It also became apparent that use of secondary chemical criteria in separating species needed review. It appeared that a one-gene one-species rule was being applied, and the relationship between secondary metabolites and taxonomy was therefore investigated. I suggested that, in many cases, the production of secondary metabolites in lichens, as in the non-lichenised ascomycete fungi producing commercial antibiotics, was the result of a series of relatively non-specific enzymes (25). Metabolism of this type means that different chemical composition can only be considered to have a genetic base if different biosynthetic pathways are involved, for, depending on the sequence and speed of enzyme actions, a great variety of end-products could result from the same genotypes.

PECULIAR SPECIES WITH ECOLOGICAL INTEREST

A number of unusual lichens attracted attention. A lichen with a distinctive ecorticate growth form collected from the *Nothofagus* forests of southern Queensland superficially resembled species from *Nothofagus* forests in Tasmania, New Zealand and South America. The genus *Sagenidiopsis* was created for this new species (26). While clearly a member of the Opegraphales, *Sagenidiopsis* could not be placed in any existing family. It appears, therefore, that the cool misty habitat of *Nothofagus* forests has resulted in the evolution of morphologically convergent lichens in at least three families.

A crustose lichen with 32-spored asci from the mangroves near Brisbane was placed in the genus *Maronea* (Acarosporaceae) by traditional taxonomy. However, ascus structure placed it in the family Porpidiaceae. A literature search revealed similar taxa had been described as species of *Maronea* from tropical South America: the genus *Maronina* was therefore created to house these species (27).

A crustose marine lichen found growing in cavities of the calcareous intertidal rock of the coral cay Heron Island, was described as a new species and named *Verrucaria cribbii* to honour the pioneering work of Dr. A.B.Cribb on marine algae and fungi (28).

FLORAS

The production of a flora requires an understanding of the group being studied, its taxonomic history and the present state of its taxonomy. Because of their breadth such works are an easy target for criticism from a range of workers on any of their many aspects - key construction, taxonomic system, form of presentation, and, I discovered, of the appropriateness of attempting the work at the particular time. I have been involved in three flora projects. The *Lichen Flora of South Australia* (29) was the first lichen flora produced in Australia this century. It permitted the identification of Australian lichens from mediterranean-type climates using a modern system of classification, with workable keys, descriptions and illustrations.

The Lichen Flora of South Australia was of limited use. Attempts to identify lichens from tropical and subtropical areas were made difficult by the absence of any modern key to the genera of lichens found in the tropics. *The Genera of Australian Lichens* (30) includes keys to all lichen genera reported from Australia to that time. Consistent, standardised generic descriptions were developed incorporating the morphological and chemical attributes upon which modern classifications depend. It was a significant irritant that one reviewer criticised the work for this very consistency, which was found to be tedious!

Following the International Botanical Congress in Sydney 1981, work was commenced on a lichen flora within the Flora of Australia Program. For this monumental work I have written chapters dealing with the photobionts of lichens (31). In addition a new system of classification was prepared based on contemporary views (32), and a new key to the genera of lichens in Australia written (33). The new key covers more genera than in any previous flora, and allows the determination of the macro-lichens when sterile. The only other comparable region for which a modern key to the genera of lichens had been published was western Europe.

BIOGEOGRAPHY

Studies of the ecology of lichens on arid zone soils required that I be my own systematist, for no research had been carried out on this group of organisms in Australia, and little anywhere in the world. Several publications concerning the lichen flora of arid south-eastern Australia resulted (4,34).

An attempt to relate the lichen flora of Brisbane to air quality patterns (35), resulted in the establishment of a lichen herbarium which eventually exceeded 20,000 collections and became a research tool in its own right (36). Because of limited studies of the lichens from tropical regions it was necessary to search for types in European Herbaria and typify names (37, 38). As a result of these studies descriptive accounts of several local floras were produced (12,39,40,41,42).

Building on these and other collections an account of the biogeographic relationships of the lichen flora within Australia, and of the relationships of the Australian lichen flora to that of the rest of the world was prepared (43). Within Australia distribution patterns resembled climatic patterns. There was, however, a remarkable diversity on the eastern coast near Brisbane, in the "McPherson-McLeay Overlap" region. An identifiable Gondwanan element in the Australian flora was not surprising, but the close link between the tropical and subtropical elements to the flora of Africa rather than to that of South America was unexpected, given the close link between the cool temperate floras of Australia and South America. A revised biogeographic treatment in the Flora of Australia series (44) produced a similar outcome.

CONCLUSION

It was my good fortune to commence research on lichens at a time when lichenology was entering a renaissance globally, and when several others became involved in Australia. My studies on the lichen flora of Australia, undertaken over a period of 30 years, have resulted in a substantial addition to knowledge and understanding of the Australian biota. These studies, and the resources generated by them, provided a significant impetus for the production of a lichen flora for Australia. More importantly, they have resulted in a better understanding of lichens, in the application of contemporary biological insights to lichen ecology and taxonomy, and in the production of the tools necessary for others to continue to advance Lichenology.

The works presented here are a significant contribution to lichen biology.

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(Reprinted from Nature, Vol. 209, No. 5018, pp. 96–97, January 1, 1966)

Nitrogen Fixation by Lichens of Arid Soil Crusts

THE nitrogen budgets for natural ecological systems are poorly understood, and the contribution of particular microflora in these associations has been only tentatively assessed[1–3]. This applies especially to arid zones where soils sometimes have a surface crust of lichens, some blue-green algae, and other cryptogams covering as much as 30 per cent of the total soil area. It is of considerable interest therefore to determine to what extent these lichens fix atmospheric nitrogen, since they might contribute appreciably to the maintenance of a favourable nitrogen balance in these areas.

About forty species of lichens are known to occur in the southern central arid zone in Australia, and twelve of the commonest were exposed to a gas mixture containing nitrogen enriched with nitrogen-15. Thus each lichen was incubated in a Warburg flask for 6 days at 21° C under artificial light, using the following gas mixture (in atmospheres): oxygen 0·2, nitrogen 0·2 (enriched with 35 atom per cent excess nitrogen-15), and helium 0·6. After this period the contents of each flask were digested in acid, and converted to ammonia by distillation in a Markham apparatus and then to nitrogen gas which was analysed in an A.E.I. MS_2 mass spectrometer. Nine lichens, including *Parmelia adhaerens* Nyl, apud Cromb., *P. australiensis* Cromb., *P. semiviridis* (F.v.M. ex Nyl.) P. Bibby, *Caloplaca citrina* (Hoffm.) T. Fries, *Caloplaca* T. Fries sp., *Dermatocarpon hepaticum* (Lam.) Th. Fr., *Diploschistes scruposus* (Schreb.) Norm., and *Lecidea decipiens* Ach., with one unidentified species, showed no significant fixation. There was a significant incorporation of nitrogen gas, however, into *Collema coccophorus* Tuck. (0·97 and 0·69 atom per cent excess in duplicate samples), whereas *Lecidea crystalifera* Tayl. (0·022 atom per cent excess) and *Parmelia conspersa* (Ehrh.) Ach. (0·0073 atom per cent excess) had a marginal fixation only.

Collema coccophorus has a blue-green algal symbiont (*Nostoc* sp.). The lichen is minute but very widely distributed in the soil lichen crust. Shields, Mitchell and Drouet[4] have suggested that this species might fix nitrogen in the arid soil-crust in California. *Lecidea crystalifera*, which is also widespread in this area, has a green algal symbiont (*Protococcus*), hence the fixation associated with this lichen is of interest and will be investigated further. The lichen has a small squamulose thallus with long rhizoids penetrating up to 1 cm into the soil. *Parmelia* *adhaerens* similarly has a green algal symbiont (*Protococcus*), and occurs on rocks where it is fairly widespread.

This preliminary work suggests that the lichen crust may contribute appreciably to the nitrogen balance in Australian arid soils.

R. W. Rogers
R. T. Lange

Department of Botany,
University of Adelaide,
South Australia.

D. J. D. Nicholas

Department of Agricultural Biochemistry,
Waite Agricultural Research Institute,
Glen Osmond, South Australia.

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SOIL SURFACE LICHENS IN ARID AND SUBARID SOUTH-EASTERN AUSTRALIA

I. INTRODUCTION AND FLORISTICS

By R. W. ROGERS*† and R. T. LANGE*

[Manuscript received 16 December 1971]

Abstract

Lichens on soils in Australia have been neglected until recently. This paper describes a study area of nearly 1 million km^2 in south-eastern Australia, and the methods used to determine the lichens found on the soil surfaces in that area.

In all, 343 locations were examined, 227 of which had soil surface lichens. From the range of lichens encountered a total of 42 taxa were delimited, and in 36 cases ascribed to previously described species or complexes; the remaining six were either undescribed, or depauperate forms which could not be placed.

The world phytogeographic implications of this study are discussed.

I. INTRODUCTION

It has been known for a long time that arid soils are commonly crusted with lichens. As early as 1776, Pallas (cited in Elenkin 1901*b*) noted a rarely broken crust of greyish lichens on the Russian steppes. Elenkin (1901*a*, 1901*b*, 1901*c*) thoroughly reviewed the early literature. Reichert (1937) wrote that "... the bare soil of the desert, when firm and not drifting, is mostly covered by lichens". This assertion has been supported by other workers including Faurel, Ozenda, and Schotter (1953) in Algeria; Cameron and Blank (1966) in California; Keller (1930) in Russia; Galun (1962) in Israel; and Rogers and Lange (1971) in South Australia.

Other than the last-mentioned report, very little work has been done on lichens from Australian arid zone soils. Because of the ecological significance of such crusts (Shields, Mitchell, and Drouet 1957; Cameron and Blank 1966; Fletcher and Martin 1949) a study of the extent, composition, and factors controlling the distribution of lichens on arid soil surfaces was initiated in south-eastern Australia. In delimiting a study area, it was assumed that factors controlling the distribution of the angiosperms were likely to control lichen distribution too.

The area for the study had therefore to be a compromise: large enough to embrace wide climatic, soil, and historical variations, yet small enough to be conveniently studied from a base in Adelaide.

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* Department of Botany, University of Adelaide, Adelaide, S.A. 5000.

† Present address: Department of Botany, University of Queensland, St. Lucia, Qld. 4067.

Aust. J. Bot., 1972, **20**, 197–213

Adelaide, which has a relatively high rainfall with a marked seasonal incidence, most falling in the winter, was selected as one climatic pole for the study. A second pole was located near Bourke in northern New South Wales, where rainfall is also seasonal but shows a marked summer maximum. Between these two is a large area with rainfall erratically distributed throughout the year. Included is an area around Lake Eyre (due north of Adelaide) which has the lowest average annual rainfall recorded on the Australian continent. Inspection of soil maps indicated great diversity of soils in the area, which lies across three States (South Australia, New South Wales, and Victoria) with three diverse histories of land usage. Thus for this study a rectangle including Adelaide, part of Lake Eyre, and Bourke (Fig. 1) was accepted as optimal in balance between scope of variation and technical resources available.

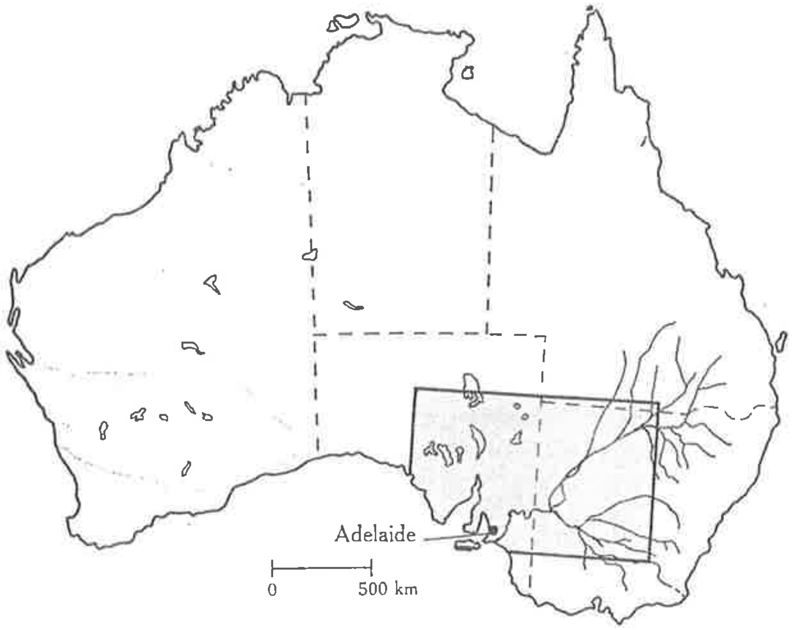


Fig. 1.—The area shaded is that shown in detailed maps of the study area.

II. Description of Study Area

Appreciation of the field work involved in this study requires a knowledge of the physical context within which the work was executed. No single work adequately describes that context; much of the information is scattered in diverse studies on single aspects of the environment. The following account strikes a balance between brevity and completeness.

(a) *Landscape*

The physical geography of arid Australia has been reviewed by Lustig (1968). Mabbutt (1969) mapped the geomorphology of a large part of the study area, but the most detailed physiographic map of the whole area was that prepared by Lobeck (1951), which served as a basis for regional nomenclature.

The predominant landscape form is the vast desert plain which, except for the Mt. Lofty–Flinders Range system, is interrupted only occasionally by relatively low hills. The generally slight relief of the whole region is apparent from the small area over 300 m in altitude (Fig. 2), and is further illustrated by the fact that St. Mary's Peak in the Flinders Range, which is the highest point in the region, reaches a height of only 1200 m.

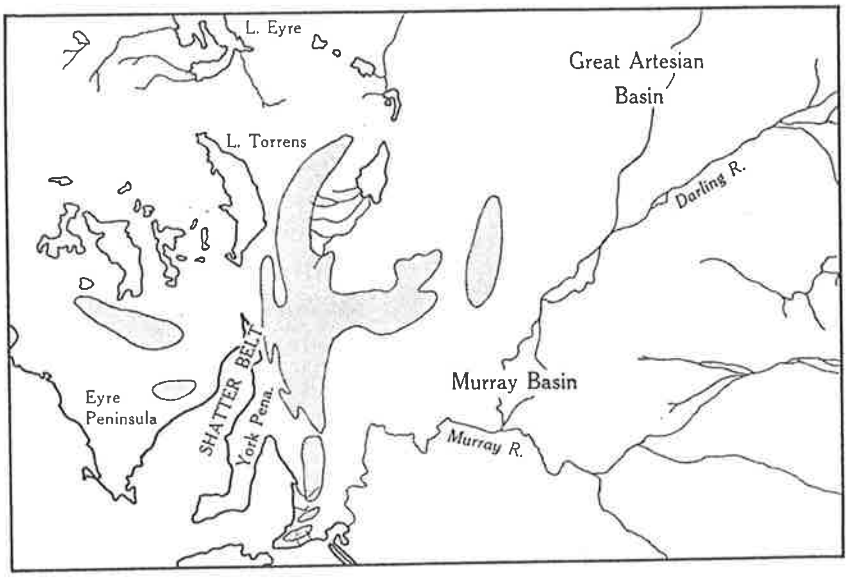


Fig. 2.—Major geographic features of the study area. Areas with an elevation above 300 m are shaded.

Arching around the east and north of the "shatter belt" is the sweep of the eastern Australian basins: the Murray Basin in the south and the Great Artesian Basin in the north. Both are virtually without relief.

The basins are flat, low-lying areas across which rivers from the eastern ranges flow towards the sea. Because of the very low gradient, the rivers meander and anastomose, some of them never reaching the main Murray–Darling river system. These rivers do not drain the basins themselves, but simply flow across them.

West of the shatter belt in the Pre-Cambrian and Cambrian rocks of South Australia lies a series of salt pans associated with internal drainage. In the north-west are areas of stony pavement either on broad flat tableland areas or on outlying mesas, overlying the Pre-Cambrian Australian Shield.

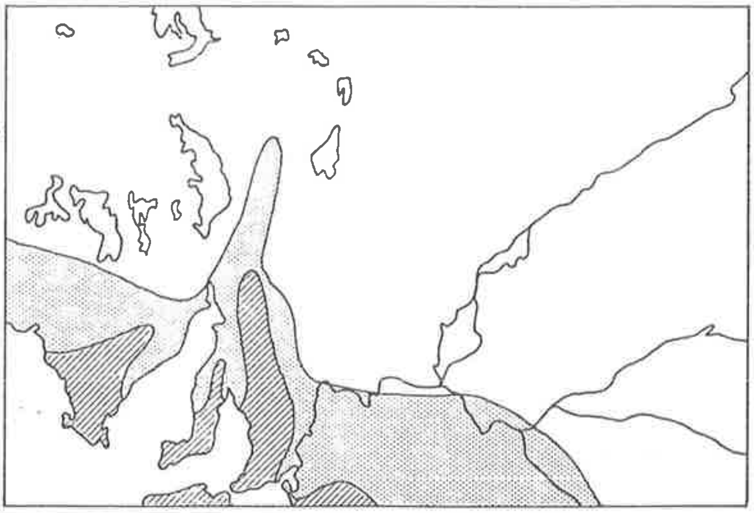
(*b*) *Climate*

(i) *Climatic Zones*

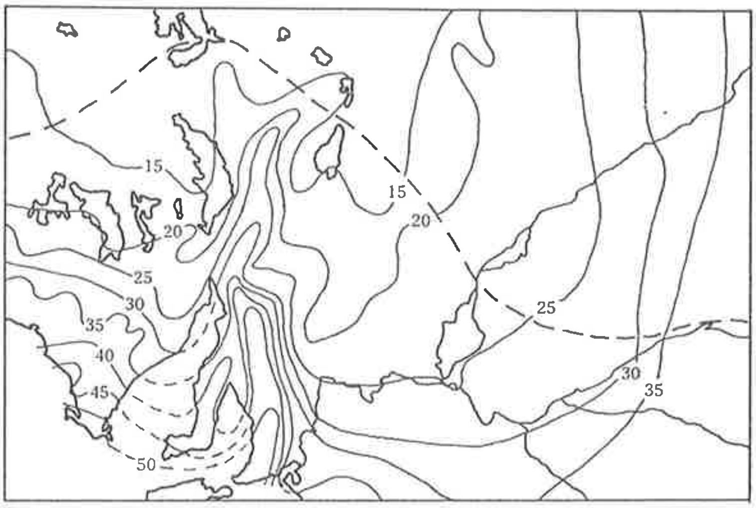
The study area has been zoned climatically in different ways by a number of workers; probably the most widely known classification is that proposed by Meigs (1953). On Meigs's zonation, virtually all the study area is classed as arid or semiarid, with a small temperate area included in the hills near Adelaide.

Perry (1967) mapped the limits of "rangeland" on the basis of the climatic variables affecting water balance, and in the light of land usage. For the purpose of this study, the area described by Perry as rangeland has been treated as arid. For convenience, the 38 cm rainfall isohyet has been taken as the upper rainfall limit of the subarid zone in South Australia, all areas wetter than that being considered humid. Such a criterion would not be suited to use on the eastern boundary of the study zone.

(3)



(4)



(5)

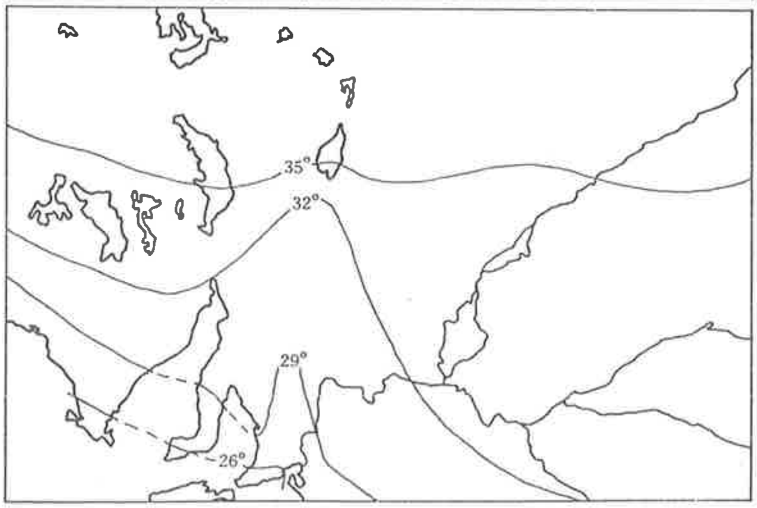


Fig. 3.—Climatic regions of the study area. Shaded areas are considered humid, stippled areas subarid, the rest arid.

Fig. 4.—Rainfall isohyets at 5 cm intervals. Isohyets above 50 cm in the region near Adelaide are too densely crowded to be drawn. The broken line marks the northern limit of the area with a seasonal precipitation maximum in the winter.

Fig. 5.—Normal January maximum temperatures (°C).

The limits of the arid zone, subarid zone, and humid zone as defined above are shown in Figure 3. This classification has been used throughout this study.

(ii) *Rainfall*

Rainfall in the area varies from less than 12 cm in the Lake Eyre Basin to more than 100 cm in restricted areas of the Mount Lofty Ranges, near Adelaide. Rainfall isohyets form a nested series paralleling the coast, except for the disturbance caused by the Mount Lofty–Flinders Ranges, which have the effect of increasing precipitation on the western face of the ranges and creating a rain shadow on the eastern face. The distribution of rainfall isohyets as shown in Figure 4 was based largely on information in climatological surveys published by the Australian Bureau of Meteorology (1955–1963).

In the north-east of the study area, rainfall is concentrated in relatively intense summer showers whereas in the south-west rainfall is mostly in the winter, falling in frequent light showers (Leeper 1960). The area with a seasonal maximum precipitation in the winter is delimited in Figure 4 (Australia, Department of the Interior, Meteorological Branch 1954).

(iii) *Temperature*

There is considerable variation in temperature regime across the area; Figure 5 shows normal January maximum temperatures. Some areas with a normal July minimum of less than 5°C have a normal January maximum of more than 35°, diurnal variations in excess of 15° not being uncommon (Jackson 1958).

(*c*) *Soils*

Soils of the area have been mapped in soil associations by Northcote (1960, 1966) and Northcote *et al.* (1968). With the exception of skeletal types on hilly areas, the soils are climatically zoned. In the humid zone are small areas of podzolic, solodized solonetz and solodic soils, but the soils in most of the areas with rainfall between 38 and 50 cm per annum are red-brown earths. In the subarid zone highly calcareous solonized brown soils (mallisols) predominate. In the arid zone of South Australia there are large areas of highly calcareous brown soils, with calcareous desert soils and stony desert loams in the drier parts. In southern New South Wales there is a vast area of grey or brown soils of heavy texture, mostly cracking clays. In northern New South Wales there are expanses of arid red earths, notable because they are particularly susceptible to erosion (Beadle 1948) and are neutral to acid in reaction, whereas virtually all of the other arid or subarid soils are neutral to strongly alkaline in reaction.

(*d*) *Vegetation*

The vegetation of most of the area has been described by Wood (1937), Beadle (1948), and Jessup (1951), each of whom published maps and floristic lists: Wood for eastern South Australia, Beadle for western New South Wales, and Jessup for a large area in arid central South Australia. The vegetation of the whole area has been mapped by Williams (1955) on a physiographic basis.

The vegetation of the study area can be conveniently considered in three broad units: the desert complex, the mallee, and the dry sclerophyll woodlands.

The dry sclerophyll fascies is virtually restricted to the humid zone, and varies from *Eucalyptus* forests near Adelaide to open *Eucalyptus* savannah, but is always marked by the presence of *Eucalyptus* trees. An understorey of grasses, herbs, and forbs is common (but not universal) in these vegetation types.

The mallee vegetation form is a distinctive subarid form, characterized by low, many-trunked *Eucalyptus* species, ranging in density from that comparable with open woodland to that resulting in a closed canopy. In wetter areas the mallee may have a sclerophyllous shrub layer below. However, in most of the subarid region bare soil is common between the trees and bushes, with a cover of forbs and grasses appearing seasonally.

The desert complex is very varied indeed. Within the study zone there are areas of layered arid woodland, of arid shrubland, and of virtually bare desert sandhills and plains.

Common to the arid shrubland, arid woodland, and some mallee areas is a layer of low shrubs of the family Chenopodiaceae, especially *Atriplex* and *Kochia* species. The soil in the desert complex is bare except for a growth of forbs and grasses after heavy rains.

The shrub vegetation, which forms the basis of the arid zone pastoral industry, has been extensively damaged by grazing sheep (Beadle 1948; Jessup 1951); many areas formerly clad with Chenopodiaceae are now devoid of any perennial shrub vegetation.

III. FLORISTICS AND DISTRIBUTION OF SOIL SURFACE LICHEN FLORA

(*a*) *Sampling Method*

To deal with the problem of sampling an extremely large area (about 1 million sq km), a sampling system had to be devised that compromised between the strict statistical requirement of random sampling and the biological requirement that the variation across the entire area be sampled. Samples were collected at regular intervals along transects formed by the roads and tracks across the area, the interval between samples (never in excess of 32 km) being determined by an assessment of the variation shown in the landscape. If it was found that sharp changes occurred in the vegetation, samples were taken from the various vegetation types found.

The routes were selected to form a grid across the study area, with the transects normal to rainfall isohyets, one of the factors predicted to control distribution. As collection and sorting of samples proceeded, the information so gained was used to modify the planned transects.

At each sampling site specimens of the soil surface lichen crust were collected from areas about 50 m in diameter. In anticipation of an effect of soil type on distribution patterns, a sample of about 400 g from the top 2 cm was taken of the typical soil at each site.

In all, 343 sites were visited (Fig. 6) and sampled along *c.* 15,000 km of transects. Of the 227 locations with soil surface lichens, 118 showed the development of a distinct lichen crust; the rest exhibited only a sparse scatter of lichens over the soil surface.

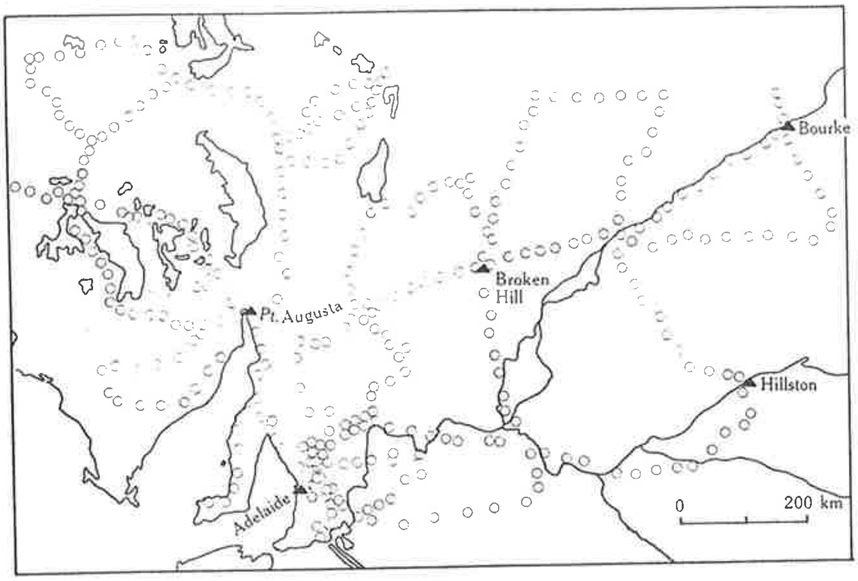


Fig. 6.—Distribution of the 343 sampled locations in relation to major centres of population.

(*b*) *Floristics of the Soil Surface Lichens*

The lichens were eventually classified into 42 taxa. Most of these taxa were at the species level; a number, however, were not. Taxa have in most cases been attributed to previously described species, usually in the broad sense of these species. It was believed that arid material ought not to be split into a number of narrowly

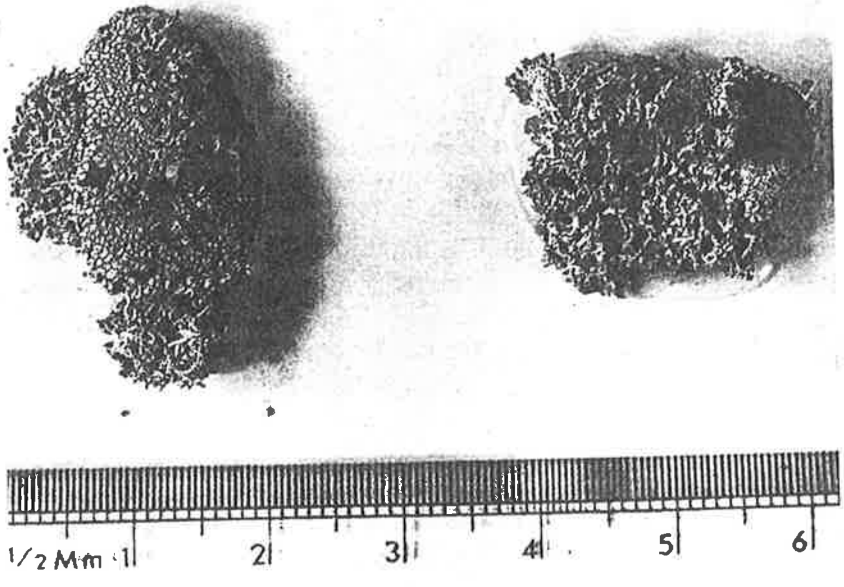


Fig. 7.—*Aspicilia calcarea* growing on pebbles and surrounding soil, showing the development of both crustose and fruticose growth habits in the same thallus. Collected in the Koonamore Vegetation Reserve, north-eastern South Australia, *R. W. Rogers* no. 1416.

circumscribed species in the absence of extensive studies on environmental modifications. Generally the nomenclatural suggestions of Weber (1962, 1963, 1967) have been followed. Herbarium specimens are lodged with the State Herbarium of South Australia.

Annotated List of Taxa

A key to these taxa is presented in Appendix I.

1. *Acarospora schleicheri* (Ach.) Mass. This is one of the two very variable species recognized by Weber (1968) in his revision of the yellow subgenus of *Acarospora*.
2. *Acarospora smaragdula* (Wahlenb.) Th. Fr.
3. ? *Acarospora* Mass. sp. indet.

4, 5. *Aspicilia calcarea* Mudd.; *A. calcarea* mod.* *fruticosa*. Two different forms of this species occurred in the study zone, the normal crustose form and the fruticose modification (syn. *Agrestia cyphellata* Thomson) (Fig. 7) which was discussed by Weber (1967).

6. ? *Biatorella* Th. Fr. sp. indet.
7. *Buellia epigaea* Tuck.
8. *Buellia subcoronata* Malme.
9. *Caloplaca subpyracella* (Nyl.) Zahlbr.
10. *Caloplaca* Th. Fr. sp. indet. This may be an extremely depauperate thallus of *Xanthoria* on soil.
11. *Chondropsis semiviridis* (F. Muell. ex Nyl.) Nyl.
12. *Cladia aggregata* (Eschw.) Nyl.
13. *Heterodea* sp. This was an undescribed species distinct chemically and anatomically from *H. mülleri*.
14. *Cladonia capitata* (Michaux.) Spreng.
15. *Cladonia verticillata* Hoffm.
16. *Cladonia balfourii* Cromb.
17. *Cladonia* squamules. This was a form group containing small, sterile basal squamules of various *Cladonia* species.
18. *Collema coccophorus* Tuck.
19. *Dermatocarpon lachneum* (Ach.) A. L. Smith. This name is used in the sense proposed by Weber (1962) including *D. hepaticum* (Ach.) Th. Fr. amongst its synonyms.
20. *Diploschistes ocellatus* (DC.) Norm.
21. *Diploschistes scruposus* (Schreb.) Norm. Possibly a complex of two or more species is treated under this name, as considerable variation in the exciple was noted.
22. *Endocarpon pusillum* Hedw.
23. *Fulgensia bracteata* (Hoffm.) Ras.
24. *Heppia lutosa* Ach.
25. *Heppia polyspora* Ach.
26. *Heterodea mülleri* (Hampe) Nyl.
27. *Lecanora atra* (Huds.) Ach.
28. *Lecidea coarctata* (J. E. Smith) Nyl.
29. *Lecidea crystallifera* Tayl.
30. *Lecidea decipiens* (Ehrh.) Ach.
31. *Lecidea planata* Müll. Arg.
32. *Lecidea psammophila* (Müll. Arg.) Zahlbr.

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* The term "modification" is used here in the sense proposed by Weber (1962).

33. *Lecidea* sp. indet.
34. *Parmelia amphixantha* Müll. Arg. This taxon contains a complex of closely related chemical forms.
35. *Parmelia convoluta* Kremph. This name applies to material commonly referred to *P. australiensis* Cromb., but chemically different.
36. *Parmelia flavescentreagens* Gyel.
37. *Parmelia versicolor* Müll. Arg.
38. *Parmelia pulla* (Neck.) Ach. This was a complex group of related species of brown *Parmelia* species.
39. ? *Rinodina orbata* (Ach.) Wainio.
40. *Siphula coriacea* Nyl.
41. *Synalissa* Th. Fr. sp. indet. This was a minute species, perhaps referable to *Peccania* Forss.
42. *Toninia caeruleonigricans* (Lightf.) Th. Fr.

IV. PHYTOGEOGRAPHY

The lichen floras from arid areas on other continents (except South America) have been reported on (Keller 1930; Faurel, Ozenda, and Schotter 1953; Klement 1955; Galun and Reichert 1960; Galun 1962; Weber 1963; Looman 1964*a*, 1964*b*) but few attempts at phytogeographic correlation on a world scale have been made. Since Weber (1962, 1963, 1967, 1968) has to a large extent rationalized the taxonomy of desert lichens, it is now possible to make a phytogeographic study of the lichens from much of the world's arid lands, and to examine the role of lichens as phytogeographic indicators.

TABLE 1

DISTRIBUTION OF SOME COMMON ARID ZONE LICHEN SPECIES ACROSS FIVE CONTINENTS

Species	Algeria (Faurel *et al.*)	Israel (Galun; Galun and Reichert)	Russia (Keller)	Europe (Klement)	Europe (Klement)	North America (Looman)	Arizona (Weber)	Australia
Acarospora schleicheri			+		+	+	+	+
Aspicilia calcarea			?		+	+	+	+
Buellia epigaea		+		+		+		+
Dermatocarpon lachneum	+	+	+	+	+	+	+	+
Diploschistes scruposus		+	+				+	+
Endocarpon pusillum				+		+	+	+
Heppia lutosa	+			+		+	+	+
Lecidea decipiens	+	+	+	+	+	+	+	+
Toninia caeruleonigricans		+	+	+	+	+		+

(*a*) *Relation to Floras of other Continents*

The large element of the soil surface lichen flora common to the study zone and arid areas around the world is shown in Table 1. Only four arid zone species found in the study area (*Buellia subcoronata*, *Lecidea crystallifera*, *Lecidea planata*, and *Parmelia convoluta*) are Australian endemics. A number of endemic species also occurs in the subarid and humid regions.

Looman (1964*b*) held that the lichen floras of arid soils in North America and Asia were relics of an ancient, once more extensive flora, now separated as a result of continental drift. The number of species that Australia has in common with extra-Australian arid areas is sufficient to discount Looman's ideas; to maintain his case, Australia must have been part of the same continental block as Asia and North America. It is widely recognized, however, that Australia was part of the "Gondwana" block, and North America and Asia part of the "Laurasia" block (Holmes 1965). It remains, therefore, to examine other hypotheses to account for these similarities. One is convergent evolution, but this is rarely invoked to explain intercontinental disjunctions. Another explanation proposed by Looman was that lichens have extraordinary powers of dispersal. Looman rejected this explanation on the ground that sexual reproduction (resulting in spores) was rare in arid zone lichens. This may be so, but in the present study *all* of the arid lichens were found bearing apothecia or perithecia at least occasionally. All the species found in Australia listed in Table 1 were frequently found fruiting, and with spores in those fructifications. Since other vegetative propagules such as soredia or isidia were not formed by the species studied, it seems that reproduction must be by spore germination or by production of large fragments. Even rare production of spores would be sufficient to allow long-range dispersal of cryptogams, which are notorious for their powers of dispersal (Rogers and Meier 1936; Gregory 1961). This idea cannot be rejected as easily as Looman would have us believe.

(*b*) *Use of Lichens as Phytogeographic Indicators*

The relatively large number of species level intercontinental disjunctions shown by lichens (27 of the 42 taxa found in the study area also occur in North America) prompts questioning of their role, and the role of other cryptogams, in phytogeographic discussions. For organisms such as the fungi, with spores so small that they may be carried into the upper atmosphere (Rogers and Meier 1936), it seems likely that the factors limiting their distribution are ecological rather than phytogeographic. It is not unreasonable to assume that given a long time span, the spores of many terrestrial fungi (including lichen fungi) will become spread right around the world and, given suitable ecological conditions, will grow where they land. It is also possible that larger fragments might be widely dispersed by biological agents, especially migrating birds.

The value of an organism in argument about intercontinental migration routes and biogeographic zonation is heavily dependent on the dispersal mechanism of the organism. Those organisms with minute, potentially air-borne propagules, as are bacteria, blue-green algae, fungi (including lichens), and perhaps some bryophytes and orchids, are of little value in such discussions because of their ability to spread over long distances. They may, however, be very sensitive indicators of *ecological* factors.

Discussing the small number of lichen endemics in arid areas, Weber (1962) wrote: "It gives one the uncomfortable feeling that lichen evolution is now essentially at a standstill. If this is indeed true, then the genetic system must differ fundamentally from that of higher plants. For, as Stebbins (1952) ably points out, the environment of arid areas is a distinct stimulus to evolution". The small number of endemics does indeed suggest that lichen evolution in arid areas has nearly stopped, but that there are some endemics indicates that it has not stopped altogether. It is in Stebbins's discussion that the reason for this slow rate of evolution can possibly be found. Stebbins traced the evolutionary stimulus of aridity to the formation of isolated communities leading to speciation which, with small fluctuations in climate, then hybridized and so on. In organisms which are able to disperse over a long range, isolated communities are unlikely to develop. The stimulus to speciation resulting from aridity which is so apparent in the angiosperms cannot therefore affect the lichen populations. It is not the genetic response of the lichens that is different, but the ecological response.

Given a long time span, then, it would be expected that those lichens now endemic to certain arid areas will, if ecological conditions are suitable, spread to the others. How long this takes will depend on the degree of specialization of the species (i.e. the likelihood of a propagule landing in a place where it can develop) and the power of dispersal of the propagule.

A special disjunction found in the present study is that shown by *Chondropsis semiviridis* and *Parmelia amphixantha*, neither of which produce soredia or isidia, between Australia and New Zealand. In light of the documented rain of Australian dust and spores on New Zealand (Moar 1969), it is not surprising that Australia and New Zealand have many lichen species in common. While Tasmania has 48% of its lichen flora in common with New Zealand (Martin 1965), the disjunction of subarid lichens is surprising, as New Zealand has so little subarid land. It thus appears that even species which form spores so very rarely as *C. semiviridis* are capable of long-range dispersal.

The recolonization of the volcanic island Krakatoa by lichens has been slow. Although the time period involved (about 90 years) is short in geological terms, Gregory (1961) has suggested that this indicates that lichens do not disperse well over long distances. The evidence presented by Moar (1969) about transport of Australian pollens, dust, and fungal spores across the Tasman Sea to New Zealand (a distance of about 2000 km) demonstrates what has been hypothesized about long distance transport. It appears that at least some of the fungal spores transported across the Tasman Sea are viable, because they are able to cause outbreaks of rust in wheat. Long distance transport of lichen spores is, therefore, still a viable hypothesis.

Since the pattern of distribution of arid soil surface lichens does not conform with the geological evidence concerning continental drift, it is likely that long-range dispersal is involved in the present distribution of arid zone soil surface lichens. Thus, knowledge about the drift of continents allows comment on the method of lichen dispersal. The converse, however, is not valid.

Evidence presented by Weber (1962) suggests that the similarities discussed above may prove to be even stronger than believed now. As more collecting and critical revision of arid lichen taxa proceeds, it seems likely that the number of species will be further reduced, and the percentage of intercontinental disjunctions thus increased. It is probably only in the wake of such revisions that valid biogeographic conclusions can be drawn involving any but the most striking similarities or differences.

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APPENDIX I

Artificial Key to the Species

KEY TO SECTIONS

I. Phycobiont a blue-green alga .... Section A

I. Phycobiont a green alga .... Section B

SECTION A

1. Thallus glistening and gelatinous when wet, colour very dark olive-green. Apothecia sessile. Spores 8 per ascus, thallus almost foliose or microfruticose 2

1. Thallus not gelatinous when wet, colour grey-green or brown. Apothecia immersed. Spores many (more than 8) per ascus, thallus squamulose 3

2. Thallus of moderate size (up to 2 cm in diam.) squamulose or foliose to fruticose, spores once septate, phycobiont *Nostoc* .... *Collema coccophorus*

2. Thallus minute, microfruticose (barely 2 mm high) packed into a crust, spores not septate, phycobiont *Gloeocapsa* or *Xanthocapsa* .... *Synalissa* or *Peccania*

3. Thallus a rosette of greyish squamules or lobes, almost foliose at times, apothecia rare, immersed .... *Heppia lutosa*

3. Thallus dark olive-green, ovate or crenate squamules with a thickened margin, apothecia immersed, usually one per squamule .... *Heppia polyspora*

SECTION B

1. Thallus foliose, fruticose, or, if crustose or squamulose, with podetia arising from the primary crustose or squamulose thallus 2

1. Thallus crustose or squamulose, but without podetia 16

2. Thallus foliose, but without podetia, either attached to the soil surface or lying free on the soil surface 3

2. Thallus fruticose, or with podetia (or pseudopodetia), the podetia either free or rising from a basal crust or squamules, either attached to the soil or free on its surface 11

Thallus foliose

3. Thallus lying free on the soil surface, or entangled in litter on the surface, but not attached to the soil by rhizoids or hyphae 4

3. Thallus attached to the soil surface at least lightly by rhizoids or hyphae 6

4. The thallus perfectly dichotomous, rolling up into a ball when dry. Lobes green above, yellow below, rhizoids absent .... *Chondropsis semiviridis*

4. The thallus irregular, always contorted and convoluted. Upper surface greyish green, the dark lower surface usually concealed within the deeply contorted lobes, rhizoids rare 5

5. Medulla yellow with potassium hydroxide .... *Parmelia convoluta*

5. Medulla unchanged with potassium hydroxide .... *Parmelia australiensis*

6. Marginal lobes rolling up from the extremities when dry, exposing the lower surface of the thallus 7

6. Marginal lobes more or less appressed to the soil, never rolling up to expose the lower surface 8

7. Thallus green or brown above, dark brown or black below, with numerous dark rhizoids and cyphellae, apothecia marginal .... *Heterodea mülleri*

7. Thallus grey or grey-green above, white or grey below, rhizoids marginal or absent, cyphellae absent, apothecia not found in the study area .... *Heterodea* sp.

8. Thallus brown or olive-brown above, usually closely adnate to the soil ...... *Parmelia pulla*

8. Thallus green or yellow-green above, variably adnate to the soil 9

9. Thallus neatly dichotomous, lobes narrow (2 mm) and entire, lower surface pale with sparse, dark rhizoids .... *Parmelia amphixantha* complex

9. Thallus much branched, not neatly dichotomous, lower surface brown, rhizoids common and dark 10

10. Thallus with very narrow, almost coraloid branches at the centre ...... *Parmelia versicolor*

10. Thallus without narrow or coraloid branches .... *Parmelia flavescentreagens*

Thallus fruticose or with podetia

11. Thallus of discrete but not fenestrate podetia rising erect from the substrate, with or without basal squamules 12

11. Thallus of divaricating often fenestrate pseudopodetia, of anastomosing fruticose or subfruticose lobes, or of short, bullate lobes with bases deeply buried in the soil 14

12. Podetia with well-formed cups, proliferating further tiers of these from the centre or margin of the cups ....*Cladonia verticillata*

12. Podetia either cupless or with more or less abortive cups, not arranged in tiers 13

13. Podetia short (up to 2 cm) usually branching, the branches all in a vertical plane, somewhat distorted, decorticate, squamules usually at the base ....*Cladonia capitata*

13. Podetia usually quite long, branches not common but, when found, often geniculate, always cylindrical partly decorticate, with many squamules at the base and up the podetia ....*Cladonia balfourii*

14. Thallus of green or brown divaricating pseudopodetia, hollow and, if fertile, fenestrate. The ends of sterile branches drawn out into a hair. Usually free on soil surfaces as the older portions rot away ....*Cladia aggregata*

14. Thallus of white or grey solid lobes, these blunt or anastomosing but not fenestrate; bases of lobes may be buried in the soil, pass into a crust, or sometimes be free on the surface ..15

15. Lobes, short bullate, forming a rosette on the soil surface, the bases of the lobes deeply buried in the soil, pseudocyphellae not found ....*Siphula coriacea*

15. Lobes anastomosing, often indistinct, never buried in the soil, but often passing into a crust on the soil or nearby pebble, pseudocyphellae common on well-developed forms ..*Aspicilia calcarea*

Thallus crustose or squamulose

16. Thallus or apothecia bright yellow or orange, at least when wet. If apothecia yellow or orange the thallus may be missing, yellow, grey-green, or orange 17

16. Thallus and apothecia never yellow or orange, but may be white, grey, sordid, pink, brown, or black 20

17. Thallus of small (usually less than 1 mm in diam.) bullate, bright citric-yellow granules, often forming a scattered crust on the soil. Apothecia, if present, immersed with many spores per ascus .... *Acarospora schleicheri*

17. Thallus of greyish granules, or if yellow, not granular but squamulose or crustose; the thallus is sometimes absent. Apothecia with an orange disc and a paler orange or yellow exciple 18

18. Thallus of large, orange squamules, apothecia deep orange with a paler exciple .... *Caloplaca* sp.

18. Thallus missing, crustose or granular, grey, or citric-yellow if wet. Apothecia orange with a yellow exciple 19

19. Thallus forming a small (1 cm in diam.) white or pale yellow crust on the soil, turning bright citric-yellow when wet, the surface mealy, marginal lobes not prominent, apothecia rare, but with a deep orange disc and a yellow exciple ....*Fulgensia bracteata*

19. Thallus greyish, often disappearing, apothecia small (less than 1 mm in diam.), with an orange disc and yellow exciple ....*Caloplaca subpyracella*

20. Thallus squamulose
(The squamules sometimes packed to apparently form a crust, but the margins then never show marginal lobes, and the crust is never really complete. The squamules may be thin or bullate, entire or crenate, colours include black, sordid, white, grey, brown, green, or pink) ..21

20. Thallus crustose
(The crust sometimes with granules some distance from the general margin, marginal lobes formed at times, the crust sometimes cracking into aereolae. The crust may be quite thick and more or less free from the soil, or very thin and barely distinguishable from the soil, colours vary from white and sordid to grey, grey-green, or brown) 28

21. Squamules green or grey-green above, when dry rolling up at the edges to show a white lower surface .... *Cladonia* sp. (squamules)

21. Squamules pink, cream, brown, or black above, not rolling up at the edges 22

 22. Squamules pink, sometimes with a white pruinose margin of varying width .... *Lecidea decipiens*

 22. Squamules white, sordid, brown, grey, or black, but showing no pink coloration 23

23. Squamules brown or pale grey, with a smooth upper surface, asci in perithecia which may be seen to open through pores in the upper surface 24

23. Squamules white, sordid, grey, or almost black, asci in apothecia not perithecia 25

 24. Squamules brown, ovate, entire, rhizoids many and fine. The spores are non-septate and small, usually 8 per ascus .... *Dermatocarpon lachneum*

 24. Squamules brown or grey, ovate, sometimes crenate, more or less umbilicate, the rhizoids always thick and long (often several centrimetres long) penetrating deep into the soil. The spores are large and muriform, usually 2 per ascus .... *Endocarpon pusillum*

25. Squamules dark grey or almost black, often cracked into a shallow, reticulate pattern, more or less pruinose, the squamules bullate. The apothecia may be as large as or larger than the squamules supporting them .... *Toninia caeruleonigricans*

25. Squamules pale, grey or sordid, thin, not bullate. The apothecia small relative to the size of squamule 26

 26. Squamules grey (or grey-brown at times) the upper surface deeply cracked into solid angles, giving the upper surface a crystalline appearance, the margins entire . . *Lecidea crystallifera*

 26. Squamules sordid, the upper surface smooth, the margins entire or crenate 27

27. Apothecia immersed or erumpent, the spores 2-celled and dark, margins of squamules entire . . .. *Buellia subcoronata*

27. Apothecia sessile, the spores hyaline, margins of squamules entire or crenate .... *Lecidea psammophila*

 28. The thallus a white, grey, or grey-green crust, apothecia small (less than 1 mm in diam.) with many spores in each ascus 29

 28. The thallus a white, grey, or sordid crust with spores 8 in each ascus, the apothecia small or large (up to 3 mm in diam.) 31

29. The thallus white, grey-brown, or greenish, often heavily pruinose forming thick plaques (less than 3 cm in diam.) with small, but still distinct marginal lobes. The apothecia are immersed in the central aeroles... *Acarospora smaragdula*

29. The thallus sordid grey, thin, scurfy, and apparently eroded, the margins indistinct, without marginal lobes, apothecia immersed to more or less sessile, depending on the degree of erosion 30

 30. A thalloid exciple present around the apothecia .... *Acarospora* sp.

 30. No thalloid exciple present around the apothecia .... *Biatorella* sp.

31. Spores multiseptate, the thallus an extensive white or greyish crust, often more or less separate from the soil, the thallus distinctly aereolate, but without marginal lobes 32

31. Spores non-septate or once septate, the thallus a white or sordid crust, closely attached to the soil, with or without aereolae, or scattered aereolae beyond the thallus margin, which may be lobed 33

 32. Apothecia minute (less than 1 mm in diam.) immersed, sometimes almost closed by the exciples, the thallus often grey and mealy .... *Diploschistes scruposus*

 32. Apothecia larger (up to 3 mm in diam.), adnate, the disc open with an obvious thalloid exciple, the thallus usually white and rather chalky .... *Diploschistes ocellatus*

33. Spores once septate and brown 34
33. Spores once septate or non-septate, but hyaline 35
    34. Thallus a very white crust, sometimes almost subfruticose, apothecia with a proper exciple .... *Buellia epigaea*
    34. Thallus a sordid crust, rather scurfy, apothecia with a thalloid exciple .... ?*Rinodina* sp.
35. Apothecia with a thalloid exciple 36
35. Apothecia with a proper exciple 37
    36. Apothecia immersed with a bluish pruinose disc, the thallus a rather mealy, granular crust, spores often only 2 per ascus ....*Aspicilia calcarea* (crustose form)
    36. Apothecia adnate with a brown disc, the thallus a smooth, aereolate crust, the exciple coloured like the thallus, spores usually 8 per ascus ....*Lecanora atra*
37. Apothecia erumpent in a crust of rather scattered, slightly bullate granules ....*Lecidea coarctata*
37. Apothecia immersed or sessile on a somewhat tesselate, aereolate crust 38
    38. Apothecia more or less sessile or immersed in a rather thin crust ....*Lecidea planata*
    38. Apothecia sessile on a crust with thick, convex aereoles ....*Lecidea* sp.

3. **Rogers, R.W.** (1972). Soil surface lichens in arid and sub- arid south-eastern Australia. II. Phytosociology and geographic zonation. *Australian Journal of Botany*, **20**, 215- 27.

SOIL SURFACE LICHENS IN ARID AND SUBARID SOUTH-EASTERN AUSTRALIA

II.* PHYTOSOCIOLOGY AND GEOGRAPHIC ZONATION

By R. W. Rogers†

[Manuscript received 16 December 1971]

Abstract

Five lichen species groups were delimited, principal components analysis and influence analysis being used as aids to group identification. With these same techniques it was demonstrated that two of the species groups formed "background" floras in adjacent geographic areas, the other three species groups, being superimposed upon the "background" floras to produce five separate geographic zones of lichen distribution.

I. Introduction

The floristic composition of the lichen flora of arid south-eastern Australia has been discussed by Rogers and Lange (1972). In this paper, the community structure of the lichens in south-eastern Australia is studied with use of the distribution data available from that study.

Determination of species groupings and the spatial distribution of these groupings have been dealt with extensively in the literature (Goodall 1962; McIntosh 1967). Before the complete data block from the field study had been assembled an association analysis (Williams and Lambert 1959) was executed. This indicated a relatively continuous interaction between the species found, with no significant negative associations occurring. It was decided that analyses which treated the lichen vegetation as a continuum would be more meaningful than divisive classifications.

With this in mind, the species groupings and distributions were studied by using "influence analysis" (Lange 1968) and "principal components analysis" (Orloci 1966). Species were also sorted into regional groups on the basis of the distribution patterns shown on maps. In this section the two numerical approaches and the regional groupings are considered. Results from all three approaches are discussed, and a series of species groups used in further studies proposed.

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* Part I, *Aust. J. Bot.*, 1972, **20**, 197.

† Department of Botany, University of Adelaide, Adelaide, S.A. 5000; present address: Department of Botany, University of Queensland, St. Lucia, Qld. 4067.

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II. INFLUENCE ANALYSIS

(a) *Method*

Influence analysis is a species classification and site ordination technique based on association analysis. It has been used previously by Lange (1968) on heath vegetation and by Barker and Lange (1969) on grazed arid woodland. In this study the computation of interspecific association has been modified, as no taxon was present

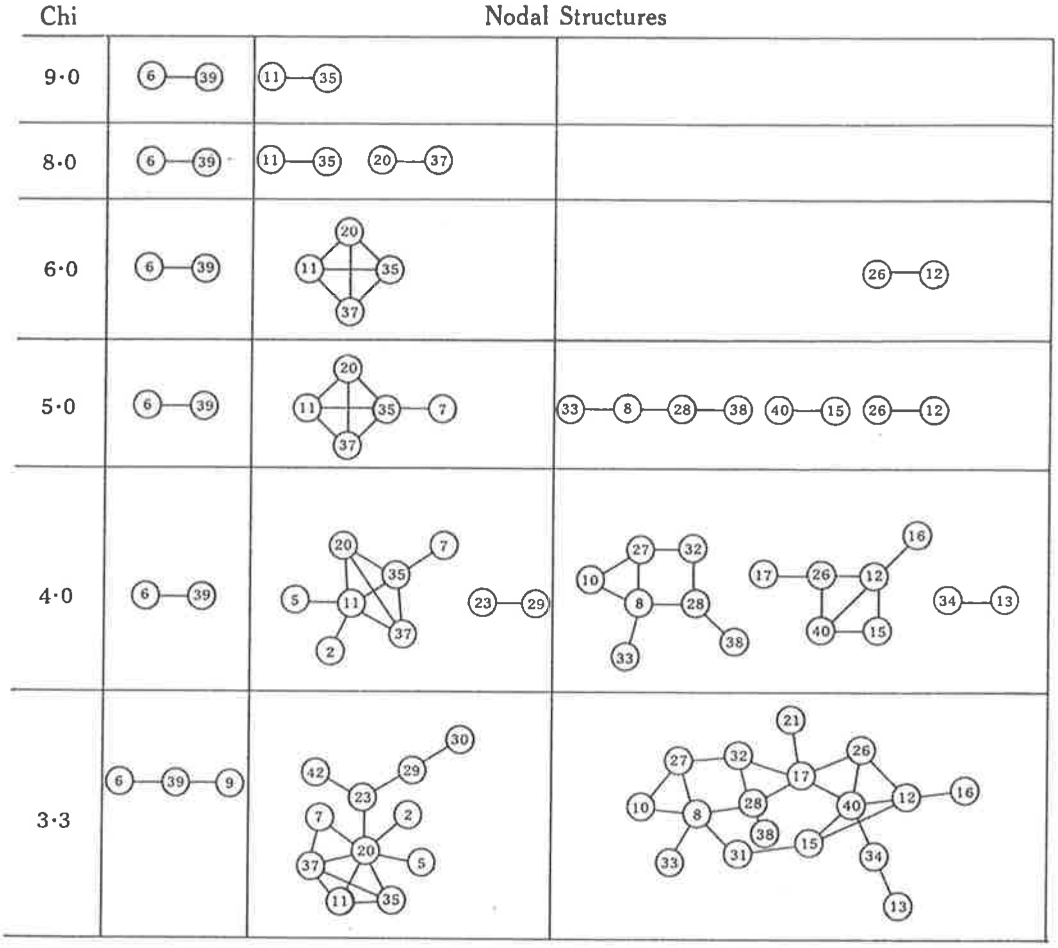

Fig. 1.—The aggregation of species into nodes as the chi level for admission into the nodes is lowered. The number code for species is as in the following list: 1, *Acarospora schleicheri*; 2, *Acarospora smaragdula*; 3, ?*Acarospora* sp.; 4, *Aspicilia calcarea*; 5, *A. calcarea* mod. *fruticosa*; 6, *Biatorella* sp.; 7, *Buellia epigaea*; 8, *Buellia subcoronata*; 9, *Caloplaca subpyracella*; 10, *Caloplaca* sp.; 11, *Chondropsis semiviridis*; 12, *Cladia aggregata*; 13, *Heterodea* sp.; 14, *Cladonia capitata*; 15, *Cladonia verticillata*; 16, *Cladonia balfourii*; 17, *Cladonia* squamules; 18, *Collema coccophorus*; 19, *Dermatocarpon lachneum*; 20, *Diploschistes ocellatus*; 21, *Diploschistes scruposus*; 22, *Endocarpon pusillum*; 23, *Fulgensia bracteata*; 24, *Heppia lutosa*; 25, *Heppia polyspora*; 26, *Heterodea mülleri*; 27, *Lecanora atra*; 28, *Lecidea coarctata*; 29, *Lecidea crystallifera*; 30, *Lecidea decipiens*; 31, *Lecidea planata*; 32, *Lecidea psammophila*; 33, *Lecidea* sp.; 34, *Parmelia amphixantha*; 35, *Parmelia convoluta*; 36, *Parmelia flavescentreagens*; 37, *Parmelia versicolor*; 38, *Parmelia pulla*; 39, ?*Rinodina orbata*; 40, *Siphula coriacea*; 41, *Synalissa* sp.; 42, *Toninia caeruleonigricans*.

in more than half the locations and only 10 of the 42 taxa occurred in more than 10% of the locations. In the calculation of association between species pairs, sites at which neither member of the species pair was present were excluded from consideration.

A computer program to calculate chi values for each species pair and to order the species pairs on chi values was written and run on the CDC 6400 computer at the University of Adelaide. Species were then grouped in an agglomerative manner into nodes on the basis of positive interspecific association, starting at the highest attained level of significance, and progressively lowering the significance level for admission into a node until a probability level of 0·001 was reached ($\chi_{1\text{d.f.}} > 3\cdot3$). The number of species which are members of a given nodal group, and present at a given site, is the influence rating assigned to that site, for the node in question.

(*b*) *Results*

A large number of significant interspecific associations were demonstrated by the association analysis; all were positive. The development of nodes amongst the associated species as the significance level for admission to the nodes was progressively lowered is shown in Figure 1. This method of analysis resulted in three nodes at a significance level of $\chi > 3\cdot3$ ($P < 0\cdot001$).

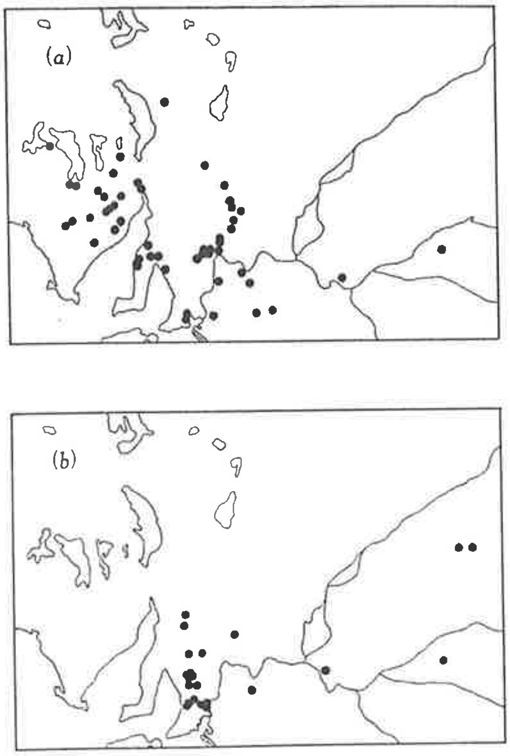

Fig. 2.—The distribution of sites with influence values greater than four, for node B species (Fig. 2*a*) and for node C species (Fig. 2*b*).

The implications of the associations were brought out by examining the field distribution of the interacting species after the approach of Lange (1968). Maps were constructed to illustrate the expression of each node. Using node B as an example, each of the sites studied could be assigned an influence value from 0 to 11 according to the number of nodal species it contained. It was apparent that isolines could not be drawn because of variation in the influence values in any area. Therefore, sites were arbitrarily differentiated into "high" influence ratings and "low" influence ratings.

Node B had three centres of development, Eyre Peninsula, northern York Peninsula, and in the Murray Basin in South Australia. Isolated high values also occurred elsewhere (Fig. 2*a*).

Node C had a major centre of development in the Mount Lofty Ranges and areas west of the range in the Murray Basin (Fig. 2*b*) where it overlapped part of the centre for node B, but extended into central New South Wales.

Node A, because of the low frequency of its species, could not be mapped meaningfully in this way.

The trend in distribution of these nodes appeared to be from node C in the wet areas, intergrading with node B species on the margins of the desert, with node A species confined to desert areas.

III. PRINCIPAL COMPONENTS ANALYSIS

Austin (1968) described principal components analysis (PCA) as "a mathematical technique for describing the relationships of a set of points (species or stands) in an economical manner". As an approach to vegetation studies it was first used by Goodall (1954), and the theory spelt out more recently by Orloci (1966).

The technique has been shown to be useful on such diverse vegetation as chalk grass land in Britain (Austin 1968), savannah in Nigeria (Kershaw 1968), tropical rain-forest in the Solomon Islands (Greig-Smith, Austin, and Whitmore 1967), and on saxicolous bryophytes and lichens (Yarranton 1967). These studies have, however, all been confined to intensive investigations in small areas. It appears that there is no published account of an attempt to apply PCA to a large-scale land survey or biogeographic problem.

(*a*) *Method*

The analysis was performed on the CDC 3600 computer in the CSIRO Division of Computing Research, Canberra.

The analysis was based on a data block in which the qualitative (0/1) scores were replaced by scores normalized by species frequency, i.e. scores were divided by $\sqrt{r_k}$, where r is the frequency of the kth species. This approach equalizes the importance of rare and frequent species in the analysis, so that common species do not dominate the analysis; this allows relative floristic richness to affect the outcome.

Following Gower (1966) it was possible to derive site ordinations from the species ordinations.

The matrices of component loadings produced by PCA were studied, and the loadings for each species or site displayed graphically by plotting its position relative to pairs of components using the components as axes. Only the first five components were studied, as it was thought unlikely that further components would be amenable to interpretation.

The component loadings for each site were plotted on maps, to indicate areas in which poles of the ordination were located.

For convenience in further discussion, the species were placed in groups on the basis of the ordination. They were grouped by arbitrary divisions depending on the sign of the vector loadings they received on the axes being considered. The groups were assigned a name, taken from a genus in the group of which only one species was involved in the whole analysis. The component loadings for sites were plotted as graphs, and areas with extreme loadings delimited.

(*b*) *Results*

(i) *Species Ordinations*

In order to illustrate the effect of the components, relationships between four selected separate axis pairs are shown in Figure 3. Component II was usually used as a basis for these comparisons, as it produced the most clear-cut results.

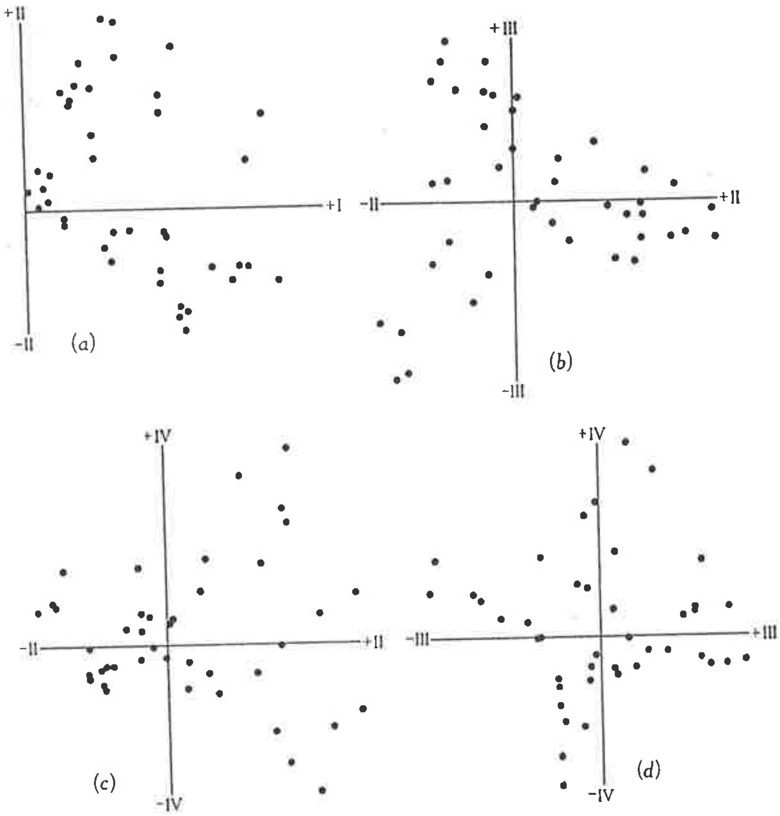

Fig. 3.—Ordination of species in relation to the indicated axis pairs, showing the formation of diffuse poles.

The effect of the components, separately and in combinations, is detailed below.

Component I had the effect of giving high loadings to frequent species, approximating to an index of "typicality" of the species.

Component II differentiated most of the species with high loadings on component I between two poles (Fig. 3*a*). One pole was typified by *Siphula coriacea*, *Lecidea coarctata*, *L. planata*, *Cladonia* squamules, and *Cladia aggregata* (the *Siphula* pole). The other pole was marked by *Parmelia convoluta*, *P. versicolor*, *Chondropsis semiviridis*, *Toninia caeruleonigricans*, and *Diploschistes ocellatus* (the *Toninia* pole).

Component III appeared, like component II, to differentiate the species with high loadings on component I. However, the most marked effect of component III was to differentiate the species of the *Toninia* pole of component II into two separate groups (Fig. 3*b*). One of these groups was typified by *Parmelia convoluta*, *P. versicolor*, *Chondropsis semiviridis*, and *Diploschistes ocellatus* (the *Chondropsis* pole) and the second by *Collema coccophorus*, *Aspicilia calcarea*, and *Caloplaca subpyracella* (the *Collema* pole).

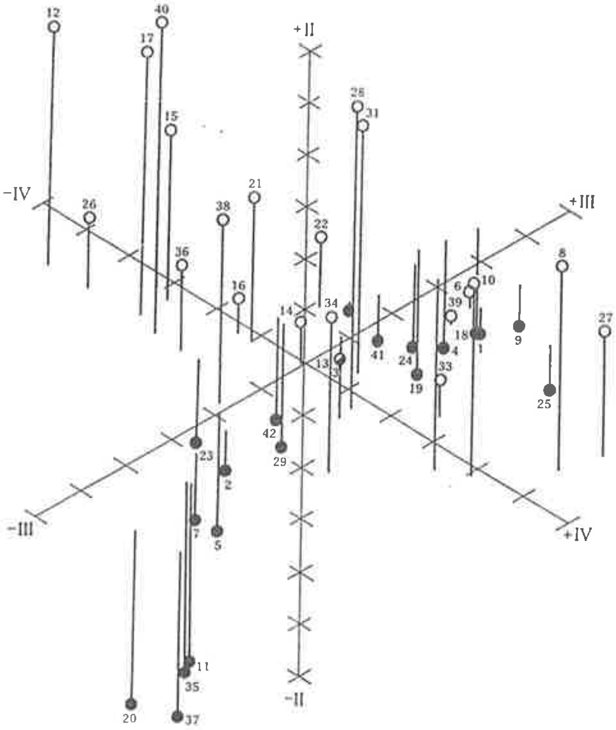

Fig. 4.—A three-dimensional ordination of species against axes II, III, and IV as indicated. The numbers code for the species as in Fig. 1.

Component IV differentiated some of the less common or "atypical" species with low loadings on component I, but not those species with very high loadings. This meant that component IV differentiated the *Siphula* pole derived by axis II into two arms (Fig. 3*c*) in a manner similar to that by which component III differentiated the *Toninia* pole. The two poles resulting were typified in one case by *Siphula coriacea*, *Cladonia* squamules, and *Cladia aggregata* (the *Cladia* pole), and the second case by *Lecanora atra*, *Buellia subcoronata*, and *Caloplaca* sp. (the *Lecanora* pole).

When the action of component IV was considered in relation to component III, it was found that four poles were produced (Fig. 3*d*). The species composition of these poles was remarkably similar to that of the poles created by the interactions of component II with component III and component IV. This reflects the relative independence of components III and IV noted above.

Component V was unusual in that it segregated two species, *Biatorella* sp. and *Rinodina* sp., both with vector loadings greater than +0·8, from all others. Because of this, this component was not plotted. The next highest loading was +0·29 for *Caloplaca subpyracella*. All other loadings lay between +0·183 and −0·183. It was possible, therefore, to segregate *Biatorella* sp., *Rinodina* sp., and *Caloplaca subpyracella* into a separate species group.

A simultaneous three-dimensional ordination based on components II, III, and IV was constructed (Fig. 4). This clearly illustrated the four separate species groups delimited by use of pairs of axes: two above the plane of axes III and IV and two below that plane.

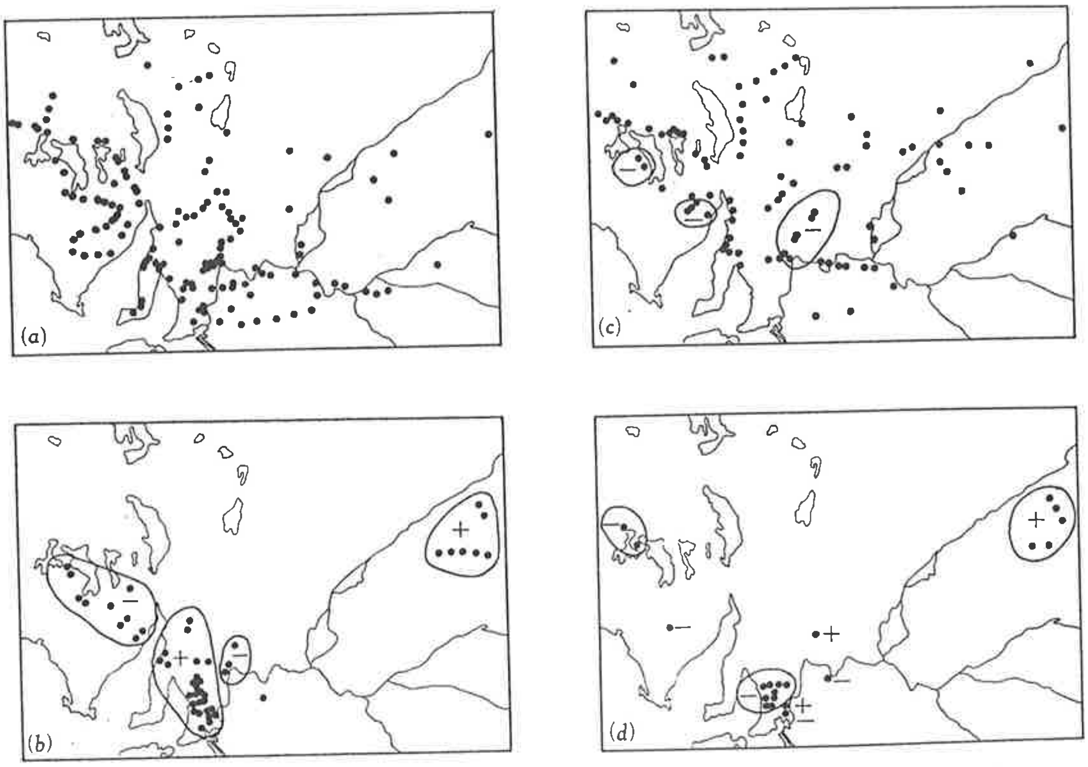

Fig. 5.—Distribution of sites with extreme loadings on axis I (*a*), axis II (*b*), axis III (*c*), and axis IV (*d*). Marked sites have loadings greater than +4, unless indicated, when the load is less than −4.

(ii) *Site Ordinations*

Extraction of the first, non-centred component is more informative with respect to sites than it is to species. The graphic plot of this component indicated that the sites are relatively homogenous. The points representing each location formed a single, more or less cigar-shaped cluster no matter which other component the loadings for component I were plotted against. When mapped, it could be seen that there was a band of high values for the component in the arid and subarid region of South Australia tailing off into western New South Wales (Fig. 5*a*), indicating the areas in which this "typical" flora was most strongly developed.

When component II was plotted against component I a large cluster of sites with negative scores on component II, and a diffuse lobe of sites with positive scores on component II, were produced. The strong positive scores on component II when mapped proved to be concentrated in the Mount Lofty Ranges near Adelaide and in central New South Wales; strong negative scores were concentrated particularly in the Murray Basin and in the north of Eyre Peninsula (Fig. 5*b*), both in South Australia.

Plotting component III against component II produced a tripolar ordination, with a large number of sites in one pole and diffuse lobes forming the other two. Sites with a strong positive loading for component III (the bulk of sites) were concentrated in the north of the study area, and sites with a strong negative loading for component III were found to be concentrated in the Murray Basin and Eyre Peninsula of South Australia (Fig. 5*c*).

Plotting component IV against component II again produced a tripolar ordination, the mass of sites at one pole and the other two poles represented by diffuse lobes. Plotting component IV against component III produced an ordination showing four lobes representing the poles formed in the plots of components II *v.* III and components II *v.* IV. Sites with strong positive loadings for component IV were mostly in central New South Wales; those with strong negative loadings were mostly in the Mount Lofty Ranges near Adelaide (Fig. 5*d*).

Component V produced high loading at only two sites, one north of Bourke in central New South Wales and one near Mildura. These sites had loadings of +5 and +7 respectively.

IV. ANALYSIS OF REGIONAL GROUPING

To erect the regional species groups, maps of species distributions and species lists were carefully scrutinized, and the species arranged into groups with a common geographic range. These groups were thus erected on a different basis from that used in the numerical analyses: coincidence of species range rather than frequency of mutual incidence at particular locations. Moreover, the composition of these groups was influenced by impressions gained during the field study.

No "best" grouping can be arrived at in this style, but simply one which seems natural to the worker arranging the species. As a result of this approach, five species groups with distinctive geographic zonation were delimited quite independently of the numerical analyses. These regional groups are listed below.

Group 1

Caloplaca sp.
Cladia aggregata
Cladonia capitata
Cladonia verticillata
Cladonia balfourii
Heterodea mülleri
Parmelia flavescentreagens
Parmelia pulla
Siphula coriacea

Group 2

? *Biatorella*
Buellia subcoronata
Cladonia squamules
Lecidea coarctata
Lecidea planata
Lecidea psammophila
Lecidea sp.

Group 3

Aspicilia calcarea
Caloplaca subpyracella
Heppia polyspora
Heterodea sp.
Lecanora atra
Parmelia amphixantha

Group 4

Acarospora smaragdula
Aspicilia calcarea
  mod. *fruticosa*
Buellia epigaea
Chondropsis semiviridis
Diploschistes ocellatus
Fulgensia bracteata
Lecidea crystallifera
Parmelia convoluta
Parmelia versicolor
Synalissa sp.
Toninia caeruleonigricans
?*Rinodina*

Group 5

Acarospora sp.
Acarospora schleicheri
Collema coccophorus
Dermatocarpon lachneum
Diploschistes scruposus
Endocarpon pusillum
Heppia lutosa
Lecidea decipiens

Of these groups, groups 1 and 4 were sharply delineated, as the species had a restricted but relatively continuous distribution, and commonly recurred in groups as listed. Group 1 was more or less confined to the Mt. Lofty Ranges; group 4 to an arc around the ranges, on northern Eyre Peninsula, and in the Murray Basin.

The species of groups 2 and 3 tended to occur on similar sites, but those in group 3 were absent from the summer rainfall areas of central New South Wales. Both groups were essentially groups of species that occurred in arid areas, but not in the extremely dry parts.

The species of group 5 were remarkably widely distributed, showing enormous ecological tolerance and occurring throughout the study area. These species seemed to form a basic soil surface lichen flora, upon which the other groups (group 1 to a lesser extent than the others) were superimposed.

V. ASSESSMENT

(*a*) *Species Groups*

Table 1 details the composition of five species groups (A, B, C, D, E) which, after due consideration of all analyses, were concluded to embody the essential distribution pattern of the lichens. This table also shows the high degree of similarity between the groups resulting from the three primary analyses; this correspondence leading to the derivation of the five new groups.

It was apparent from Table 1 that influence analysis (IA) node C was equivalent to the PCA *Cladia* + *Lecanora* groups combined, and that node B was equivalent to the PCA *Chondropsis* group. The species not grouped by influence analysis mostly belonged to the PCA *Collema* group.

IA node A species were the three species strongly influenced by PCA component V, previously tentatively separated as a species group.

The regional groups were less in agreement with the PCA groups and IA nodes than were those analyses with each other. However, regional group 1 was very similar in composition to the PCA *Cladia* group and IA node C. Regional group 4 was very similar to the PCA *Chondropsis* group and the IA node B. The species of regional group 2 were included in the PCA *Lecanora* or *Cladia* group and in IA node C. Group 3 species were divided between the PCA *Lecanora* and *Collema* groups, and between IA node C and the species not grouped by influence analysis. Most of the regional group 5 species were in the PCA *Collema* group, and were ungrouped by influence analysis.

Only two species, *Diploschistes scruposus* and *Endocarpon pusillum*, were placed in radically different groups by the various methods used for grouping. These two species were placed alternatively in the two extreme groups of an apparent climatic sequence. This was probably a reflection of their wide range of distribution, from the wettest to some of the driest areas studied.

TABLE 1

RELATIONSHIP BETWEEN THE FINAL SPECIES GROUPS A, B, C, D, AND E, AND THE GROUPS RESULTING FROM THE VARIOUS METHODS OF ANALYSIS

Species group	Species	Principal components analysis					Influence analysis				Regional grouping				
		Axes II, III, IV				Axis V									
		Cladia	*Lecanora*	*Chondropsis*	*Collema*	*Caloplaca*	Node C	Node B	Node A	Ungrouped	I	II	III	IV	V
A	*Siphula coriacea*	+					+				+				
	Cladonia squamules	+					+					+			
	Cladia aggregata	+					+				+				
	Heterodea mülleri	+					+				+				
	Cladonia verticillata	+					+				+				
	Diploschistes scruposus	+					+								+
	Parmelia flavescentreagens	+								+	+				
	Cladonia capitata	+									+				
	Cladonia balfourii	+					+				+				
	Parmelia pulla	+									+				
B	*Lecidea coarctata*	+					+					+			
	Lecidea planata	+					+					+			
	Buellia subcoronata		+				+					+			
	Lecidea psammophila		+				+					+			
	Caloplaca sp.		+				+				+				
	Lecanora atra		+				+						+		
	Lecidea sp.		+				+					+			
	Parmelia amphixantha		+				+						+		
	Heterodea sp.		+				+						+		
C	*Parmelia convoluta*			+				+						+	
	Diploschistes ocellatus			+				+						+	
	Chondropsis semiviridis			+				+						+	
	Parmelia versicolor			+				+						+	
	Aspicilia calcarea mod. *fr.*			+				+						+	
	Buellia epigaea			+				+						+	
	Acarospora smaragdula			+				+						+	
	Lecidea crystallifera			+				+						+	
	Toninia caeruleonigricans			+				+						+	
	Fulgensia bracteata			+				+						+	
D	*Dermatocarpon lachneum*				+					+					+
	Collema coccophorus				+					+					+
	Heppia lutosa				+					+					+
	Aspicilia calcarea				+					+			+		
	Heppia polyspora				+					+			+		
	Synalissa sp.				+					+				+	
	Acarospora schleicheri				+					+					+
	Acarospora sp.				+					+					+
	Lecidea decipiens				+			+							+
	Endocarpon pusillum	+								+					+
E	*Caloplaca subpyracella*				+	+			+				+		
	Biatorella?	+				+			+			+			
	Rinodina?	+				+			+					+	

(*b*) *Distribution Patterns*

The lichens of species group D, which are almost ubiquitous and essentially confined to bare soil, form a basic flora for most of the study area. The geographical range of the lichens in species group D embraced the entire range of species in groups B, C, and E, and some of the range of those in species group A. Species group A (which generally occurs with plant litter) is much less extensive in distribution than species group D, which it overlaps slightly, but it does not share its range with many of the species of groups B, C, and E. Lichens of these latter groups are best understood as bringing regional elaboration to the group D soil surface flora.

With this understanding of two overlapping floras (groups A and D) and three superimposed groups (groups B, C, and E), five geographic regions with respect to lichen floras could be delimited. These regions were:

(1) The *Mount Lofty Ranges* (group A species predominant, often superimposed on group D species).
(2) *Central New South Wales* (group B species superimposed on group D species).
(3) *Northern Eyre Peninsula* (group C species superimposed on group D species).
(4) The *northern Murray Basin* in South Australia (as (3) above).
(5) The *remainder of the study area* (group D species with an admixture of species from groups A, B, C, and E).

These generalized areas are illustrated in Figure 6.

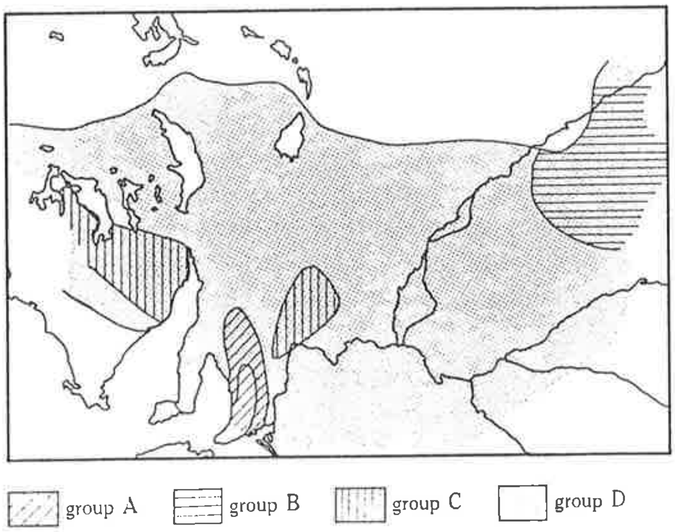

Fig. 6.—Distribution of species groups A, B, C, and D.

(*c*) *Retrospective Comment on Procedures*

At the beginning of this section it was pointed out that in view of what was known about soil surface lichens, continuous rather than divisive classifications seemed desirable. Subsequently both of the numerical methods used reinforced the belief that the data were of a continuous nature. However, the detail of the results proved impossible to map in a continuous manner for two main reasons. The sample locations were too sparsely scattered over the area to cope with the variation (one sample to 3000 sq km) and a great number of these samples were negative for all species.

In practice there was no option but to condense each continuum into two classes representative of extreme conditions. In the final construction of the species groups, however, the information from each continuum was invaluable in interpreting the placement of species in those groups.

The essentially similar results produced by two very different numerical approaches indicated that the relationships expressed by them are real; the manner in which they reinforced each other simplified the construction of the final regional analysis. This demonstrates the value of computer-facilitated analyses in ecological and biogeographical studies.

VI. Phytogeography of the Region

The most complete phytogeographic study of the Australian region is that of Burbidge (1960), in which Australia was divided into three zones: Tropical, Temperate, and Eremaean, on the basis of their phanerogamic floras. Between the Temperate, Tropical, and Eremaean zones Burbidge defined broad interzones within which edaphic conditions caused an intermixture of the floras of the abutting regions. The present study area includes part of the temperate and Eremaean zones, and also part of Interzone 2 as defined by Burbidge.

The distribution of lichens in the study area is compatible with Burbidge's zonation. Considering the species groups defined in Table 1, groups A and B are essentially Temperate species, and groups C and D essentially Eremaean. Interzone 2 shows relatively extensive development of group B species, but all of these (except *Buellia subcoronata*) also occur in the Temperate zone near Adelaide.

Species of group C form a band across the south of the Eremaea in South Australia, but do not extend as far north or east as species of group D. Thus the Eremaea could be divided into two subzones, one fringing the Temperate zone in the south, the remainder across the north of the study area.

Species group C contains the vagant lichens considered by Keller (1930) to be indicators of steppe vegetation, and also a species of *Diploschistes*, the genus considered by Reichert (1936, 1937) to indicate steppe vegetation. Thus, it is likely that the division of the Eremaea in South Australia into two portions on presence or absence of group C species would be equivalent to dividing it into steppe and desert as in North Africa and the Turko-Iranian areas.

VII. Acknowledgments

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Dr. R. T. Lange (Botany Department, University of Adelaide) suggested the project and provided assistance throughout. Dr. I. Noy-Meir (Botany Department, Hebrew University of Jerusalem) executed the principal components analysis.

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SOIL SURFACE LICHENS IN ARID AND SUBARID SOUTH-EASTERN AUSTRALIA

III.* THE RELATIONSHIP BETWEEN DISTRIBUTION AND ENVIRONMENT

By R. W. ROGERS†

[Manuscript received 26 April 1972]

Abstract

From a consideration of the distribution of species and species groups in relation to soil and climatic factors, it is shown that mean annual rainfall and mean maximum January temperature largely explain the distribution pattern of arid zone soil surface lichens. A past distribution of lichen crusts in southern Australia is postulated on the basis of factors controlling lichen crust development, and known variations from this pattern explained in terms of stocking history.

I. INTRODUCTION

Factors affecting the distribution of plants in the arid zone of south-eastern Australia can be grouped into three basic types: climatic factors, substrate factors, and biotic factors. These are all susceptible to study (Moore 1953*a*, 1953*b*). This paper deals with those factors of climate and soil which relate to lichen distribution on a broad scale. The effect of an historical biotic influence on the distribution of lichens on a relatively small scale has been discussed by Rogers and Lange (1971).

Examination of the completed distribution maps of species and species groups (Rogers and Lange 1972; Rogers 1972) strongly supported the impression gained during the field study that mean annual rainfall, the seasonal distribution of rainfall, and soil type were all closely related to the distribution of lichens. Examination of data associated with soil maps suggested that several soil variables might be involved; these included pH, nature of the surface, calcium concentration, and sodium concentration.

As the collation of environmental data for the study area proceeded, it became apparent that the mean maximum temperature for January (the hottest month) was also related to the distribution patterns. This suggested that a single value climatic index reflecting both rainfall and temperature effects would be useful. A range of such indices was available, none of which, however, was mapped in a suitably detailed form.

The relationships between all of the variables discussed above (except single value climatic indices) and the distribution of both lichen species and crusts are discussed below.

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† Department of Botany, University of Adelaide, Adelaide, S.A. 5000; present address: Department of Botany, University of Queensland, St. Lucia, Qld. 4067.

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II. Collection of Environmental Data

Climatic data for each location were obtained by interpolation from the maps presented by Rogers and Lange (1972); descriptive climatic terms are used in the sense defined in that publication.

At each location a soil sample (about 400 g) was collected from the top 2 cm of the soil type upon which lichen growth was most profuse. By examination of these samples and reference to field notes soil surfaces were graded into five classes. These were: clays; sands; crusted loams (usually friable highly calcareous soils which formed a distinct but fragile surface crust about 2 cm thick); hard-setting soils (e.g. many red-brown earths); amorphous soils (a category of fine soils that were compacted and apparently apedal); and rock pavement, a category for those areas of the landscape so strewn with gibbers or other rock fragments that the soil surface was completely covered.

Chemical characteristics (pH, extracted calcium and sodium) were, because of the usually high calcium content of the soil, determined from a saturated soil extract prepared after the method of Richards (1947). The pH of the fresh extract was measured with a glass electrode and the sample stored under refrigeration. When all extracts had been prepared, the sodium content was determined with an EEL flame photometer, and the calcium content with a Techtron A2 atomic absorption spectrophotometer. A strontium chloride buffer (1000 p.p.m.) was used to prevent phosphate interference in the calcium determination. Concentrations were calculated in terms of micromoles of element per gram of soil.

The pH values obtained, with the exception of a single very low value (pH 5·4), ranged between 6·5 and 8·9. These values were assigned to groups with a class interval of 0·4 pH unit. The very low value was included in the lowest class (pH 6·5).

The class intervals for calcium and sodium concentrations presented a problem. The range of calcium concentrations encountered was from 100 to 15,150 μmoles/g soil, and the range for sodium concentrations from 32 to 49,890 μmoles/g soil; in both cases the vast bulk of values were in the lower part of the range. Classes were therefore constructed on a logarithmic scale to ensure more uniform representation of sites in the higher classes.

III. Evaluation of Relationship between Distribution and Environmental Data

It was decided to present the relationships between distribution and environmental variables as histograms. No further statistical treatment was attempted, because of the low intensity of the data (presence/absence of species without knowledge of frequency or density at each location). This method is highly informative and useful, although less rigorous than a multiple regression approach.

In order to reveal the factors important in influencing species distribution the following argument was invoked.

Species distribution is largely controlled by environmental variation. Thus, if a number of species tend to occur together, it is because they respond in a like way to environmental conditions. Therefore, if the species of a group tending to occur together all show a similar response to any given environmental variable, but a response different from that of other species, the variable either controls or is correlated with a variable which controls the distribution pattern. The species involved in this study have been grouped, on the basis of common occurrence, in the previous paper of this series (Rogers 1972).

Thus for example, if it could be shown that all the species of species group A (Rogers 1972) responded in a like manner to rainfall but in a manner different from that shown by groups B, C, and D, it could be claimed that rainfall (or a correlated factor) played an important part in control of the distribution of the species group.

To determine whether or not species in a species group responded in a like manner to environmental variables, the following procedure was followed.

The histograms relating species frequency to values of environmental variables were placed in order. The order was determined primarily by the modal value of the histogram, i.e. the species with its modal value in one extreme class interval was placed first in the ordination, and followed by that with its mode in the next highest interval, and so on. Once the species were arranged in order the species group to which each belonged was scored beside it. If members of species groups were placed in close proximity by the environmental ordination this was taken to indicate that the species in the group responded to that environmental factor in similar ways, i.e. they were controlled either by that factor or by a closely correlated factor.

If the distribution of a species group is controlled by the environmental variable being considered, it would be expected that the centre of development of that species group would be related to the pattern of that variable. This would allow a check on the conclusions reached on the basis detailed above.

IV. The Frequency Histograms

In this section the relationships between species frequency and the set of environmental variables are presented, and some remarks about the nature of the frequency distributions across the range of environment made. Causation of the pattern is considered in a later section.

(*a*) *Frequency Distribution in relation to Mean Annual Rainfall*

In Figure 1 the frequency histograms for the more common species are ordered by the mode of the histogram, those with modes in high rainfall classes appearing at the top left-hand side of the figure, those with modes in low rainfall classes at the bottom right-hand side. In this figure the broad rainfall tolerance of most species was apparent. The histograms have a more or less smooth outline, usually without marked discontinuities. The 10 to 15 cm per annum, or driest, class was the only one in which all lichens were notably less frequent.

(*b*) *Frequency in relation to Seasonal Rainfall Incidence*

The frequency of common species for sites with summer or winter rainfall predominant was calculated (Table 1). Many species did not occur at all in areas with summer rainfall predominant, and most others had a markedly higher frequency in areas with winter rainfall predominant. Two species, *Buellia subcoronata* and *Lecidea planata*, were more frequent in areas with summer rainfall predominant than in areas with winter rainfall predominant; the frequency of *Lecidea psammophila* was virtually the same in both rainfall regions.

(*c*) *Frequency in relation to Soil Extract pH*

The relationship between frequency and pH is illustrated in Figure 2, in which the frequency histograms for each species are arranged with their modes in ascending order of pH value. It is apparent that most of the histograms exhibit definite pH modes, although *Lecidea decipiens* and *Heppia polyspora* occur with a more or less uniform frequency across the whole pH range.

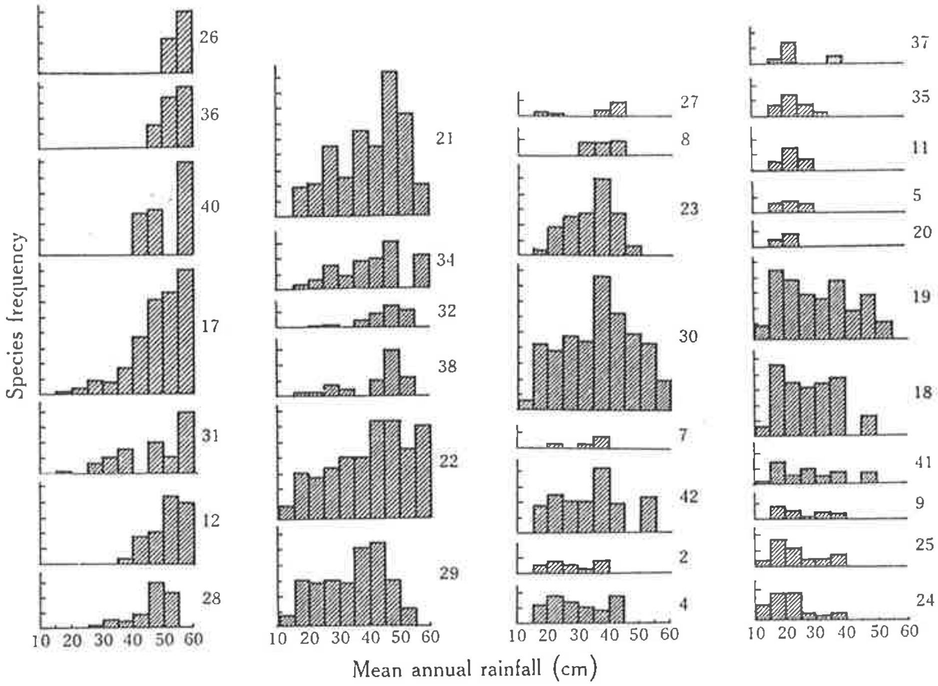

Fig. 1.—Histograms showing relationship between species frequency and mean annual rainfall. The scale divisions on the *Y*-axis are 10% frequency intervals. A key to the species treated (numbers to right of each histogram) is provided below, the numbering being consistent with other papers in this series.

1. *Acarospora smaragdula*
4. *Aspicilia calcarea*
5. *Aspicilia calcarea* mod. *fruticosa*
7. *Buellia epigaea*
8. *Buellia subcoronata*
9. *Caloplaca subpyracella*
11. *Chondropsis semiviridis*
12. *Cladia aggregata*
*17. *Cladonia* squamules
18. *Collema coccophorus*
19. *Dermatocarpon lachneum*
20. *Diploschistes ocellatus*
21. *Diploschistes scruposus*
22. *Endocarpon pusillum*
23. *Fulgensia bracteata*
24. *Heppia lutosa*
25. *Heppia polyspora*
26. *Heterodea mülleri*
27. *Lecanora atra*
28. *Lecidea coarctata*
29. *Lecidea crystallifera*
30. *Lecidea decipiens*
31. *Lecidea planata*
32. *Lecidea psammophila*
34. *Parmelia amphixantha*
35. *Parmelia convoluta*
36. *Parmelia flavescentreagens*
37. *Parmelia versicolor*
38. *Parmelia pulla*
40. *Siphula coriacea*
41. *Synalissa* sp.
42. *Toninia caeruleonigricans*

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* Material treated in this and the preceding papers as *Cladonia* squamules has now been shown to be *Ramalea cochleata* Muell.-Arg.

(*d*) *Frequency in relation to Calcium*

The relationship between frequency and determined calcium is shown in Figure 3. Two species, *Dermatocarpon lachneum* and *Collema coccophorus*, occurred across the entire range of calcium concentration. Most species were absent from the higher class which, because of the logarithmic class interval, represents half the total range.

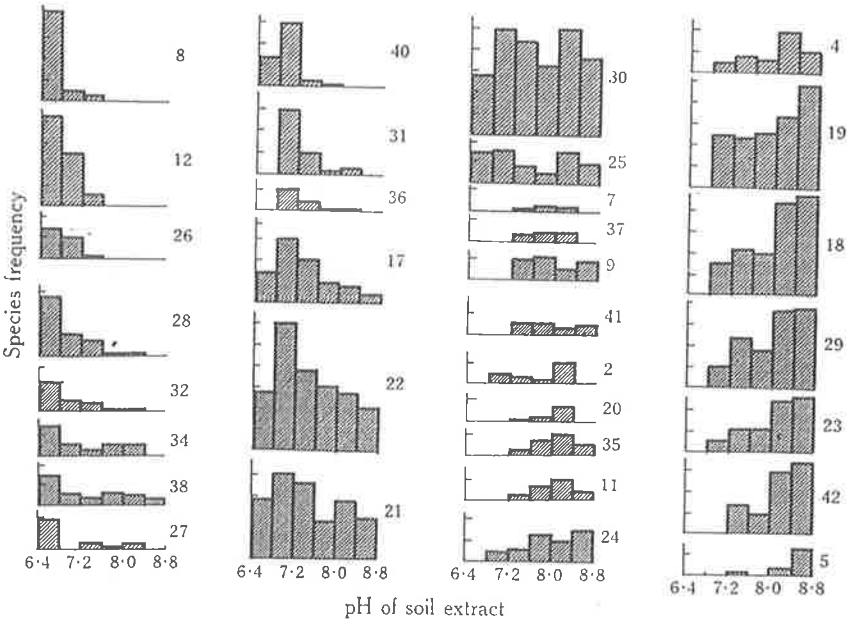


Fig. 2.—Histograms showing relationship between species frequency and pH of the soil extract. The scale divisions on the *Y*-axis are 10% frequency intervals. A key to the species treated (numbers on right of each histogram) is provided on Fig. 1.

TABLE 1

FREQUENCY OF SPECIES IN AREAS WITH PREDOMINANT SUMMER AND WINTER RAINFALL

Species	Summer rain	Winter rain	Species	Summer rain	Winter rain
Acarospora smaragdula	0	6·3	*Heppia polyspora*	7	9·6
Aspicilia calcarea	3	14·6	*Heterodea mülleri*	0	1·6
Aspicilia calcarea mod. *fruticosa*	0	5·0	*Lecanora atra*	1	2·1
Buellia epigaea	0	2·1	*Lecidea coarctata*	2	3·8
Buellia subcoronata	5	0·4	*Lecidea crystallifera*	2	37·8
Caloplaca subpyracella	2	5·4	*Lecidea decipiens*	11	54·1
Chondropsis semiviridis	0	8·4	*Lecidea planata*	7	4·6
Cladia aggregata	0	5	*Lecidea psammophila*	2	2·1
Cladonia squamules	1	16·1	*Parmelia amphixantha*	3	10·0
Collema coccophorus	13	37·2	*Parmelia convoluta*	0	8·4
Dermatocarpon lachneum	13	37·5	*Parmelia flavescentreagens*	0	2·8
Diploschistes ocellatus	0	4·2	*Parmelia versicolor*	0	5·0
Diploschistes scruposus	4	35·4	*Parmelia pulla*	0	5·4
Endocarpum pusillum	12	39·6	*Siphula coriacea*	0	4·2
Fulgensia bracteata	0	21·2	*Synalissa* sp.	2	10·0
Heppia lutosa	11	18·3	*Toninia caeruleonigricans*	2	26·7

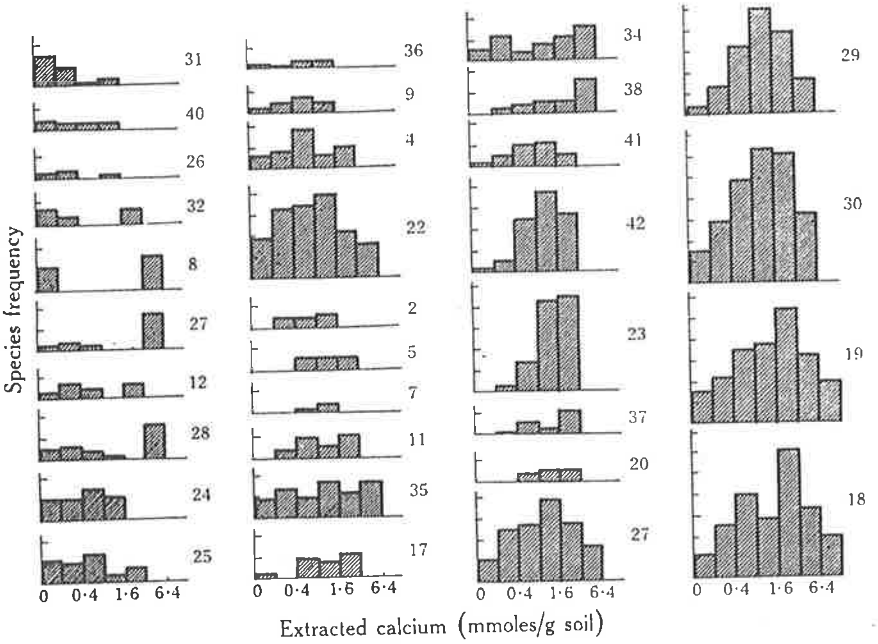


Fig. 3.—Histograms showing relationship between species frequency and calcium concentration. The scale divisions on the *Y*-axis are 10% frequency intervals; the class intervals on the *X*-axis are logarithmic. A key to the species treated (numbers on right of each histogram) is provided on Fig. 1.

(*e*) *Frequency in relation to Sodium*

The relationship between frequency and determined sodium is shown in Figure 4. The shape of the histograms suggests that sodium concentration does not play an

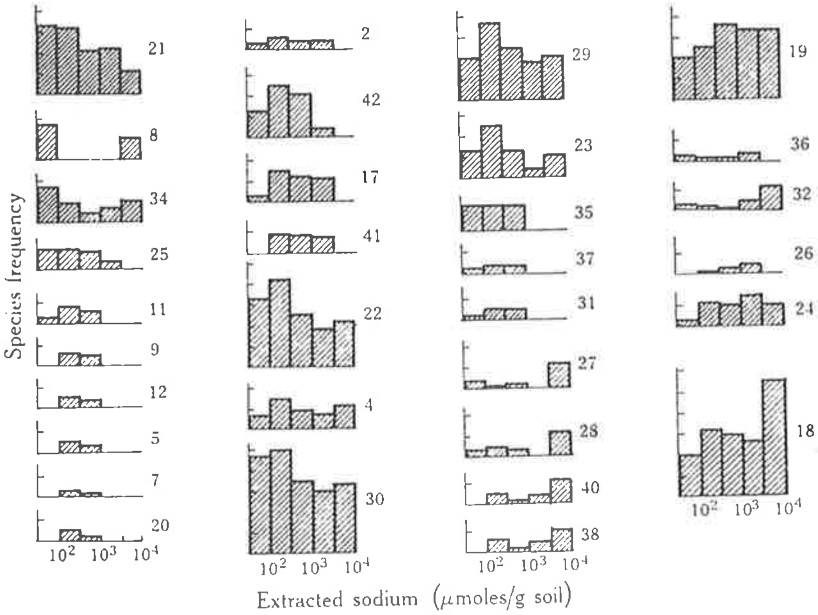
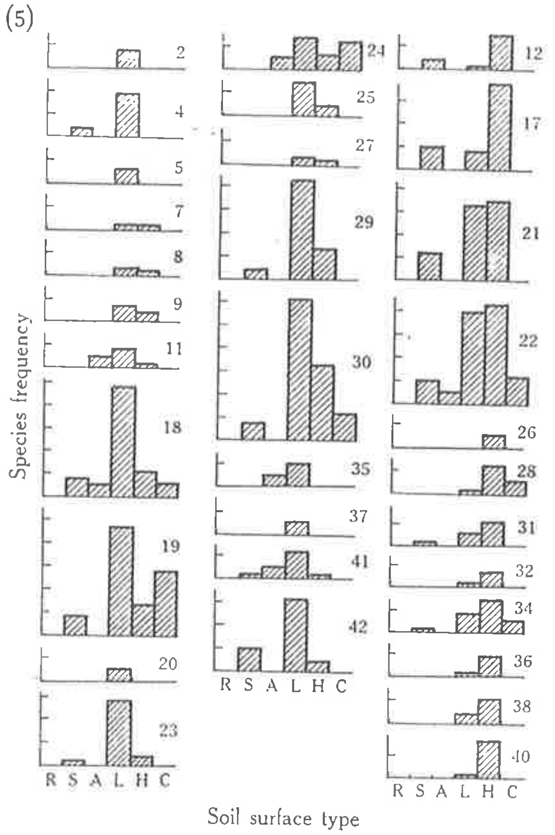


Fig. 4.—Histograms showing relationship between species frequency and sodium concentration. The scale divisions on the *Y*-axis are 10% frequency intervals; the class intervals on the *X*-axis are logarithmic. A key to the species treated (numbers on right of each histogram) is provided on Fig. 1.

important role in determining species distribution within the range of concentrations encountered. Most species are broadly spread across a large part of the range, but some have more limited ranges, especially *Diploschistes ocellatus*, *Caloplaca subpyracella*, *Cladia aggregata*, *Aspicilia calcarea* mod. *fruticosa*, and *Buellia epigaea.*

(5)



(6)

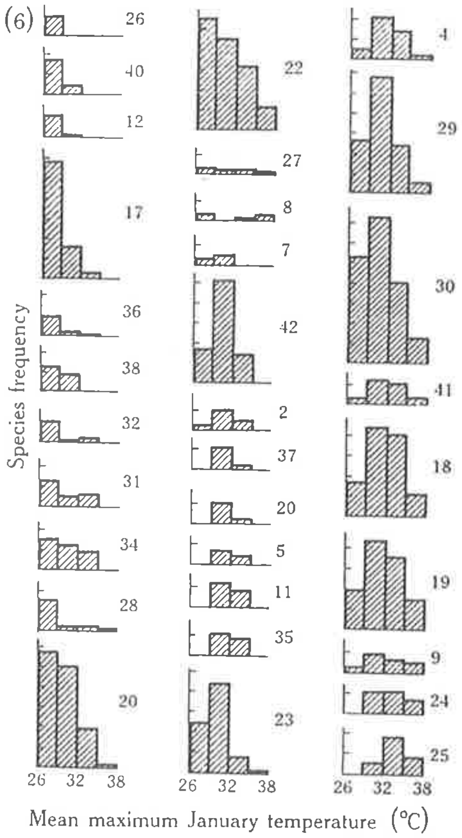


Fig. 5.—Histograms showing relationship between species frequency and nature of the soil surface. The scale divisions on the *Y*-axis are 10% frequency intervals. The letters on the *X*-axis refer to rock (R), sand (S), amorphous (A), loam (L), hard-setting (H), and clay (C) surfaces respectively. A key to the species treated (numbers on right of each histogram) is provided on Fig. 1.

Fig. 6.—Histograms showing relationship between species frequency and mean daily maximum temperature for January. The scale divisions on the *Y*-axis are 10% frequency intervals. A key to the species treated (numbers on right of each histogram) is provided on Fig. 1.

(*f*) *Frequency in relation to Soil Surface Type*

The frequency of the more common species on each soil type is presented graphically in Figure 5. No soil lichen can occur on areas completely paved with rocks, but lichens occur on all other soil surface types. Maximum frequency for all species occurs on either crusted loam or hard-setting surfaces. *Collema coccophorus* and *Endocarpon pusillum* both occur on all surface types that support any soil lichens. *Aspicilia calcarea* mod. *fruticosa*, *Diploschistes ocellatus*, and *Parmelia versicolor* occur only on crusted loams, and *Heterodea mülleri* occurs only on hard-setting surfaces. All other species occurred on more than one soil surface type: seven of the total 42 species occurred on clay surfaces, 30 on hard-setting surfaces, 39 on crusted loams, six on amorphous surfaces, and 18 on sands.

(g) *Frequency in relation to Mean Daily Maximum Temperature for January*

The frequency of the more common species in each temperature class is presented in Figure 6. The species are ordered in this figure first by mode of the frequency histogram, then by tolerance of high temperatures. No species has a maximum frequency in the highest maximum temperature class. Only one species, *Heppia lutosa*, falls in the second highest class, all others are in the two lower groups.

(h) *Frequency of Lichen Crust Formation in relation to Environmental Variation*

The histograms in Figure 7 summarize the relationships between frequency of crust formation and mean annual rainfall, soil extract pH, soil extract calcium and sodium concentrations, the nature of the soil surface, and mean daily maximum temperature for January. It was calculated that 45% of sites examined with winter rainfall predominant and 13% of sites with a summer rainfall predominant were crusted.

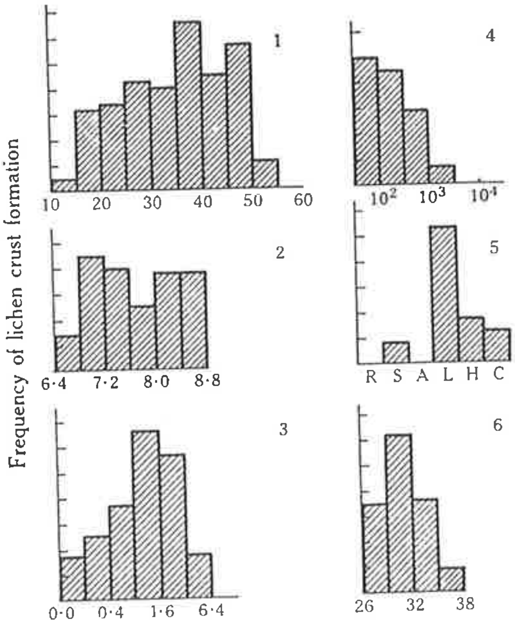


Fig. 7.—Histogram showing relationship between the frequency of lichen crust formation and selected environmental variables. The scale divisions on the *Y*-axis are 10% frequency intervals. A key to the environmental variables treated (numbers on right of each histogram) is provided below; further explanation of each appears either in the text or in the preceding figures.

1. Mean annual rainfall.
2. pH of the soil extract.
3. Extracted calcium per gram of soil.
4. Extracted sodium per gram of soil.
5. Nature of the soil surface.
6. Mean daily maximum temperature for January.

V. Relationship between Ordinations and Species Group Membership

In this section the environmental factors which are related to the distribution of species groups are determined by comparing the environmental ordinations of species with species group membership.

In Table 2 the species are ordered by the rainfall corresponding with their modal frequency, and also the community group to which the species belongs. It is apparent that species in group A all have their highest frequencies in high rainfall areas, species of group B in somewhat lower rainfall areas, and species of groups C and D at still lower rainfall levels. Mean annual rainfall must therefore be considered a factor related to the distribution of the species groups involved.

Table 2

RELATIONSHIP BETWEEN ORDINATION OF SPECIES ON THE BASIS OF FREQUENCY MODE FOR RAINFALL, AND THE ASSIGNED SPECIES GROUPS

Species for modal frequencies in high rainfall areas are at the top of the list

Species	Species group A	B	C	D
Heterodea müllleri	+			
Parmelia flavescentreagens	+			
Siphula coriacea	+			
Cladonia squamules	+			
Lecidea planata		+		
Cladia aggregata	+			
Lecidea coarctata		+		
Diploschistes scruposus	+			
Parmelia amphixantha		+		
Lecidea psammophila		+		
Parmelia pulla	+			
Endocarpon pusillum				+
Lecidea crystallifera			+	
Lecanora atra		+		
Buellia subcoronata		+		
Fulgensia bracteata			+	
Lecidea decipiens				+
Buellia epigaea			+	
Toninia caeruleonigricans			+	
Acarospora smaragdula			+	
Aspicilia calcarea				+
Parmelia versicolor			+	
Parmelia convoluta			+	
Chondropsis semiviridis			+	
Aspicilia calcarea mod. *fruticosa*			+	
Diploschistes ocellatus			+	
Dermatocarpon lachneum				+
Collema coccophorus				+
Synalissa sp.				+
Caloplaca subpyracella				+
Heppia polyspora				+
Heppia lutosa				+

Table 3

RELATIONSHIP BETWEEN ORDINATION OF SPECIES BASED ON THE RATIO OF FREQUENCY IN WINTER RAINFALL AREAS TO FREQUENCY IN SUMMER RAINFALL AREAS, AND THE ASSIGNED SPECIES GROUPS

Species	Species group A	B	C	D
Species occurring in summer rainfall areas				
Buellia subcoronata		+		
Lecidea planata		+		
Lecidea psammophila		+		
Heppia polyspora				+
Heppia lutosa				+
Lecidea coarctata		+		
Lecanora atra		+		
Caloplaca subpyracella				+
Parmelia amphixantha		+		
Dermatocarpon lachneum				+
Collema coccophorus				+
Endocarpon pusillum				+
Synalissa sp.				+
Lecidea decipiens				+
Aspicilia calcarea				+
Diploschistes scruposus	+			
Toninia caeruleonigricans			+	
Cladonia squamules	+			
Lecidea crystallifera			+	
Species not occurring in summer rainfall areas				
Aspicilia calcarea mod. *fruticosa*			+	
Acarospora smaragdula			+	
Buellia epigaea			+	
Chondropsis semiviridis			+	
Cladia aggregata	+			
Diploschistes ocellatus			+	
Fulgensia bracteata			+	
Heterodea müllleri	+			
Parmelia convoluta			+	
Parmelia flavescentreagens	+			
Parmelia versicolor			+	
Parmelia pulla	+			
Siphula coriacea	+			

When species are ordered on the basis of the ratio:

$$\frac{\text{frequency in areas with winter rainfall predominant}}{\text{frequency in areas with summer rainfall predominant}}$$

it is apparent that groups B and D occur in summer rainfall areas, whereas those species in groups A and C either do not occur or occur only rarely in areas with summer rainfall (Table 3). Seasonal distribution of rainfall is thus demonstrated to be closely related to species distribution.

If the species are ordered on the basis of modal frequency in relation to the pH of the soil extract (Table 4) it is apparent that species in groups A and B tend to occur on acid–neutral or slightly alkaline soils, whereas species of groups C and D tend to occur on strongly alkaline soils. The same effect, although not as sharply defined, is apparent if the calcium concentration of the soil extract is considered (Table 5). This indicates that while both the pH and the calcium concentration of the soil extract are related to distribution patterns, pH is the more closely related to distribution.

TABLE 4

RELATIONSHIP BETWEEN ORDINATION OF SPECIES ON THE BASIS OF FREQUENCY MODE FOR SOIL EXTRACT pH, AND THE ASSIGNED SPECIES GROUPS

Species with modal frequencies on acid (low pH) soils are at the beginning of the list

Species	Species group				Species	Species group			
	A	B	C	D		A	B	C	D
Buellia subcoronata		+			*Buellia epigaea*			+	
Cladia aggregata	+				*Parmelia versicolor*			+	
Heterodea mülleri	+				*Caloplaca subpyracella*				+
Lecidea coarctata		+			*Synalissa* sp.				+
Lecidea psammophila		+			*Acarospora smaragdula*			+	
Parmelia amphixantha		+			*Diploschistes ocellatus*			+	
Parmelia pulla	+				*Parmelia convoluta*			+	
Lecanora atra		+			*Chondropsis semiviridis*			+	
Siphula coriacea	+				*Heppia lutosa*				+
Lecidea planata		+			*Aspicilia calcarea*				
Parmelia flavescentreagens	+				*Dermatocarpon lachneum*				+
Cladonia squamules	+				*Collema coccophorus*				+
Endocarpon pusillum	+			+	*Lecidea crystallifera*			+	
Diploschistes scruposus	+				*Fulgensia bracteata*			+	
Lecidea decipiens				+	*Toninia caeruleonigricans*			+	
Heppia polyspora				+	*Aspicilia calcarea* mod. *fruticosa*			+	

When the species are ordered by frequency mode in relation to the sodium concentration of the soil extract, no relation with species grouping can be detected (Table 6). This implies that species in all groups react in a similar way to sodium concentration.

Since all species have their highest frequencies on either crusted loams or hard-setting soils, it is possible to group the species into two classes: those with maximum frequency on hard-setting soils and those with maximum frequency on

TABLE 5

RELATIONSHIP BETWEEN ORDINATION OF SPECIES ON THE BASIS OF FREQUENCY MODE FOR SOIL EXTRACT CALCIUM CONCENTRATION, AND THE ASSIGNED SPECIES GROUPS

Species with modal frequencies on soils with low calcium concentration are at the beginning of the list

Species	Species group				Species	Species group			
	A	B	C	D		A	B	C	D
Lecidea planata		+			*Buellia epigaea*			+	
Siphula coriacea	+				*Chondropsis semiviridis*			+	
Heterodea mülleri	+				*Parmelia convoluta*			+	
Lecidea psammophila		+			*Cladonia* squamules	+			
Buellia subcoronata		+			*Parmelia amphixantha*		+		
Lecanora atra		+			*Parmelia pulla*	+			
Cladia aggregata	+				*Synalissa* sp.				+
Lecidea coarctata		+			*Toninia caeruleonigricans*			+	
Heppia lutosa				+	*Fulgensia bracteata*			+	
Heppia polyspora				+	*Parmelia versicolor*			+	
Parmelia flavescentreagens	+				*Diploschistes ocellatus*			+	
Caloplaca subpyracella				+	*Diploschistes scruposus*	+			
Aspicilia calcarea				+	*Lecidea crystallifera*			+	
Endocarpon pusillum	+			+	*Lecidea decipiens*				+
Acarospora smaragdula			+		*Dermatocarpon lachneum*				+
Aspicilia calcarea mod. *fruticosa*			+		*Collema coccophorus*				+

TABLE 6

RELATIONSHIP BETWEEN ORDINATION OF SPECIES ON THE BASIS OF FREQUENCY MODE FOR SOIL EXTRACT SODIUM CONCENTRATION, AND THE ASSIGNED SPECIES GROUPS

Species with modal frequencies on soil with low sodium concentrations are at the beginning of the list

Species	Species group				Species	Species group			
	A	B	C	D		A	B	C	D
Diploschistes scruposus	+				*Lecidea decipiens*				+
Buellia subcoronata		+			*Lecidea crystallifera*			+	
Parmelia amphixantha		+			*Fulgensia bracteata*			+	
Heppia polyspora				+	*Parmelia convoluta*			+	
Chondropsis semiviridis			+		*Parmelia versicolor*			+	
Caloplaca subpyracella				+	*Lecidea planata*		+		
Cladia aggregata	+				*Lecanora atra*		+		
Aspicilia calcarea mod. *fruticosa*			+		*Lecidea coarctata*		+		
Buellia epigaea			+		*Siphula coriacea*	+			
Diploschistes ocellatus			+		*Parmelia pulla*	+			
Acarospora smaragdula			+		*Dermatocarpon lachneum*				+
Toninia caeruleonigricans			+		*Parmelia flavescentreagens*	+			
Cladonia squamules	+				*Lecidea psammophila*		+		
Synalissa sp.				+	*Heterodea mülleri*	+			
Endocarpon pusillum	+			+	*Heppia lutosa*				+
Aspicilia calcarea				+	*Collema coccophorus*				+

crusted loams. It is apparent from Table 7 that species of group A are all more common on hard-setting soils, and that those of group C are all more common on crusted loamy soils. Excepting *Endocarpon pusillum* (which could alternatively be

TABLE 7

RELATIONSHIP BETWEEN ORDINATION OF SPECIES ON THE RATIO OF FREQUENCY ON HARD SURFACE SOILS TO FREQUENCY ON CRUSTED LOAMS, AND THE ASSIGNED SPECIES GROUPS

Species which were more common on hard soil surfaces are at the beginning of the list

Species	Species group				Species	Species group			
	A	B	C	D		A	B	C	D
Cladia aggregata	+				*Buellia subcoronata*		+		
Cladonia squamules	+				*Caloplaca subpyracella*				+
Diploschistes scruposus	+				*Chondropsis semiviridis*			+	
Endocarpon pusillum				+	*Collema coccophorus*				+
Heterodea mülleri	+				*Dermatocarpon lachneum*				+
Lecidea coarctata		+			*Diploschistes ocellatus*			+	
Lecidea planata		+			*Fulgensia bracteata*			+	
Lecidea psammophila		+			*Heppia lutosa*				+
Parmelia amphixantha		+			*Heppia polyspora*				+
Parmelia flavescentreagens	+				*Lecanora atra*		+		
Parmelia pulla	+				*Lecidea crystallifera*			+	
Siphula coriacea	+				*Lecidea decipiens*				+
Acarospora smaragdula			+		*Parmelia convoluta*			+	
Aspicilia calcarea				+	*Parmelia versicolor*			+	
Aspicilia calcarea mod. *fruticosa*			+		*Synalissa* sp.				+
Buellia epigaea			+		*Toninia caeruleonigricans*			+	

TABLE 8

RELATIONSHIP BETWEEN THE ORDINATION OF SPECIES ON THE BASIS OF FREQUENCY MODE FOR MEAN MAXIMUM TEMPERATURE FOR JANUARY, AND THE ASSIGNED SPECIES GROUPS

The species with modal frequencies in low temperature areas are at the beginning of the list

Species	Species group				Species	Species group			
	A	B	C	D		A	B	C	D
Heterodea mülleri	+				*Acarospora smaragdula*			+	
Siphula coriacea	+				*Parmelia versicolor*			+	
Cladia aggregata	+				*Diploschistes ocellatus*			+	
Cladonia squamules	+				*Aspicilia calcarea* mod. *fruticosa*			+	
Parmelia flavescentreagens	+				*Chondropsis semiviridis*			+	
Parmelia pulla	+				*Parmelia convuluta*			+	
Lecidea psammophila		+			*Fulgensia bracteata*			+	
Lecidea planata		+			*Aspicilia calcarea*			+	
Parmelia amphixantha		+			*Lecidea crystallifera*				+
Lecidea coarctata		+			*Lecidea decipiens*				+
Diploschistes scruposus	+				*Synalissa* sp.				+
Endocarpon pusillum				+	*Collema coccophorus*				+
Lecanora atra		+			*Dermatocarpon lachneum*				+
Buellia subcoronata		+			*Caloplaca subpyracella*				+
Buellia epigaea			+		*Heppia polyspora*				+
Toninia caeruleonigricans			+		*Heppia lutosa*				+

placed in group A), group D species are more common on crusted loamy soils. Four members of group B are more common on hard soils, and two members more common on loamy soils.

This indicates that the nature of the soil surface is more strongly related to factors influencing the distribution of groups A and C than to those influencing groups B and D.

Ordering of species by frequency mode in relation to normal January maximum temperatures shows a close relationship between the temperature at which modal frequency is found and the species group (Table 8). Essentially, group A is most common in the lowest temperature class, and groups B, C, and D occur in an ascending order of temperature classes. The placing of *Buellia epigaea* is ambiguous, so it is included in the low temperature preference, but at the end of the series with low temperature modes. The species of group A are, with the exception of *Diploschistes scruposus,* limited to the lower temperature classes, and those of group B are relatively more common in the three lower classes. Generally species of group C are confined to the two central temperature classes, whereas species in group D occur in each class, except *Heppia polyspora* and *H. lutosa,* which occur in all but the lowest temperature class. This is the most clear-cut relationship found between species grouping and environmental ordination, which indicates either a strong causative influence or close correlation with such an influence on the distribution of species.

VI. DISCUSSION

(*a*) *Factors controlling Distribution of Lichen Species*

The environmental variables discussed ordered the species of the species groups in three different ways. Mean annual rainfall and mean maximum temperature for January both arrayed the four separate species groups quite distinctly in the order A, B, C, D. This order proceeded from wet to dry frequency modes for rainfall and from cool to hot frequency modes for temperature. Within the study area it was true that the wettest areas were also coolest, and that the driest were the hottest. In the light of this relationship it is not unexpected that both rainfall and mean maximum January temperature appeared to affect the species frequency in a like manner.

In terms of seasonal rainfall, there were only two detectable groupings. Species groups A and C were linked together in this ordination, both occurring in areas with a marked predominance of winter rainfall. Similarly species groups B and D were found to occur in areas with winter rainfall and also areas with predominantly summer rainfall.

Similar groupings of species reflecting the order resulting from the rainfall and temperature ordinations result from consideration of the three influential soil factors (surface type, pH, and calcium content). Species in groups A and B tended to have modal frequencies on soils which were relatively acid, with low calcium concentration and hard surfaces. Species in groups C and D tended to have modal frequencies on soils which were relatively alkaline, with high calcium concentration and crusted surfaces.

Thus, while mean annual rainfall or mean maximum temperature for January could explain the distribution of the species groups, they could also be explained by seasonal distribution of rainfall and by soil characteristics.

The situation, however, is not as simple as it appears from the discussion above. Soil type is largely controlled by climate. Acid, hard-setting soils with a low calcium content are mostly restricted to wetter areas: alkaline and loamy soils with a high calcium content are more or less restricted to dry areas. Hence it is to be expected that soil factors will produce ordinations reflecting those produced by mean annual rainfall.

Similarly the remaining factor, seasonal distribution of rainfall, is not independent of mean annual rainfall, because the highest rainfall reached in the summer rainfall area was not nearly as high as that reached in the winter rainfall area. The exclusion of species in group A from areas with predominantly summer rainfall could be a reflection of the relatively low rainfall in that area. Only one species in group A commonly occurred in areas with rainfall as low as the wettest area with summer rainfall. For the lower rainfall areas, however, there are areas of similar mean annual rainfall in both summer and winter rainfall zones.

Thus, the absence of species of group C from summer rainfall areas must be the result of the seasonal distribution of rainfall, or of a variable related to it but not related to soil type.

Therefore, on a broad scale there is no necessity to invoke factors other than climate to explain the distribution of soil surface lichens. It appears that mean annual rainfall, mean maximum temperature, and the seasonal distribution of rainfall are the major parameters required to explain all the distribution patterns discovered. To obtain more direct evidence of factors influencing distributions than the correlative approach taken here would require ecological and physiological studies of the kind reported by Rogers (1971) for *Chondropsis semiviridis*. It was shown that the duration of drought, which was related to mean annual rainfall, was likely to limit the distribution of that species in very dry areas, and the effect of heat on wet thalli to prevent its development in areas with summer rainfall. It was suggested that competition for light would restrict its distribution in higher rainfall areas where the vegetation density was much higher. The correlations discussed above suggest that the same factors control the distribution of all lichen species, but in different ways.

Some species showed a remarkable tolerance to the extremes of environment encountered in this study. Material referred to the species *Endocarpon pusillum* occurred on all soil surface types that supported any lichen growth across the complete pH and sodium range, from the highest to lowest rainfall and January temperature classes, and in all but the highest calcium concentration range. Other taxa with wide tolerances included *Cladonia* sp. squamules, *Collema coccophorus*, *Diploschistes scruposus*, *Lecidea crystallifera*, *Lecidea decipiens*, and *Dermatocarpon hepaticum*.

Some species in group C, notably *Diploschistes ocellatus*, *Aspicilia calcarea* mod. *fruticosa*, and *Buellia epigaea* have singularly restricted ranges in relation to all the variables examined.

A comparison of special interest is that between the tolerance ranges of *Aspicilia calcarea* and *A. calcarea* mod. *fruticosa*. The fruticose modification always occurred in a restricted range within the wider range of the crustose form. Because both forms can occur in close proximity to one another, microenvironmental factors are probably involved in determining fruticose or crustose development even within the narrow range of soil and climatic variables suited to the fruticose modification.

(*b*) *Factors controlling Distribution of Lichen Crusts*

Since a lichen crust is the result of development of populations of the lichen species, it was expected that the factors influencing the distribution of the crust would be those influencing individual species.

It was apparent from the data that crusts develop over a very wide range of rainfall and pH conditions. Crust formation did, however, show a marked relationship to soil calcium and sodium concentrations (most common in the mid and low ranges respectively). Crusts were developed predominantly on loamy soils, although they did occur on soils with hard-setting clay and sandy surfaces.

The data relevant to seasonal distribution of rainfall indicated that crusts tended not to occur in areas with summer rainfall. However, a considerable development of crust in central New South Wales suggested that the general absence of crusts from areas with summer rainfall was related to the relatively low rainfall common in those areas. The absence of crusts from areas with high mean maximum temperatures for January may be explained in a similar manner.

Distribution of lichen crusts was thus apparently controlled by mean annual rainfall and by the related factors of calcium and sodium concentrations and the nature of the soil surface.

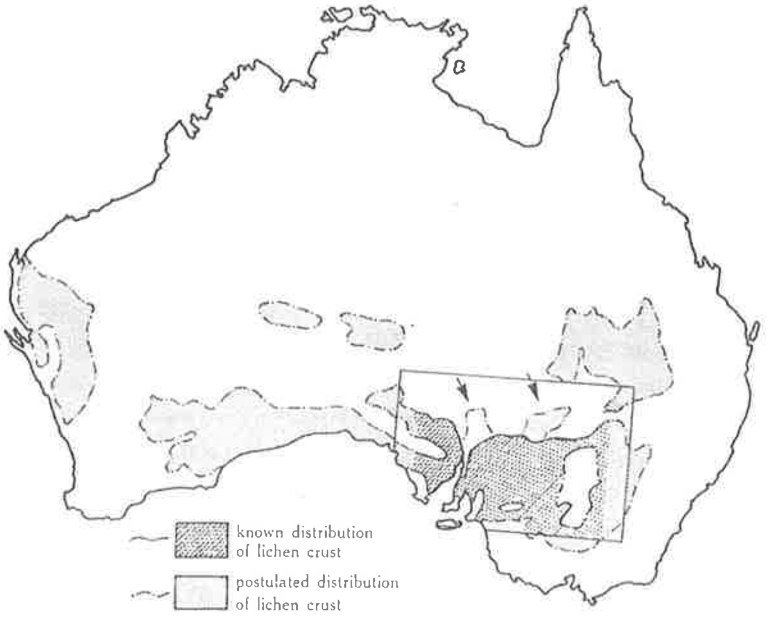


Fig. 8.—Postulated distribution of lichen crusts on southern Australian soils in relation to that actually found in the study area. The Flinders and Barrier Ranges are indicated by arrows.

(*c*) *Probable Extent and Distribution of Lichen Crusts in Southern Australia*

From the information presented above, it is possible to construct a map showing the part of southern Australia which would be expected to support a soil surface lichen crust. Similarly, it is possible to map those parts of the study zone which actually do support a lichen crust. These two pieces of information are presented on Figure 8. An additional small area of lichen crust may have existed on the red-brown earths in the rain shadow immediately west of Melbourne.

Within the study zone, two extensive areas for which a lichen crust is postulated do not have one. These areas are centred on the Barrier Range in western New South Wales, and the Flinders Range in South Australia (both arrowed on Fig. 8). These areas were settled early in the history of pastoral occupation of arid lands and, because of the terrain, have a more permanent water supply than the surrounding plains. These factors have probably resulted in a long history of relatively intense stocking with sheep. In the light of a detailed study of the effect of trampling by sheep on lichen crusts (Rogers and Lange 1971) it seems that the history of stocking in the Barrier and Flinders Ranges would account for the absence of lichens from them now.

The predicted extension of lichen crusts across the Nullarbor Plain is confirmed by R. Filson and G. C. Bratt (personal communication) and in central New South Wales by I. Noy-Meir (personal communication).

It is likely that under continued stocking the area of lichen crust will be further reduced, although it has been shown (Rogers and Lange 1971) that stocking need not result in total destruction of the lichen crust. Information in unpublished records from the Koonamore Vegetation Reserve (Botany Department, University of Adelaide) shows that extensive areas, stripped of topsoil in 1926, have developed a lichen crust: however, even after 45 years without sheep the regeneration is far from complete.

VII. Acknowledgments

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Dr. R. T. Lange, Botany Department, University of Adelaide, suggested the project and Mr. J. Hutton, Division of Soils, CSIRO, advised on soil analysis.

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OIKOS 22: 93–100. Copenhagen 1971

Lichen populations on arid soil crusts around sheep watering places in South Australia

R. W. Rogers and R. T. Lange

Department of Botany, University of Adelaide

Rogers, R. W. and Lange, R. T. 1971. Lichen populations on arid soil crusts around sheep watering places in South Australia. – Oikos 22: 93–100. Copenhagen.

Lichen populations, which encrust and stabilize soil surfaces in much of arid Australia, were studied around sheep watering places in two large paddocks near Whyalla, South Australia.

In quadrat studies twenty-four taxa of lichen were found to occur on the soil surface. Frequency data for many species reflected the relative intensity of stocking pressure at different distances from the watering place. Influence Analysis, a technique derived from Association Analysis, showed that many significant interactions existed in the distribution of species in the quadrats. The spatial distribution of the interacting species showed that many of them were influenced in similar ways by stocking pressure and watercourse conditions. Others, while effected by stocking pressure, were not influenced by watercourse conditions.

Stocking pressure caused differential destruction of species populations near the watering places. Unlike the higher vegetation, the soil crust lichen vegetation has no species which are stimulated to greater population development by intense stocking pressure. On destruction of the original lichen crust the soil surface is therefore left bare.

Dr. R. W. Rogers and Dr. R. T. Lange, Department of Botany, University of Adelaide, S. A. 5001, Australia.

В окрестностях Вайаллы (южная Австралия) вблизи мест водопоя овец в двух точках исследованы популяции лишайников на поверхности почвы, широко распространенных в аридных районах Австралии. На поверхности почвы обнаружсно 24 вида лишайников. Различная интенсивность вытаптывания почвы на разном расстоянии от воды определяет характер распределения отдельных видов лишайников. Обнаружена взаимозависимось в распределении некоторых видов. Анализ распределения таких взаимосвязанных видов показал, что распределение одних видов определяется характером вытаптывания и близостью источника воды, а другие виды реагируют лишь на вытаптывание почвы. Вытаптывание вызывает дифференциальную гибель отдельных видов вблизи мест водопоя. В противоположность более высокой растительности, среди лишайников нет таких форм, развитие которых стимулировалось бы в условиях интенсивного вытаптывания. При разрушении лишайникового покрова поверхность почвы обнажается. В этом случае почва подвергается ветровой и водной эрозии, которая является важнейшей проблемой для аридных районов.

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1. Introduction

About 70% (5 million Km²) of the Australian continent is arid, either semi-desert or desert (Meigs 1953). A great deal of this area nevertheless carries sufficient natural vegetation to support a major grazing industry; in the more temperate (southern) parts sheep flocks are of importance to the Australian economy (Bureau of Agricultural Economics 1969).

As in many comparable areas of the world, overstocking has caused landscape deterioration (White 1958) and has prompted closer attention to the underlying ecological situations (Perry 1967). A fundamental ecological unit of the sheep-vegetation system appears to be the piosphere (Lange 1968). Consequences to native vegetation of long term grazing are clearly revealed by analyses based on the piosphere concept (Barker and Lange 1969).

A striking feature of Australian arid vegetation grazed by sheep is the crust of lichens over the soil surface; the crust extends uninterrupted over vast areas. This feature has been ignored in the past, but recently (Rogers, Lange and Nicholas 1966) it has become clear that the crust warrants attention just as does the shrubby vegetation browsed by sheep.

This paper reports on variation in the lichen populations about watering places, where differential stocking pressure (decreasing with radial distance from water) allows the effect of stocking to be assessed.

2. Study areas

Analyses of piosphere situations were undertaken at two locations, one in Two-mile paddock on Middleback Station, the other in Barrett's paddock on Tregelana Station. Both stations are close to Whyalla, South Australia (fig. 1). A "station" in Australian usage is a large area (usually in excess of 100 km²) of arid land used for grazing; it is equivalent to a large American "ranch".

2.1. Two-mile paddock

Two-mile paddock, with an area of 20 km², has two sheep watering places about 5 km apart. One of these, Two-mile dam, was chosen as the focus for an initial study. Two-mile dam is scooped out of the margin of a broad flood plain. Attention was directed to adjoining country served by this watering place, covered with *Kochia sedifolia* F. v. M. shrubs interspersed with small groves of *Acacia sowdenii* Maiden trees. Such vegetation is highly valued as a grazing unit. The soils are mainly solonised brown calcareous earths. Sheep have watered at the dam for 70 years, and change in vegetation close to the dam is quite noticeable.

2.2. Barrett's paddock

Barrett's paddock, with an area of 15 km², has only one watering place for sheep; a through supplied with water through a pipeline. The trough is sited near the centre of the western boundary of the paddock, about 150 m from the fence. There is a slight downslope from west to east. The vegetation is complex, with dense groves of *Casuarina cristata* Miq. and *Acacia sowdenii* over a shrub stratum mostly of *Kochia sedifolia* or *Atriplex vesicaria* Heward. The soils are solonized brown calcareous earths. The eastern part of the paddock is subject to inundation after heavy rains. The watering place has been in use for 30 years.

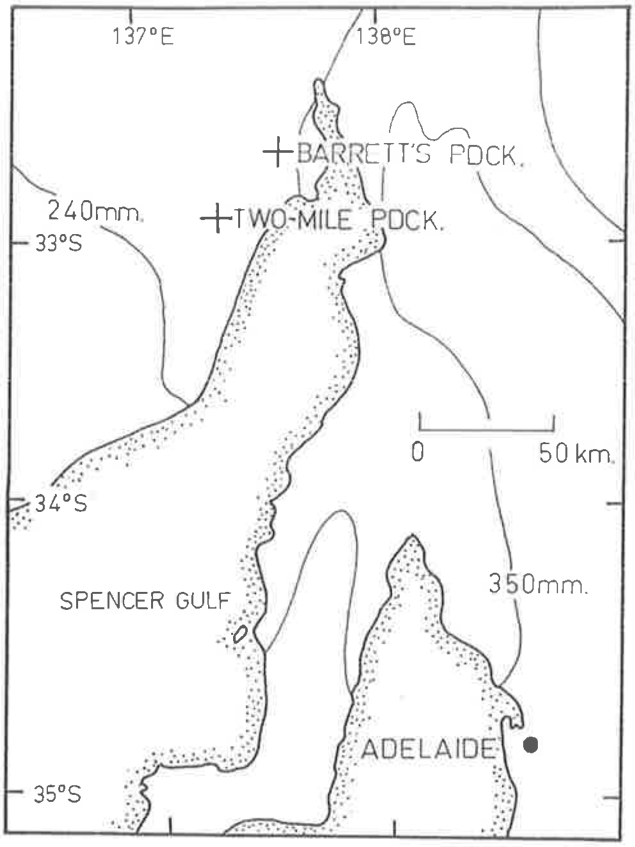

Fig. 1. The location of study sites at Two-mile and Barrett's paddocks in relation to the 240 mm and 350 mm rainfall isohyets.

3. Methods

3.1. Basis

The piosphere concept holds that a special ecological situation comes into operation when a watering place for stock is established in otherwise waterless rangeland, and stock which must drink are depastured there. From the watering place stock range radially for food to some limit set by the need to return to drink regularly. This causes a gradient in stocking pressure which attenuates with radial distance from the watering place. As a factor in the environment of plant populations, the stocking effect is then more or less of circular architecture involving concentric zonations. The vegetation is ex-

Tab. 1. Percentage frequency of lichen species at Two-mile paddock at each range from the watering place. 100 quadrats were examined at each range.

Species	No.	Range from water in metres 18	45	90	135	180	225	315	405	495	585	675	760
Acarospora smaragdula (Wahlenb.) Th.F.	1	0	2	0	0	0	1	1	3	7	4	5	9
Aspicilia calcarea Mudd. (crustose)	2	4	0	5	13	31	18	38	46	54	56	59	47
A. calcarea Mudd. (fruticose)	3	0	0	0	0	0	0	3	2	1	7	6	9
Caloplaca ? subpyracella (Nyl.) Zahlbr.	5	0	0	0	1	1	1	0	1	2	2	2	0
Cladonia foliacea Schaer.	7	0	0	0	0	0	0	0	6	2	9	13	4
Collema ? coccophorus Tuck.	8	25	42	57	47	67	62	56	59	51	52	55	62
Dermatocarpon lachneum (Ach.) A. L. Sm.	9	0	1	3	1	2	2	10	11	5	16	15	17
Diploschistes ocellatus (D.C.) Norm.	10	0	0	0	0	0	0	1	1	1	3	2	3
D. scruposus (Schreb.) Norm.	11	0	0	0	0	0	1	6	11	5	4	10	9
Endocarpon pusillum Hedw.	12	5	2	1	4	11	11	26	29	24	35	43	33
Fulgensia bracteata (Hoffm.) Räs.	13	0	0	1	0	1	2	25	15	33	41	24	27
Heppia lutosa Ach.	14	1	3	3	10	12	6	20	15	28	23	27	26
Heppia ? polyspora Tuck.	15	0	0	0	0	4	7	2	7	7	12	11	11
Lecidea coarctata (J.E. Sm.) Nyl.	17	0	0	0	0	1	0	0	0	0	0	4	1
L. crystallifera Tayl.	18	0	1	0	0	1	2	8	9	9	11	24	11
L. decipiens (Ehrh.) Ach.	19	2	0	1	2	8	11	36	35	53	54	59	56
Parmelia amphixantha Müll. Arg.	20	0	0	0	0	0	0	3	1	2	0	1	0
P. molliuscula Ach.	22	0	0	0	0	0	0	0	0	0	0	1	1
P. pulla (Neck.) Ach.	23	0	0	0	0	0	0	0	1	1	0	1	0
Toninia caeruleonigricans (Lightf.) Th. Fr.	24	1	3	7	4	8	3	19	22	32	29	20	22

pected to, and does, register the effect of stocking in a corresponding manner (Barker and Lange 1969), which is best revealed and interpreted by sampling centred on the watering place.

Various forms of Association Analysis are available for revealing how community structure relates to environmental factors (Goodall 1962). One form of Association Analysis successfully applied in such a context is Influence Analysis (Lange 1968, Barker and Lange 1969), which was chosen for this study.

3.2. Sampling

Samples were laid out on radial traverses designed to bring out pattern centred on the watering point. At sample sites, a transect 20 m long was laid out and the presence was noted of all lichen species in each of ten 15 cm × 20 cm quadrats placed 2 m apart.

Frequency of each species at each range from the watering place was calculated as the percentage of quadrats at that range with the given species occurring in it. For Association Analysis, incidence data from the ten small quadrats in each transect were pooled.

In Two-mile paddock, 10 traverses at intervals at 10° were placed with transects at ranges of 18, 45, 90, 135, 180, 225, 315, 405, 495, 585, 675 and 760 metres from the dam.

At Barrett's paddock a permanent radial grid existed, with 32 traverses at intervals of 11¼°, forming a complete circle for sampling. The positions of samples on this grid were staggered on alternate traverses: samples along one series of traverses were at ranges of 23, 70, 135, 225, 360, 630, 990 and 1170 metres, and on the alternate traverses at ranges of 45, 90, 180, 270, 450, 810 and 1170 metres from the watering place. In addition, on each traverse a transect was laid where the fence surrounding the watering place crossed the traverse; for convenience this distance has been treated as at a radius of 10 m.

4. Results

4.1. Two-mile paddock

4.1.1 . *Frequency data*

Twenty taxa of lichen occurred in the 120 transects, at least one species occurring in each. The taxa, and their frequencies at each range from the dam, are listed in Tab. 1.

4.1.2. *Incidence data*

Many significant interspecific associations occurred at *chi* levels on one degree of freedom > 3.3 ($p < 0.001$); all these interactions were positive.

The underlying patterns in this mass of interactions were revealed first by grouping those species associated at the highest attained levels of significance, then by lowering the significance level and admitting further associated species into consideration. This process resulted in the recognition of nodes (independent elements of pattern) in the populations. The development of these nodes is shown in Fig. 2.

Two separate nodes existed at the highest levels of significance. They remained independent and gained further species as significance levels were lowered, until the level at which *chi* $> 3.5_{1d.f.}$ was reached. At that level the nodes fused by association of *Acarospora smaragdula* (species 1) of node I with *Cladonia foliacea* (species 7)

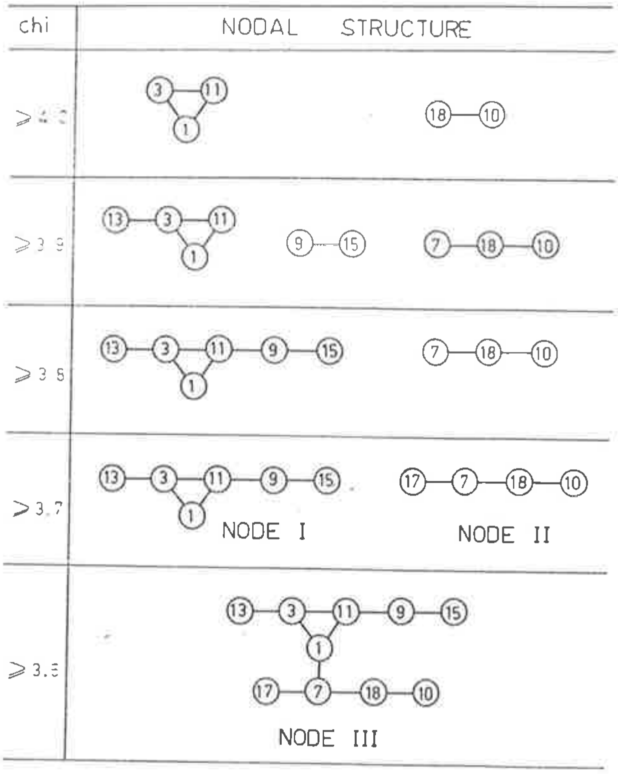

Fig. 2. Development of nodal structure derived from data collected in Two-mile paddock as *chi* (significance) levels of association are reduced. Numbers refer to species names listed in Tab. 1.

of node II. At that significance level 10 of the 20 species were linked into a single node, node III.

The implications of these interactions were brought out by examining the field distribution of the interacting species, after the approach of Lange (1968). Maps could be constructed to illustrate the expression of any node. In terms of node I, each of the 120 transects in Two-mile paddock took one of the values from zero to six according to the number of nodal species contained. On a map showing the distribution of transects classified in these terms, isotels (lines enclosing areas of the same outcome) could be constructed. This was done for each of the nodes I, II and III (Fig. 3).

4.2. Barrett's paddock

4.2.1. Frequency data

Twenty-four taxa of lichen occurred in 146 of the 175 transects. These taxa and their frequencies are listed in Tab. 2.

4.2.2. Incidence data

As at Two-mile paddock, many significant interspecific interactions, all positive, occurred. These were grouped into nodes, the development of which is shown in Fig. 4.

Three independent nodes existed at the highest levels of significance. These three gained species as the significance level was lowered, but remained independent at the lowest *chi* level ($chi > 3.3_{1df.}$) considered. The

Tab. 2. Frequency of lichen species and number of quadrats studied at Barrett's paddock for each range from the watering place.

Species		Range from water in metres														
	No.	10	23	45	70	90	135	180	225	270	360	450	630	810	990	1170
Acarospora smaragdula (Wahlenb.) Th. Fr.	1	0	0	0	0	0	0	3	1	2	0	4	2	7	2	1
Aspicilia calcarea Mudd. (crustose)	2	0	0	1	2	5	7	16	25	23	18	17	28	17	40	37
Aspicilia calcarea Mudd. (fruticose)	3	0	0	0	0	1	0	1	0	1	1	5	6	1	6	1
Buellia epigaea Tuck.	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Caloplaca ? subpyracella (Nyl.) Zahlbr.	5	0	0	0	0	0	0	1	0	0	1	1	1	1	2	1
Chondropsis semiviridis (Nyl.) Nyl.	6	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
Cladonia foliacea Schaer.	7	0	0	0	0	0	1	0	0	4	2	2	2	1	3	6
Collema ? coccophorus Tuck.	8	0	16	27	31	32	44	45	60	50	51	51	50	62	65	58
Dermatocarpon lachneum (Ach.) A. L. Sm.	9	0	0	1	0	0	2	2	6	2	7	3	7	2	13	8
Diploschistes ocellatus (D.C.) Norm.	10	0	0	0	0	0	0	0	1	0	3	2	4	3	3	2
D. scruposus (Schreb.) Norm.	11	0	0	0	0	0	1	3	1	2	1	4	2	1	2	4
Endocarpon pusillum Hedw.	12	0	0	2	3	1	5	7	16	9	12	10	13	13	30	28
Fulgensia bracteata (Hoffm.) Räs.	13	0	0	0	0	0	1	5	5	1	4	7	12	6	12	10
Heppia lutosa Ach.	14	0	5	8	9	13	17	19	32	24	27	26	31	27	39	38
Heppia polyspora Tuck.	15	0	0	1	1	1	6	3	3	2	2	5	8	4	14	10
Lecanora atra (Huds.) Ach.	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lecidea coarctata (J. E. Sm.) Nyl.	17	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1
L. crystallifera Tayl.	18	0	0	0	0	0	1	3	3	2	1	4	4	3	9	9
L. decipiens (Ehrh.) Ach.	19	0	0	0	0	1	8	17	22	16	11	21	31	20	40	31
Parmelia amphixantha Müll. Arg.	20	0	0	0	0	0	0	1	0	0	0	0	0	7	1	9
P. australiensis Cromb.	21	0	0	1	1	4	0	0	0	0	0	0	0	0	1	2
P. molliuscula Ach.	22	0	0	0	0	0	0	2	1	0	0	0	0	0	1	2
P. pulla (Neck.) Ach.	23	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Toninia caeruleonigricans (Lightf.) Th. Fr.	24	0	0	0	0	1	2	7	10	4	2	7	16	4	22	9
Number of quadrats examined		150	160	130	160	150	130	110	110	100	90	100	90	90	90	170

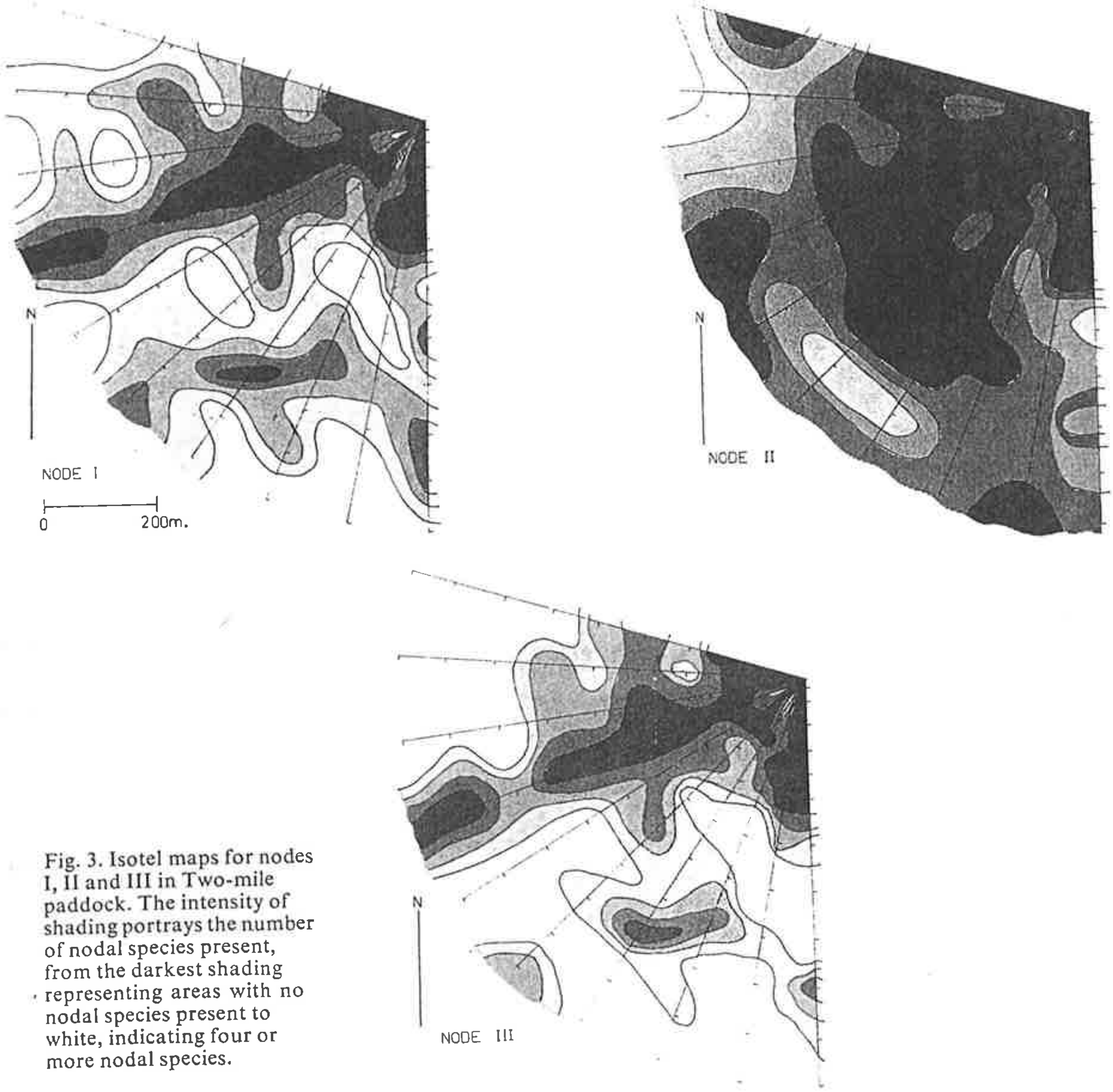

Fig. 3. Isotel maps for nodes I, II and III in Two-mile paddock. The intensity of shading portrays the number of nodal species present, from the darkest shading representing areas with no nodal species present to white, indicating four or more nodal species.

terminal nodes (nodes IV, V and VI) contained respectively ten, six and three species, a total of 19 species out of the 24 recorded for the site. Meaningful isotel maps (Figs. 5, 6) could be constructed for nodes IV and V, but node VI species were considered too infrequent for meaningful mapping.

5. Discussion

5.1. Between-site differences

The two sites were very different topographically. The watering place at Two-mile paddock was the centre of pattern for both stocking and drainage; as a result stocking pressure could not be separated from topography as an influence. In contrast, the watering place in Barrett's paddock was independent of topographic influences, because it was supplied with water from a long pipeline. It could, therefore, be assumed that any effect centred on the watering place at Barrett's paddock was related to stocking.

5.2. Two-mile paddock

5.2.1. Frequency data

The frequency data left no doubt that the watering place was the focus of an influence which reduced the frequency of each soil crust lichen species. Different species were affected to different degrees and according to different relationships, as was apparent from the nature of the curves in Fig. 7. *Collema coccophorus* was little affected by the influence until very close to the watering place, where its frequency decreased rapidly.

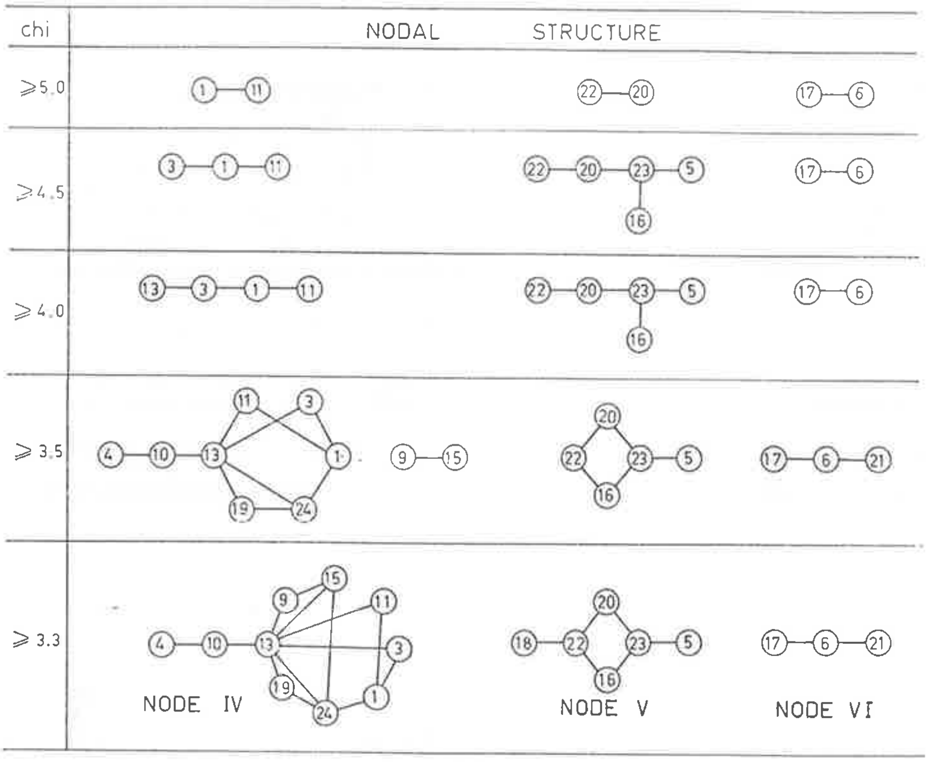

Fig. 4. Development of nodal structure derived from data collected at Barrett's paddock as *chi* (significance) levels of association are reduced. Numbers refer to species names listed in Tab. 2.

In contrast *Dermatocarpon lachneum* showed a linear relationship between frequency and range from the watering place. *Heppia lutosa* and *Lecidea decipiens* represented intermediate stages in a graded series of responses with *Collema coccophorus* and *Dermatocarpon lachneum* as poles. These effects could not be ascribed solely to stocking pressure, but could have been the product of a topographic variable.

5.2.2. *Incidence data*

Influence Analysis also showed the watering place to be the centre of an influence, because nodal species were mostly absent near the watering place (Fig. 3). It was interesting that nodes I and II, while independent of each other (and with isotels differently disposed) both reflected an influence centred on the watering place.

A feature of nodes I and III (Fig. 3) was a long tongue of low ratings along one traverse. This traverse ran along a drainage line into the dam. This observation would support an hypothesis that the low ratings were associated with topography.

In other piosphere studies all isotels of interactions between plant species were essentially concentric on the watering place, and it seemed reasonable to expect that all isotels of any significant interactions in piosphere lichen crust populations would be similar. This was not the case. At distance from the watering place, general concentricity disappeared and the pattern became a mosaic. In situations like this, drawing of isotels becomes somewhat arbitrary, even though the pattern is real. The mosaic revealed showed no correlation with obvious environmental variables.

5.3. Barrett's paddock

5.3.1. *Frequency data*

The layout of species frequency value around the watering place in Barrett's paddock was very similar to that around Two-mile dam (Fig. 7). At Barrett's paddock there was no reasonable doubt that the influence causing the low frequency values near the watering place was stocking pressure.

5.3.2. *Incidence data*

Examination of the isotel maps for nodes IV and V (Figs. 5 and 6) showed the watering place to be the centre of an area of low ratings. This left no reasonable doubt that stocking pressure was an influence causing the low ratings. It was clear from Fig. 5 that there were two tongues of low ratings running more or less east-west across the study area. One was north of the watering place, and the other was an extension of the low value zone around the watering place. The more northerly tongue was found to correspond with a watercourse, hence it appeared that watercourse conditions had an effect similar in consequence to intense stocking. The tongue from the watering place therefore, could be a response either to watercourse conditions or to intense

Fig. 5. Isotel map for node IV in Barrett's paddock. Intensity of shading has the same meaning as in Fig. 3.

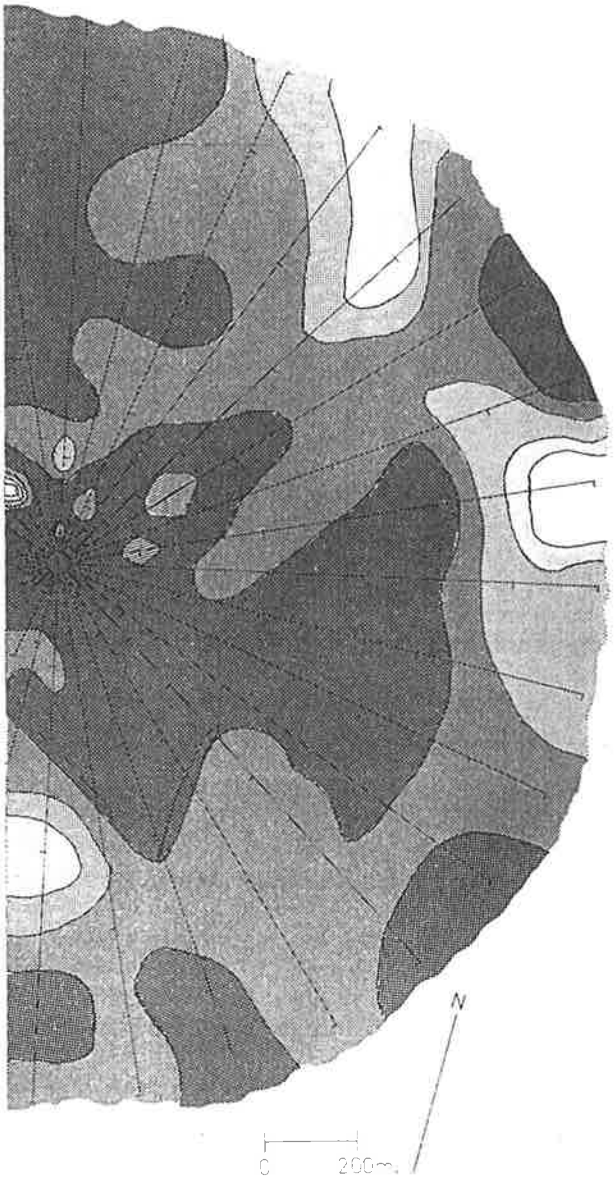

Fig. 6. Isotel map for node V in Barrett's paddock. Intensity of shading has the same meaning as in Fig. 3.

stocking pressure. This question was resolved by examination of low level aerial photographs and ground reconnaissance. Ground surveys showed that the tongue centred on the watering place did not occupy a watercourse. Aerial photography, however, showed an extraordinary concentration of sheep tracks along the tongue, apparently skirting *Casuarina* thickets. This appeared to account for the distorted concentricity of isotels about the watering place.

The species of node V, while showing a pattern of isotels (Fig. 6) similar to that of node IV (Fig. 5), did not show a tongue of low values along the watercourse. Node V species were apparently susceptible to stocking pressures. but were not influenced by the topographic factors effecting the species of node IV.

5.4. Community structure

There were species not treated by the Influence Analyses because they showed no significant interactions. While there were no significant effects on their incidence, there were nevertheless effects on their frequencies.

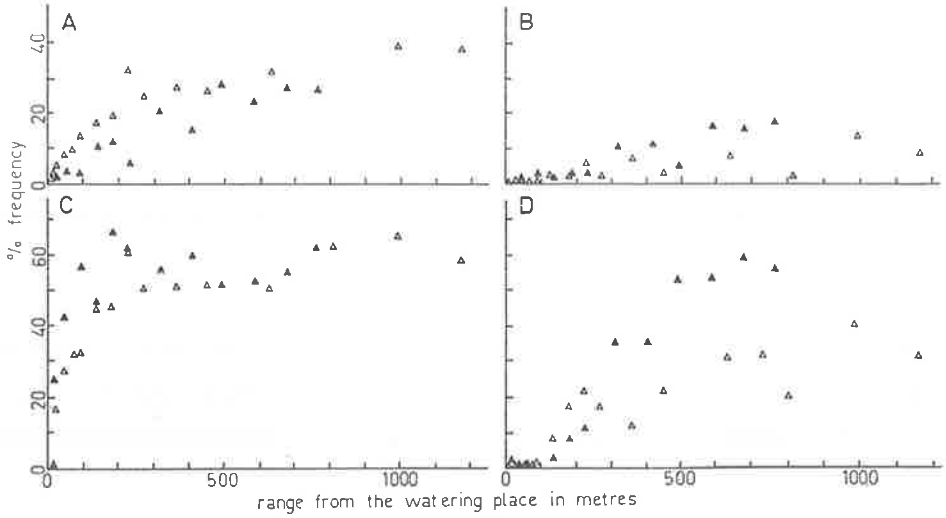

Fig. 7. Relationship between % frequency and distance from the watering place for (A) *Heppia lutosa*, (B) *Dermatocarpon lachneum*, (C) *Collema coccophorus* and (D) *Lecidea decipiens*. Solid triangles indicate frequency at Two-mile paddock, open triangles at Barrett's paddock.

It was noteworthy that no species of lichen showed development of populations in watercourses, or in response to stocking. Thus the overall soil crust lichen vegetation differed from the higher plant flora which, in the piosphere, had elements which increased in frequency under the highest stocking pressures. Deterioration of higher vegetation under stocking need involve no change in plant cover, but simply change in species composition. In contrast deterioration of lichen populations in this study implied reduction in lichen cover, and resultant soil mobility. Soil erosion is one of the major problems in arid lands.

It is clear that node III, at Two-mile paddock, and node IV, at Barrett's paddock, behave in very similar ways in relation to stocking and topographic factors. The species composition of these nodes is also very similar (Tab. 3).

Two nodes at Barrett's paddock were absent at Two-mile paddock. It was not clear what these nodes reflected except that they reflected a difference in environment between the two paddocks. Node V contained three foliose species *Parmelia amphixantha*, *P. molliuscula* and *P. pulla*, and node VI two vagant foliose species that lie free on the soil surface, *Chondropsis semiviridis* and *Parmelia australiensis*. The only foliose species occurring in a nodal group at Two-mile paddock was *Cladonia foliacea*; all other species were crustose or squamulose.

Tab. 3. The composition of node III at Two-mile paddock and that of node IV at Barrett's paddock.

Nodal Species	Node III	Node IV
Acarospora smaragdula	+	+
Aspicilia calcarea (fruticose)	+	+
Dermatocarpon lachneum	+	+
Diploschistes ocellatus	+	+
D. scruposus	+	+
Fulgensia bracteata	+	+
Heppia polyspora	+	+
Cladonia foliacea	+	—
Lecidea coarctata	+	—
L. crystallifera	+	—
Buellia epigaea	—	+
Lecidea decipiens	—	+
Toninia caeruleonigricans	—	+

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DISTRIBUTION OF THE LICHEN *CHONDROPSIS SEMIVIRIDIS* IN RELATION TO ITS HEAT AND DROUGHT RESISTANCE

BY R. W. ROGERS*

Botany Department, University of Adelaide, Adelaide, South Australia 5001

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SUMMARY

The distribution of *Chondropsis semiviridis* (FvM. ex Nyl.) Nyl. was mapped for Australia. Studies in gas exchange physiology demonstrated that length of drought is likely to limit distribution of the species. Similarly, it is shown that sensitivity to heat when wet is likely to prevent the species from establishing in arid areas with a summer rainfall season. The surge of respiration upon wetting of lichen thalli noted by other workers was so short for *C. semiviridis* that it could not affect the limits of its distribution.

INTRODUCTION

Chrondropsis semiviridis (FvM. ex Nyl.) Nyl. is the only species in the genus *Chondropsis* (Parmeliaceae). It is an unusual species, in that it has no attachment to its substrate (the soil), but lies free on the surface, and may be blown about by the wind. When dry, the thallus rolls up into a ball with the rhizoid-free lower surface outermost, and the upper surface, which is covered with a brown, opaque prosoplechtenchymatous layer, inwards. Upon wetting the thallus unrolls very rapidly and lies flat on the soil surface (Plate 1), the upper prosoplechtenchymatous layer becomes hyaline and the deep green of the algal layer visible.

The thallus which is almost perfectly dichotomous, branches at angles of about 90°, is devoid of soredia or isidia, and is very rarely fertile. Reproduction is apparently by simple fragmentation of the thallus.

DISTRIBUTION

The distribution of *Chondropsis semiviridis* was mapped from available herbarium records (Fig. 1). The species is apparently largely restricted to a band across the south of Australia in the zone with a marked winter rainfall. It is not often found outside the 15 mm and 35 mm rainfall isohyets: beyond this area the only collections of recent date are from the subalpine areas in southern New South Wales and central Otago, New Zealand.

In a study of 343 locations in south-eastern Australia, *C. semiviridis* was found to occur at twenty of them. The relationship between species frequency, mean annual rainfall, and normal maximum temperature for January (the hottest month) is shown in Fig. 2, from which it is apparent that *C. semiviridis* occurs chiefly in the cooler, dryer parts of southern Australia.

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* Present address: Botany Department, University of Queensland, St Lucia 4067, Australia.

Fig. 1. Distribution of *Chondropsis semiviridis* in Australia. ▲, Locations from which *C. semiviridis* has been collected in Australia, shown in relation to the 15 cm and 35 cm rainfall isohyets. The dotted line represents the northern limit of the zone with a seasonal maximum rainfall in winter.

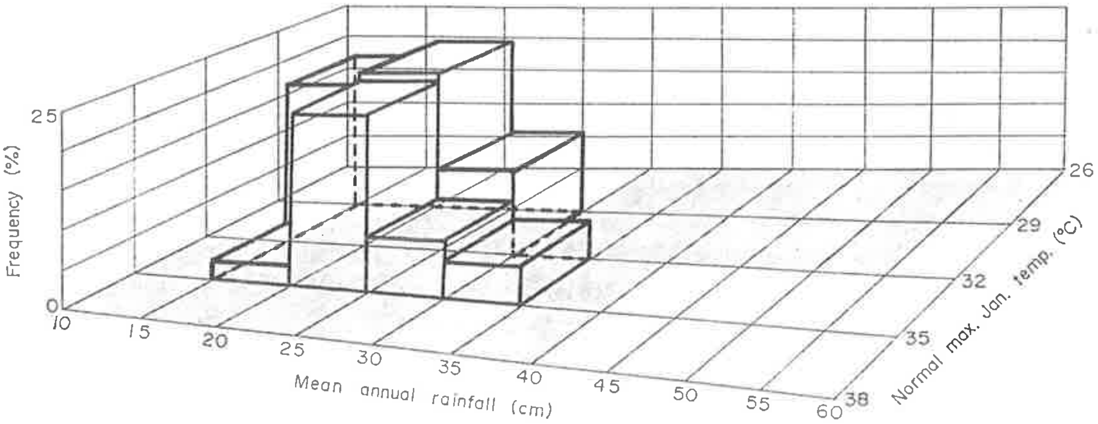
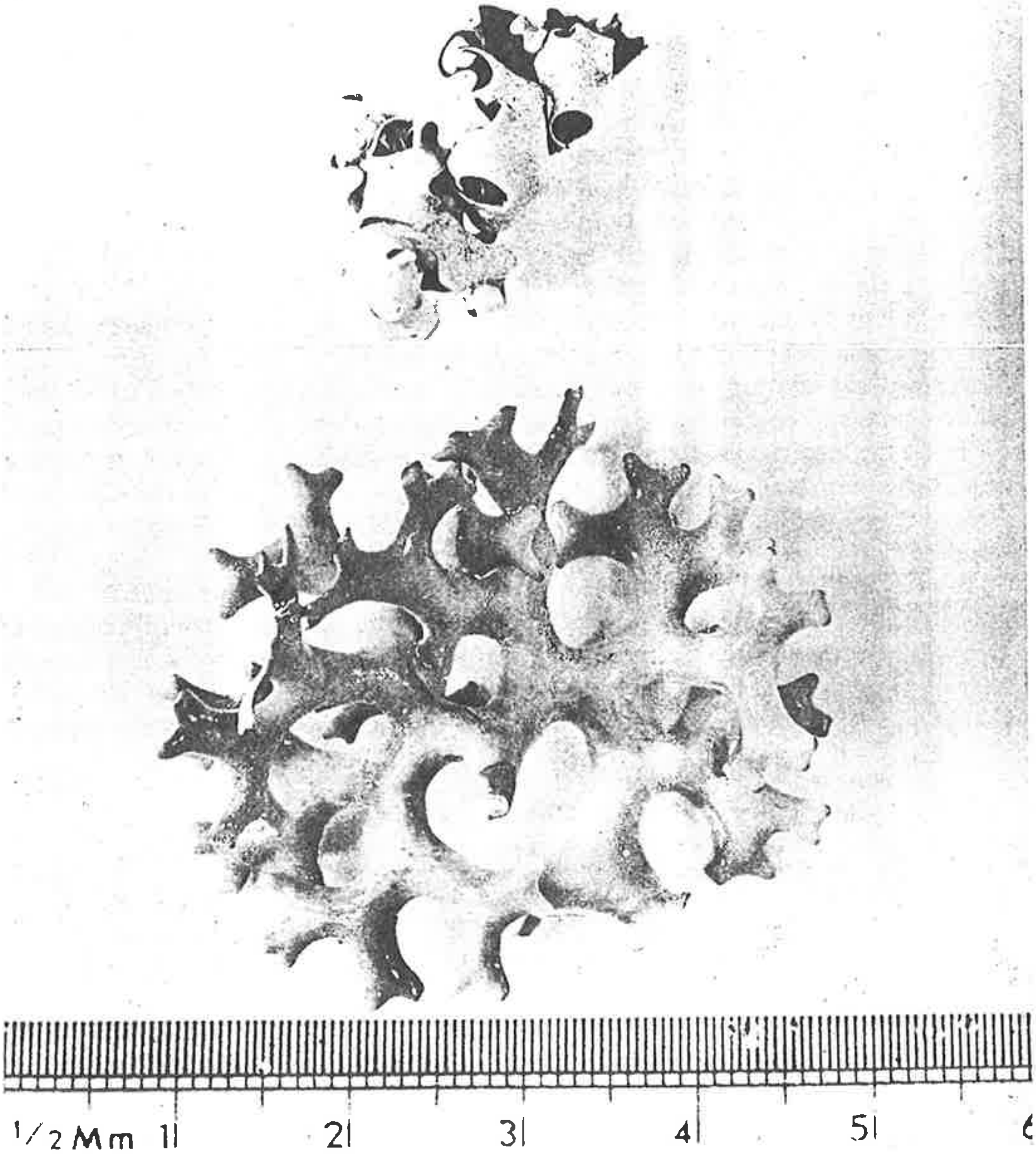


Fig. 2. The relationship between frequency of *Chondropsis semiviridis*, mean annual rainfall, and normal maximum temperature for January. The shaded area represents environmental conditions realized in the study zone.



The same thallus of *Chondropsis semiviridis* before (top) and after wetting (bottom). The scale is callibrated in half millimetres.

DROUGHT RESISTANCE

The extensive studies of Ried (1960a, b) suggested that drought resistance would play a role in controlling the distribution of lichens, although Lange (1953) believed that it did not. Ried's studies indicated that not only drought duration, but also frequency of cycles of wetting and drying may be important. Rewetting dry thalli, he found a remarkable surge in respiration, which rose to several times its normal level, eventually falling again to that level, whereas photosynthesis rose only slowly to its normal level.

The effect of drought was studied following the approach of Lange (1953), despite evidence from Ried (1960a, b) and Lange and Bertsch (1965) that the duration of Lange's study was inadequate. Longer studies were not attempted as it was not self evident under what conditions less damage would be done to the thallus than in the air-dry state in which *Chondropsis semiviridis* spent most of its life in nature. Recent studies (Pearson, 1970) also suggest that lichen thalli function most effectively under conditions of varying stress rather than under uniformly 'favourable' conditions.

Three aspects of drought-related stress were studied: (1) the effect of wetting on photosynthesis and respiration of previously droughted thalli; (2) the effect of prolonged drought on the respiration rate to which wetted thalli stabilize; (3) the rate of respiration of thalli when air dry.

Methods

Effect of wetting. Water-saturated terminal lobes of thalli were used to study the effect of temperature on respiratory and photosynthetic rates in Warburg manometers. A thiourea–diethanolamine–carbon dioxide buffer was used for photosynthetic studies (Umbreit, Burris and Stauffer, 1964). The relation between temperature and gas-exchange is shown in Fig. 3. From this it was decided that 25°C was an appropriate temperature to study gas exchange, as no adverse effect of temperature was apparent after an exposure of several hours at that temperature, and the metabolic rate was high.

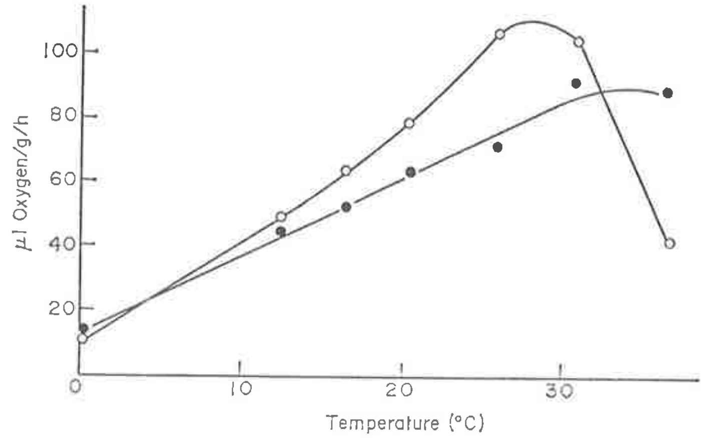


Fig. 3. The relationship between temperature and oxygen exchange. ●, Oxygen uptake in the dark; ○, oxygen evolution in the light.

All short-term studies were made using an oxygen electrode, and longer-term studies using Warburg manometers. To study the effect of wetting, fragments of thalli were introduced into the reaction chamber of an oxygen electrode, and oxygen consumption in the dark, or evolution in the light, recorded. After not more than 30 minutes the thalli were removed, oven dried and weighed so that rates of oxygen exchange/g dry weight could be calculated.

Effect of prolonged drought. To study the effect of prolonged drought, collections were made over a 3-year period, and stored in brown paper bags. For preliminary respiratory studies terminal lobes were wetted and allowed to stand wet for 12 hours whilst transient wetting effects passed. Oxygen uptake was measured in Warburg manometers. To assess the changes which take place following wetting as the preceding drought period was lengthened, dry terminal lobes were placed in an oxygen electrode reaction cell filled with water; the time taken to reach compensation point, and to replace the oxygen used in the initial respiratory burst, was recorded.

Measurement of respiration rates in air-dry thalli. In order to determine the demand on metabolic reserves of the lichen caused by long periods in air-dry conditions it was decided to measure respiration of air-dry thalli. Thalli were placed in a desiccator over a saturated solution of sodium chloride in water at 25°C (relative humidity = 75%) or over a saturated solution of ammonium nitrate in water at 25°C (relative humidity = 60%) (Wexler and Hasegawa, 1954) for 7 days, by which time equilibrium was reached between atmospheric vapour pressure and the water content of the thalli.

The thalli were then transferred to Warburg manometers in which solutions of sodium hydroxide of a concentration calculated to maintain the relative humidity at 75% or 60% (Robinson and Stokes, 1959) had been introduced to the centre well instead of the usual potassium hydroxide. Extra large wicks of filter paper were used to ensure absorption of the carbon dioxide evolved. The respiratory rates of thalli in equilibrium with air of known humidities were then calculated.

Results

The initial burst of oxygen uptake apparently reached a peak after about 3 minutes, and then slowly fell to about half the peak value in 40 minutes. This level was then maintained for 48 hours (Fig. 4). Oxygen evolution gradually rose to a stable value within 30

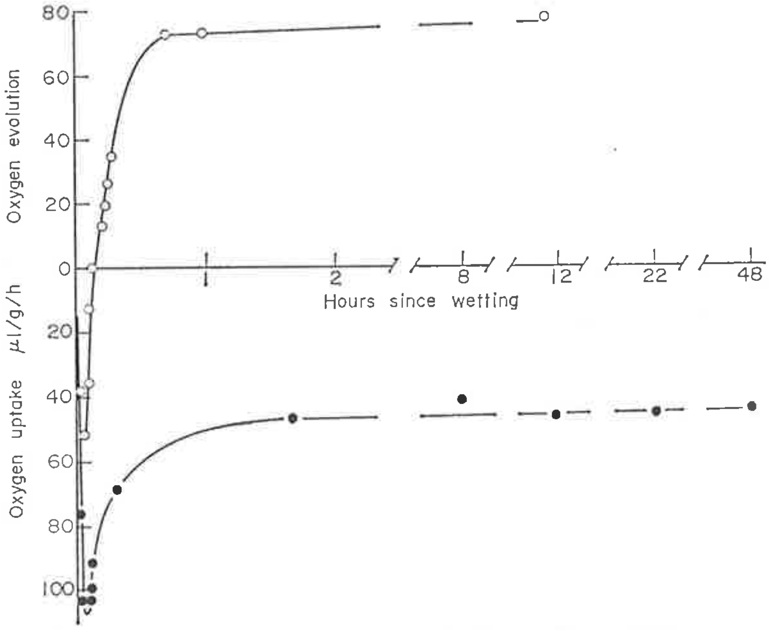


Fig. 4. The change in oxygen exchange after dry thalli were immersed in water; ●, in the dark; ○, in the light.

minutes, and then maintained that value. In this study compensation point was reached in 8 minutes, and restoration of oxygen to its original concentration in the reaction chamber took about 16 minutes.

Even the longest droughted material available (38 months) showed some respiratory activity. It is apparent from Fig. 5 that the respiratory half-life for droughted *C. semiviridis* is about 9 months, respiration rate falling from about 50 μl O_2/g/h for fresh material to about 24 μl O_2/g/h at 8 months, to about 12 μl O_2/g/h at 18 months and to a little above 8 μl O_2/g/h at 24 months.

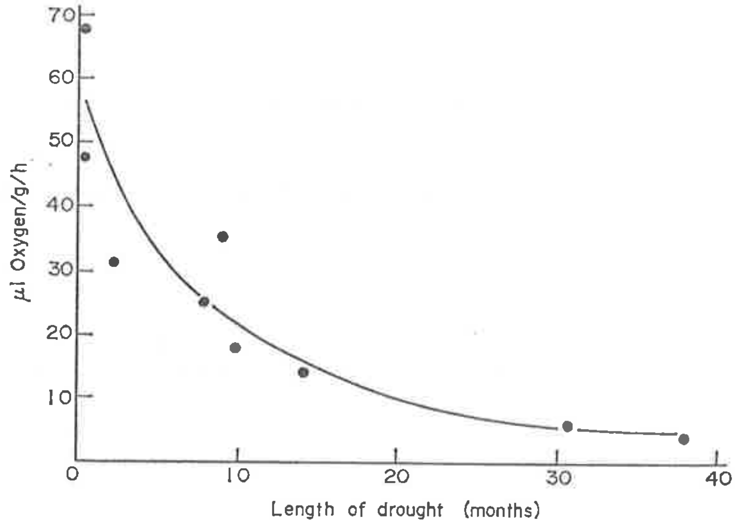


Fig. 5. The rate of oxygen uptake by thalli subjected to varying lengths of drought.

The effect of prolonged drought on the time taken to reach compensation point and restoration point is shown in Fig. 6. Material subjected to a 36 week drought reached compensation point, but failed to show production of oxygen in excess of usage. Material subjected to a 64 week drought showed no photosynthetic activity. Oxygen consumption

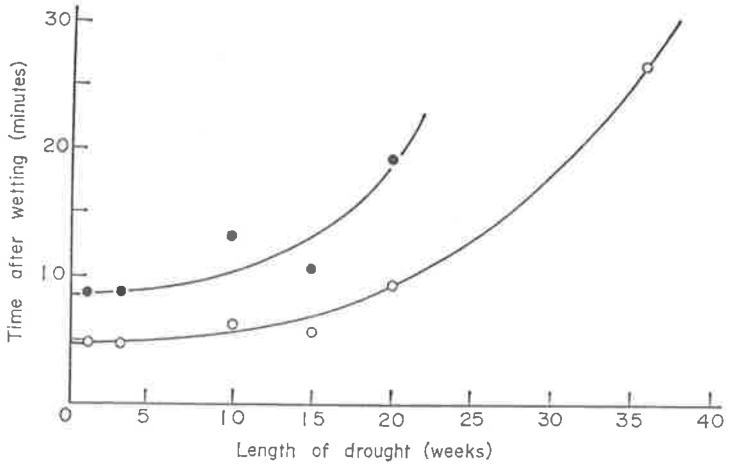


Fig. 6. The time taken for thalli subjected to varying lengths of drought to reach compensation point (○) and to restore oxygen consumed in the initial respiratory burst (●).

proceeded at a uniform rate regardless of light conditions. It is, however, possible that material stored in the light may have shown some photosynthetic activity, as the chlorophyll may have decayed more rapidly in the dark than in the light.

The rate of oxygen uptake of air-dry thalli was extremely low, averaging 0.37 μl O_2/g/h at 60% relative humidity and 0.39 μl O_2/g/h at 75% relative humidity. This was about 1% of the rate when saturated with water at the same temperature (25°C).

EFFECT OF HIGH TEMPERATURE

In his classic study Lange (1953) demonstrated that although lichens are extremely resistant to heat when air dry, they are very susceptible to heat damage when wet. The effect of heat on both air-dry and wet thalli was therefore examined.

Methods

Variation in gas-exchange physiology was used as an indicator of viability after exposure to heat. Following the method of Lange (1953), heat resistance was measured by calculating rates of gas exchange after treatment as a percentage of the rate before treatment.

Terminal lobes of *Chondropsis semiviridis* were incubated at a range of temperature from 25 to 105°C on filter papers in closed petri dishes for 30 minutes. There were two treatments with equal replication: water-saturated thalli and air-dry thalli. On removal from the oven, all material was thoroughly wetted, allowed to stand for several hours, then gas exchange rates measured using an oxygen electrode.

Results

The effect of heat on gas-exchange is illustrated in Fig. 7. When wet thalli were used it was apparent that exposure to temperatures in excess of 30°C for 30 minutes impaired both oxygen uptake and oxygen evolution. Gas exchange was completely stopped by exposure for 30 minutes to a temperature of 55°C. On the other hand, dry thalli were much more resistant. Oxygen evolution was reduced by exposure to temperatures in

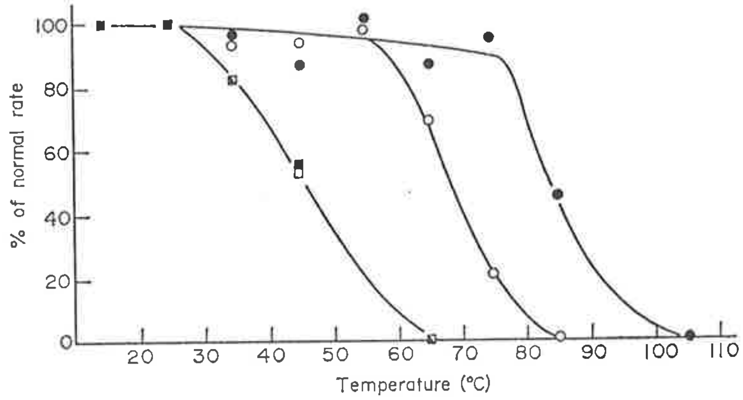


Fig. 7. The effect of exposure to heat on the oxygen exchange of thalli. Squares represent thalli saturated with water, circles represent air-dry thalli. Filled symbols represent oxygen uptake in the dark, open symbols oxygen evolution in the light.

excess of 65°C, and ceased by 85°C, whereas oxygen consumption was not affected at temperatures below 75°C, and not stopped by a treatment less severe than 105°C.

TEMPERATURE STRESS ACTUALLY ENCOUNTERED IN THE FIELD

Methods

As part of a programme to document the climatic environment on the Koonamore Vegetation Reserve, 250 miles north of Adelaide, and on the northern boundary of the distribution of *Chrondropsis semiviridis*, an air and soil temperature recording apparatus was installed in December 1967. Temperature sensors were Phillips E 241 AP, IK5 thermistors, which were linked to a Both type R12 galvanometric recorder. The whole system was powered by a 3M 510-12 gas-heated thermoelectric generator.

Thermistors were installed at a depth of 0.5 cm in the soil, and at a height of 25 cm in the air. The thermistors in air were housed in small double roofed, vented aluminium shields.

Results

Using the record for the month 12 February to 11 March 1969 as an example, an indication of heat stress could be obtained. During that month the highest soil temperature measured at 0.5 cm depth was 65°C, which was recorded twice for short periods. Table 1 shows the average number of consecutive hours per day with temperatures in excess of the range of values indicated.

Table 1. *Mean number of hours per day above the indicated temperatures during one month* (12 *February to* 11 *March* 1969)

	Air temperature (at 25 cm)		
	35°C	40°C	45°C
Hours	10.1	6.9	1.4
	Soil temperature (at 0.5 cm)		
	40°C	50°C	60°C
Hours	4.9	1.9	0.3

On one occasion soil temperature at 0.5 cm depth was in excess of 60°C for a period of five consecutive hours; on the same day air temperature was in excess of 45°C for six consecutive hours.

IMPLICATIONS OF PHYSIOLOGICAL STUDIES

It was apparent that the initial surge of respiratory activity lasted only a few minutes compared with a number of hours in lichens studied by Ried (1960b). *Chondropsis semiviridis* when wet for only a few minutes in full sun would therefore be capable of augmenting its food reserves, whereas those species studied by Ried would have been seriously depleted. It appeared that *C. semiviridis* was adapted to making use of light showers and heavy morning dews.

This conforms with the findings of Lange, Schulze and Koch (1970) who, in a study in the Negev, showed that *Ramalina maciformis* absorbed sufficient moisture overnight from dew and the air to permit a 3-hour burst of photosynthesis at dawn. To do this *R. maciformis* must recover from the effect of wetting as rapidly as *Chondropsis semiviridis*.

The measurements they made showed that in the Negev (much drier than any Australian desert) *Ramalina maciformis* could, with a morning dew, fix an average of 0.54 mg CO_2/g dry weight per day. Thus it appears that the response of *Chondropsis semiviridis* to wetting is similar to that shown by the other arid lichen studied in detail, but different from the response of humid zone material.

The ability of the species to survive drought was considerable. Short-term experiments indicated that after a drought period of 20 weeks oxygen evolution could rapidly recover to the stage where it exceeded oxygen uptake, and so the thallus was presumably capable of continued growth. This period of 20 weeks is longer than any drought period the lichen is likely to meet in Australia. However, the respiration during five dry days would use the amount of photosynthetic product produced by the same thallus when saturated with water, and in full sun for 1 hour. This is calculated on the basis of an average relative humidity at Kòonamore Vegetation Reserve of about 60% (Osborn, Wood and Paltridge, 1935), and assuming a temperature of 25°C and a respiratory rate when dry less than 1% of the wet rate. Lange *et al.* (1970) showed that photosynthesis in desert lichens ought to occur relatively commonly after dawn, either in response to absorption of moisture from the air, or by wetting from dew. Since *C. semiviridis* takes many hours to unroll at 100% relative humidity, and will not unroll at all in 75% relative humidity, absorption of water vapour from air at night probably does not permit photosynthesis to occur at high levels although it would stimulate respiration as no direct sunlight would fall on the upper (photosynthetic) surface. It is likely that in nature only liquid water (dew or rain) allows *C. semiviridis* to unroll and expose its photosynthetic surfaces to full light.

Therefore, *C. semiviridis* must be restricted in distribution to areas within which the thallus intercepts rain or is wet by dew for at least 73 hours per annum in sun light (the amount of time calculated as necessary for replacement of metabolic reserves used in a year by air-dry thalli). Respiratory increase due to absorption of water vapour at night without corresponding photosynthesis, would increase the necessary wet daytime hours required for the lichen to survive. Accepting the estimate of a 3-hour photosynthetic burst in response to dew, and allowing for the same photosynthetic period in response to rainfall *C. semiviridis* probably could not survive in an area with less than 25 days dew or rain per annum. Since in southern Australia mean number of rain days per annum and mean annual rainfall are closely related, it is not surprising that the dry limit of distribution of *C. semiviridis* coincides with a rainfall isohyet.

Thalli of *C. semiviridis* are very sensitive to heat when wet. At a temperature of 45°C, an air temperature not uncommon in the study area, the thallus, if wet, has its photosynthetic ability reduced to half in 30 minutes. When dry the thallus is much more heat resistant, showing no damage after 30 minutes at 55°C, and little damage at 65°C. The latter temperature is the highest recorded at a depth of 0.5 cm in the soil during the summer of 1968–69 at the Koonamore Vegetation Reserve, near the northern limit of *C. semiviridis*. Sensitivity to heat while wet thus explains the absence of *C. semiviridis* from those areas with a pronounced summer rainfall maximum.

The southern limit may be explained if it is assumed that *C. semiviridis* requires relatively high light intensities to photosynthesize. The data of Stalfelt (1939) suggests that this is so for many lichens. Such intensities probably do not occur on the soil surface in the rather denser vegetation of higher rainfall areas but only in sparsely vegetated regions. This results in thalli on the soil in high rainfall areas being exposed simultaneously to high respiration rates and low photosynthetic rates, especially during the winter.

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The State herbaria of Queensland, New South Wales, Victoria and South Australia provided lists of collection locations for their holdings of *Chondropsis semiviridis*, as did Dr D. N. McVean and Dr G. C. Bratt for their personal holdings.

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Correlations of stocking with the cryptogamic soil crust of a semi-arid rangeland in southwest Queensland.

I. W. HODGINS AND R. W. ROGERS
Botany Department, University of Queensland, Qld 4072, Australia

Abstract The soil crust community from a sub-tropical grassland in southwest Queensland was found to include 34 taxa with cyanobacteria, other algae, lichens, fungi, mosses and liverworts represented. Cyanobacteria and liverworts were the major components of the cryptogamic cover. This is a significant component of the biodiversity of the region. Changes in the structure of this community were significantly correlated with distance from a linear water supply (bore drain) and with dung density. It was concluded that hoof impact by grazing stock had measurably affected the cryptogamic community even under a moderate stocking policy. This research suggests that management for sustainable use of low-nutrient rangelands should include consideration of soil crust condition.

Key words: algae, bryophytes, cyanobacteria, grassland, grazing, lichens, mulga, piosphere.

INTRODUCTION

The introduction of domesticated animals to the mulga lands of southwest Queensland (including provision of many artificial water supplies), has resulted in changes to the vegetation (Burrows 1986) and populations of native fauna (Johnson *et al.* 1986). Soon after the introduction of stock, over-exploitation of native pastures resulted in decline of production of wool and beef per hectare (Gasteen 1986). Concern with the impact of human activities on biodiversity and ecosystem functioning has recently resulted in government policies calling on industries to become ecologically sustainable (Pickup & Stafford Smith 1993; Morton *et al.* 1995). One of the components of these ecosystems which has received very little attention in Queensland is the community of organisms forming a crust on surfaces with low cover of vascular plants. These crusts, known as cryptogamic, cryptobiotic or microphytic crusts, are composed of species of cyanobacteria, algae, fungi, lichens and bryophytes.

The distribution, structure (species composition) and function of cryptogamic crust communities have been reviewed by Harper and Marble (1988); West (1990) and Metting (1991); and their roles in the rangeland ecosystems of Australia have been examined by Eldridge and Greene (1994). A study by Rogers (1994) of four species of the thallose liverwort genus *Riccia* around a watercourse in Idalia National Park appears to be the only paper dealing with soil bryophytes from subtropical or tropical semi-arid Australia.

Cryptogamic crusts appear to have a number of ecological roles. They influence the rate of wind and water erosion by binding soil particles with exudates and filaments, which has important hydrological consequences affecting the distribution of water and nutrients in the ecosystem. By trapping nutrients at the soil surface, cryptogams help make essential elements available to other organisms and, in addition, the nitrogen-fixing activities of free-living and lichenized cyanobacteria and other soil bacteria may contribute significantly to the nitrogen cycle. The presence of a crust may affect the germination and establishment of vascular plants, with implications for the rehabilitation of degraded sites and in the conservation of threatened species (Lesica & Shelly 1992; Scarlett 1994).

Impact of stocking

The vegetation around stock watering places changes with distance away from the water supply as the impact of grazers depends on their numbers and the amount of time spent in an area. The term 'piosphere' (Lange 1969) has been used to designate the area around a water supply where impact of grazing animals on vegetation and soil can be observed, with intensity of stocking related inversely to distance from water. In arid areas sheep can range several kilometres from water,

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depending on pasture condition and temperature. Evidence of the time sheep spend in an area can be found in the amount of dung present (Lange & Willcocks 1978): dung density and distance from water can thus provide two assessments of stocking intensity against which variation in vegetation parameters can be compared. Zonation of vegetation is most noticeable around point sources of water in areas of uniform vegetation such as the chenopod shrublands of arid and semi-arid South Australia (Lange 1969). Increased soil erosion resulting from loss of vegetation cover is a major concern in these regions. In such environments loss of topsoil, which contains most of the available plant nutrients, appears to lead to the replacement of economically important species such as perennial grasses by species with lower productivity such as annual grasses, other herbs, shrubs and trees (Pressland 1976; Miles 1993).

Areas with a low stocking intensity are likely to have greater cryptogam cover than those with a high stocking intensity that destroys soil crusts, particularly during drought, resulting in wind and water erosion (Williams *et al.* 1995a,b) and possibly sealing and compaction (Eldridge *et al.* 1995).

In arid chenopod shrublands in South Australia, Rogers and Lange (1971) and Andrew and Lange (1986) identified a clearly defined piosphere pattern in the cover and floristics of lichens in cryptogamic soil crusts around a point water source. A site was chosen on Glencoban Station near Cunnamulla in southwest Queensland to test the hypothesis that a piosphere pattern will be present in the crust community on the soil surface adjacent to a linear water source. This paper reports on a study of the cryptogamic soil crust community where we found evidence of a piosphere pattern in the cover, frequency and richness of cryptogams on the soil surface adjacent to a bore drain.

METHODS

Study site

The study site is in a paddock of ~2000 ha situated 38 km southeast of Cunnamulla in southwest Queensland. Glencoban bore, in the northern part of the paddock (28°09′S, 146°02′E), supplied water for stock in this and the surrounding paddocks by means of continuously flowing bore drains (shallow unlined ditches) constructed along the contour. Because bore drains are artificial water supplies in country with very low relief, it is assumed that stock impact will be more uniform than around natural water sources such as creeks and waterholes. Bore drains appear to have little direct impact on the vegetation more than a few metres from their edges. At the time of this study a piped reticulation system was being commissioned to supply four troughs evenly spaced in the paddock, permitting closure of the drain system.

The study site lies within the Gilruth land system of Mills *et al.* (1990). Relief is very low (< 1%). Consequently runoff is predominantly sheetflow, and there are no well-defined watercourses. Water collects in depressions (runon areas) where most infiltrates into the soil, leaving deposits of fine sediments (silts and clay). Plant litter and dung is deposited at the upper perimeter of runon areas.

The climate is semi-arid and subtropical, with about 60% of rainfall falling in the summer. Rainfall is highly variable, and dry periods are frequent. Frosts are common in the winter, and, when atmospheric moisture is present, dew may make a small but important contribution to precipitation.

Field work

Field work was carried out in March and April 1995 with some ephemeral and fertile bryophytes also collected in June 1995. Six 800 m transects were used to collect data on cover of cyanobacteria, lichens, and liverworts; frequency of lichens and bryophytes; and species richness of all nonvascular cryptogams. Transects were perpendicular to the bore drain and were sited to avoid major heterogeneities in the landscape such as scalds. Transects were irregularly spaced from 500 m west to 1000 m east of the bore with five south of the bore drain and one to the north. Along each of the six transects, sampling sites were situated at distances of 10, 25, 50, 100, 200, 300, 400, 600 and 800 m from the bore drain. At each of these sampling sites a 30 m tape was laid out perpendicular to the transect and the presence of a cyanobacterial mat, lichens or liverworts was noted for each centimetre mark along the tape giving a measure of cover for each site based on 3000 points. To determine species richness and frequency, a 33 × 33 cm quadrat was placed on the ground at every metre mark along the 30 m tape. Samples of lichens, bryophytes, fungi and cyanobacteria present in the quadrats were removed for determination.

To establish the relationship between distance from a water supply and recent stocking, dung counts were made in a strip 1 m wide on each side of the 30 m tape at each sampling site. Groups of dung pellets were counted as single egestion events. Old material that may have washed in from adjacent areas was ignored.

At each sampling site microtopography was classified as ‘runoff’ where much of the soil surface was covered with rock and *Amphipogon* sp. was the dominant vegetation, or ‘runon’ where rock was absent and *Acacia aneura* and *Aristida* sp. were dominant.

Statistical analysis

Evidence of relationships between cover of cyanobacteria, liverworts and lichens and the two measures of stocking intensity (dung density and distance from the

Table 1. Frequencies of occurrence of the nine most common species of macroscopic soil-crust cryptogams in 33 × 33 cm quadrats from six transects (180 quadrats per distance) adjacent to a bore drain in semi-arid Queensland.

	Frequency (%)								
Distance from bore drain (m)	10	25	50	100	200	300	400	600	800
Species									
Endocarpon rogersii	4	10	11	14	9	7	13	22	19
Heppia lutosa	6	14	19	29	22	52	32	37	39
Peltula australiensis	3	1	3	9	5	6	3	3	4
Riccia cartilaginosa	9	22	24	28	33	59	37	51	50
R. crinita	3	10	13	17	19	39	32	30	33
R. lamellosa	0	3	4	6	5	3	2	29	13
R. limbata	4	12	2	2	1	6	1	0	13
Goniomitrium enerve	4	17	17	32	27	42	32	52	51
Pleuridium nervosum	6	15	9	16	18	34	22	47	20

bore drain) was sought using Spearman's rank correlation coefficients (Rosner 1990). The relation between species frequency and distance from the bore drain for the nine macroscopic species collected from quadrats (listed in Table 1) was examined using Friedman's test (Conover 1980) with the transects treated as blocks. The chi-square test was used to compare the frequencies of the nine species on the two surface conditions, runon and runoff, against the null hypothesis that frequency was unaffected by microtopography.

Nomenclature

Soil algae were determined to genus using a key by Archibald based on the classification of Bourelly (Archibald 1990). Liverworts were identified using keys in Na-Thalang (1980) and Scott (1985) and mosses using keys in Scott and Stone (1976) and Catcheside (1980). Aberdeen (1979) was referred to for identifying fungi. Lichens were determined using keys in Rogers (1992) and Filson and Rogers (1979). Nomenclature follows McCarthy (1991) for lichens, Streiman and Curnow (1984) for mosses and Scott and Bradshaw (1985) for liverworts.

RESULTS

Twenty-eight taxa were found in quadrats examined for the presence of macroscopic cryptogams (Table 2). Five additional bryophyte taxa were found by casual observation in the field in the vicinity of the transects when the ground had been moist for several weeks. *Pallavicinia* sp. developed in soil samples cultured in the glasshouse in Brisbane.

Table 2. Cryptogams from soil crust, Glencoban Station, south-west Queensland

CYANOBACTERIA

Anabaena sp.
Aphanocapsida sp.
Dasygloea sp.
Hapalosiphon sp.
Lyngbya sp.
Microcoleus sp.
Nostoc sp.
Porphyrosiphon sp.
Scytonema sp.

CHRYSOPHYTA

Chloridella sp.

BACILLARIOPHYTA

Diatom

Chlorophyta

Geminella sp.
Filamentous sp.
Colonial sp.

Fungi

Geoglossum sp.
Tulostoma sp.

LICHENS

Buellia epigaea (Hoffm.) Tuck.
Endocarpon rogersii McCarthy
Heppia lutosa (Ach.) Nyl.
Peltula australiensis (Müll. Arg.) R. Filson
Placynthium nigrum (Huds.) Ach.

LIVERWORTS

Fossombronia sp.*
Pallavicinia sp. **
Riccia albida Sull. ex Austin
R. crinita Na-Thalang
R. cartilaginosa Stephani
R. lamellosa Raddi
R. limbata Bisch.

MOSSES

Bryum pachytheca C. Müll.*
Bryum sp.*
Ephemerum sp.*
Goniomitrium enerve Hook. f. et Wils.
Pleuridium nervosum (Hook.) Mitt.
Pottia brevicaulis (Hedw.) B.S.G.*

*Detected at study site but not found in quadrats.
**Detected in soil samples cultured in glasshouse.

Cover

Cyanobacterial cover of the sampling sites ranged from 1 to 42% (mean 18.4%) with other components (lichens and bryophytes) adding less than one percentage to the mean, although bryophyte cover would be expected to more than double when moist. Correlation of cyanobacterial cover with distance was significant for two transects. Significant relationships were not always found between dung and distance or dung and cover for individual transects. However, when cover data from the six transects were pooled, significant positive correlations were found between cyanobacterial cover and distance ($\rho = 0.88$, $P < 0.01$), liverwort cover and distance ($\rho = 0.78$, $P < 0.05$) and lichen cover and distance ($\rho = 0.83$, $P < 0.02$) (Fig. 1a–c). Dung density for the pooled transects was significantly negatively correlated with distance ($\rho = -0.8$, $P < 0.02$) (Fig. 1d). Cyanobacterial and lichen cover also had significant negative correlations with dung density ($\rho = -0.73$, $P < 0.05$ and $\rho = -0.88$, $P < 0.01$, respectively). The average cyanobacterial cover on runon areas was 22% compared with 30% for runoff zones.

Frequency

Of the 1620 quadrats examined, samples were collected from 709 which contained macroscopic cryptogams (lichens, bryophytes and fungi) (Table 1). Frequencies of the nine most common species were analysed using Friedman's test which showed that frequency varied significantly with distance from the water source for five of the nine species (Table 3). Of the other four species, three (*Endocarpon rogersii*, *Peltula australiensis* and *Riccia limbata*) had the lowest frequencies of the nine species, while the moss *Pleuridium nervosum* had relatively high frequencies.

Microtopography of twenty-five sampling sites was classified as runon and twenty-nine as runoff. Frequency on runoff zones compared to runon zones was higher for the five most common species ($P < 0.01$) (Table 4). The frequencies of the four rarer species (*Endocarpon rogersii*, *Peltula australiensis*, *Riccia lamellosa* and *R. limbata*) were not significantly different between the two surfaces.

Species richness

Richness of sampling sites (total richness of 30 quadrats) averaged across the six transects increased significantly ($P < 0.05$) with distance from the bore drain (Fig. 2). Richness at a sampling site ranged from zero to twenty-three species, with lowest richness at a site close to the bore drain with high litter cover. Average richness of a site was almost nine species. The soil crust community usually included: four or five cyanobacteria (*Lyngbya* sp., *Microcoleus* sp. and *Porphyrosiphon* sp. were most common); the chromophyte *Chloridella* sp.; often two *Riccia* spp. (particularly *R. cartilaginosa* and *R. crinita*); and the two desiccation-tolerant mosses *Goniomitrium enerve* and *Pleuridium nervosum*.

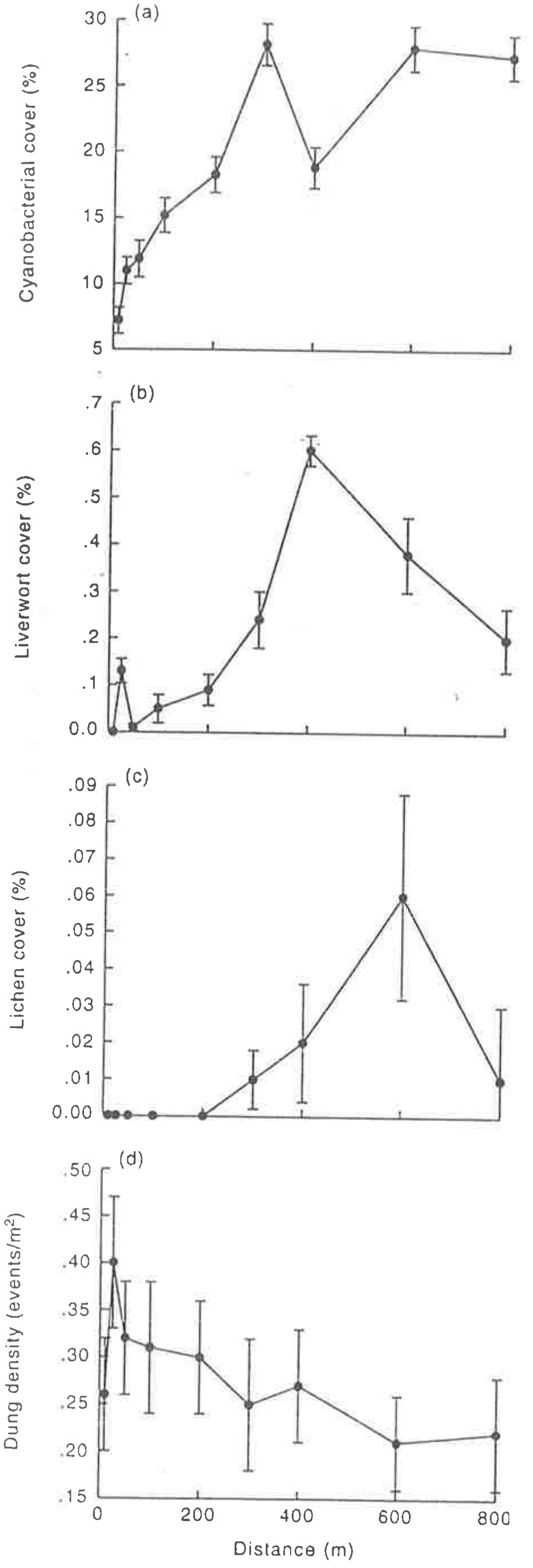

Fig. 1. Average values of cryptogam cover and dung density correlated significantly with distance from a bore drain in a native pasture in semi-arid southwest Queensland (a) cyanobacteria ($P < 0.01$), (b) liverworts ($P < 0.05$), (c) lichens ($P < 0.02$)and (d) average dung density ($P < 0.02$), averaged data from six transects. Bars represent ± 1 SE.

DISCUSSION

Crust composition

The study site supports an extensive and rich cryptogamic soil crust community dominated mainly by cyanobacteria and bryophytes. One of the most striking differences to most other reports of such communities is the prominence of liverworts at Glencoban. Some areas in southern Africa have similar high occurrences of *Riccia* (Volk 1984), but in most areas with well-developed crusts, lichens appear to be the dominant component, as in southern Australia (Rogers 1970), North America (Nash *et al.* 1977), the Negev Desert and Namibia (West 1990). Rogers (1970) recorded 10 lichen species on soil crusts within 100 km of Bourke, about 270 km south of Glencoban, and this site may contain a similar number. Because of their slow growth rates and, in most cases, lack of movement on hydration, lichens may be susceptible to overgrowth by cyanobacteria, especially when rain falls during the warmer months.

Table 3. Results of Friedman's test of variation of species frequency with distance for nine soil-crust cryptogams

Species	T_2	d.f.
Endocarpon rogersii	1.00ns	8, 40
Heppia lutosa	3.08**	8, 40
Peltula australiensis	0.30ns	8, 40
Riccia cartilaginosa	6.92**	8, 40
R. crinita	2.89*	8, 40
R. lamellosa	2.48*	8, 40
R. limbata	1.66ns	8, 40
Goniomitrium enerve	4.02**	8, 40
Pleuridium nervosum	1.24ns	8, 40

Significance: ns $P>0.05$; $*P<0.05$; $**P<0.01$.

Table 4. Frequencies of nine cryptogam species on two microtopography classes and their comparison using the chi-square test

	Frequency (%)		
	Runon	Runoff	χ^2
Endocarpon rogersii	11	14	2.49ns
Heppia lutosa	19	35	28.6*
Peltula australiensis	5	4	0.69ns
Riccia cartilaginosa	28	40	13.48*
R. crinita	13	29	41.6*
R. lamellosa	7	8	0.13ns
R. limbata	5	3	2.44ns
Goniomitrium enerve	21	39	31.04*
Pleuridium nervosum	16	25	13.92*

Significance: ns $P>0.05$, $*P<0.01$.

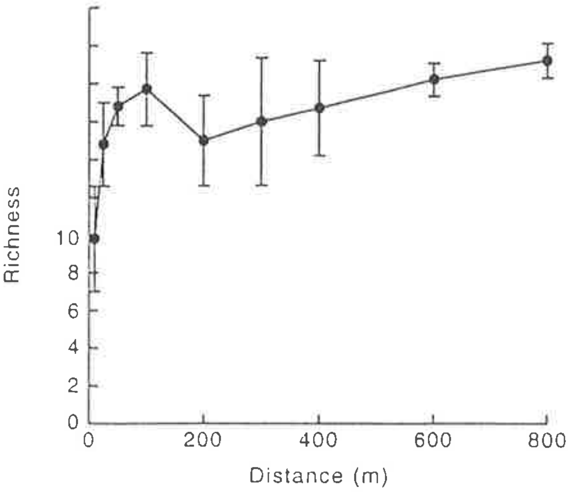

Fig. 2. Change of species richness with distance, data averaged from six transects in a native pasture in semi-arid southwest Queensland. Richness correlated significantly with distance ($P<0.05$). Bars represent ± 1 SE.

The cyanobacteria most common at Glencoban are genera reported from arid areas world wide (Rogers 1989; Lange *et al.* 1992). Samples of three of the genera collected possessed heterocysts (*Anabaena*, *Nostoc* and *Scytonema*) and are therefore presumed to be capable of nitrogen fixation. The specimens identified as *Hapalosiphon* may also be heterocystous but no heterocysts were found. In addition, however, Belnap *et al.* (1994) suggested that cyanobacteria with a thick sheath may fix nitrogen. Both *Microcoleus* and *Porphyrosiphon* develop such a sheath at Glencoban and should therefore be considered possible sources of nitrogen for the community.

Impact of stocking

This study shows the structure of cryptogamic soil crusts may be significantly affected by hoof impacts where stock obtain water from linear sources. Although the piosphere effect around a point source of water is expected to exhibit a geometric decline with distance, the effect adjacent to a linear source may approach a linear decay, but, in both cases, local factors affect these patterns including soil surface character, vegetation, and the habits of stock. This often results in local areas of severe degradation even under moderate stocking policies.

The values of average crust cover obtained are comparable to those found by O'Neill (1994) in mallee woodland at Mungo National Park (semi-arid, New South Wales, 25.9%). Similarly Eldridge and Tozer (1996) reported cover levels of 10–30% for similar soils in northwestern New South Wales. Cover in runoff zones was affected by the presence of silcrete pebbles which often significantly reduced the area available for colonization. The poor correlation of the individual transect data for cover with distance and dung density and the large variability within the data (the standard deviation was usually greater than the mean) indicates a patchy distribution of cryptogams.

While frequency of five of the common species correlated with the expected impact of stocking, the results for the other four species require explanation. For the three rare species, sampling may not have been extensive enough to establish whether there was a trend in their frequency or their frequency may be so low that, at the level of stocking employed, damage was unlikely. The situation for *Pleuridium nervosum* is different; although it had a frequency similar to the more common species, frequency was not significantly related to distance. This species may have characteristics which make it more tolerant of disturbance than the other bryophytes at this site. When examining these plants the stems were found to be very fragile with the upper portion readily separating under slight tension. No sporophytes were observed in the field on this species and only one in the glasshouse. It is therefore suspected that fragmentation may be the main reproductive and dispersal strategy of this species accompanied by regeneration of gametophores from rhizoids. Such reproductive and survival mechanisms may allow this species to colonize available sites more rapidly than other species and to tolerate hoof impact more readily. However, the frequency of this species was significantly lower on runon than runoff zones.

Within 10–20 m of the bore drain the vegetation was dissimilar to that further away; tree density appeared higher (presumably the result of 100 years of irrigation) and different grasses were present, producing considerable litter, covering the soil and precluding its colonization by cryptogams. However, removing the 10 m distance data from the statistical analyses had no major effect on the significance of the results; some were more significant while others dropped slightly.

Cryptogams at this site appear to occupy favourable sites in a patchy environment. Unfavourable sites include areas of loose sediments and high litter cover. Because of the heterogeneity in the landscape, sheep probably do not use the area uniformly; rocky areas with little feed are not attractive while shade and areas with good feed will be visited more often.

Application to land management

Change in the proportion of soil crust condition classes present at a site over time would be a result of interplay of the factors affecting cryptogam distribution. Since such changes affect ecosystem processes like nutrient cycling and the recruitment of vascular plants, an easily applied measure of soil crust condition could be a useful tool for rangeland management. The major determinants of cryptogam distribution appear to be water availability, stocking intensity and soil stability. Soil stability is most vulnerable when stock concentrate close to water. This often occurs in small holding paddocks when stock are confined for long periods for hand feeding during droughts. Although changes can be rapid under extreme conditions of aridity, it appears likely soils with poorly developed crusts would be most at risk.

An estimate of the proportion of condition classes present at a site, readily obtained by a method similar to that used to determine cover in this study, would incorporate assessments of cover and richness. Little training and no special equipment would be needed for such work and damage to crusts by sampling would also be avoided. Such monitoring of crust condition may usefully extend the paddock-level information available to land managers employing the resource assessment techniques developed by Tongway (1994).

CONCLUSIONS

Stock had measurable impacts on cryptogamic soil crust cover, frequency and richness adjacent to a linear water source. These impacts and the ecological function of cryptogamic soil crusts suggests soil crust condition should be of great concern to land managers. The composition of the cryptogamic soil crust community of southwest Queensland is substantially different to soil crust communities reported from southern Australia and contributes significantly to the biodiversity of this region.

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8 Lichens of Hot Arid and Semi-arid Lands

RODERICK W. ROGERS

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I. Introduction

The lichens of arid regions have long been the subject of investigation. As early as 1771, Pallas (cited in Elenkin, 1901b) collected and commented upon desert lichens, but it is not until the present century that very much effort has been directed to their study, and even then the effort has been rather fragmented. It is certainly not possible to produce the type of integrated account of the ecology and phytosociology of desert lichens today that Barkman (1958) produced for western European epiphytes. There is, however, sufficient information available to make an overall account worthwhile.

The term "desert" is a vague and emotive one: to define the study area for this account, therefore, the maps prepared by Meigs (1953) have been followed. Meigs mapped areas using the index of aridity proposed by

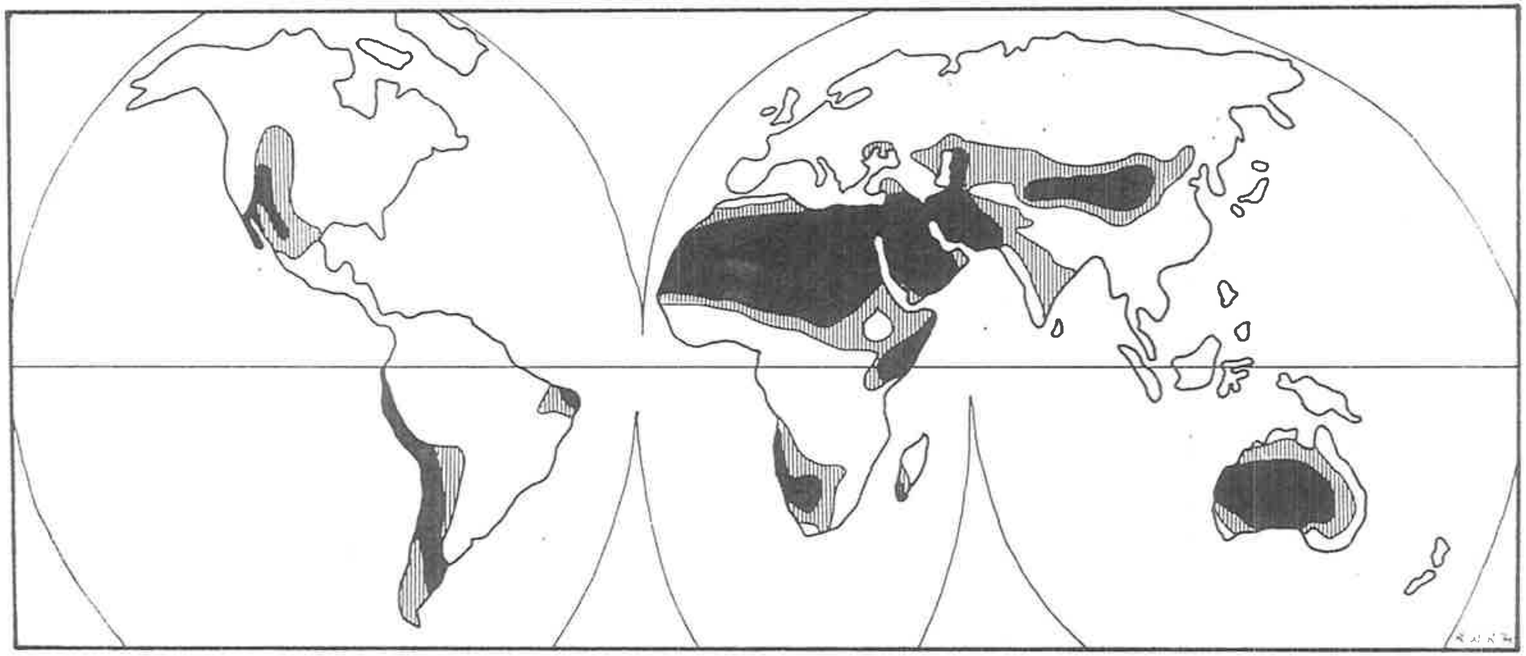

FIG. 1. The distribution of hot arid (black) and semi-arid (shaded) lands in the world.

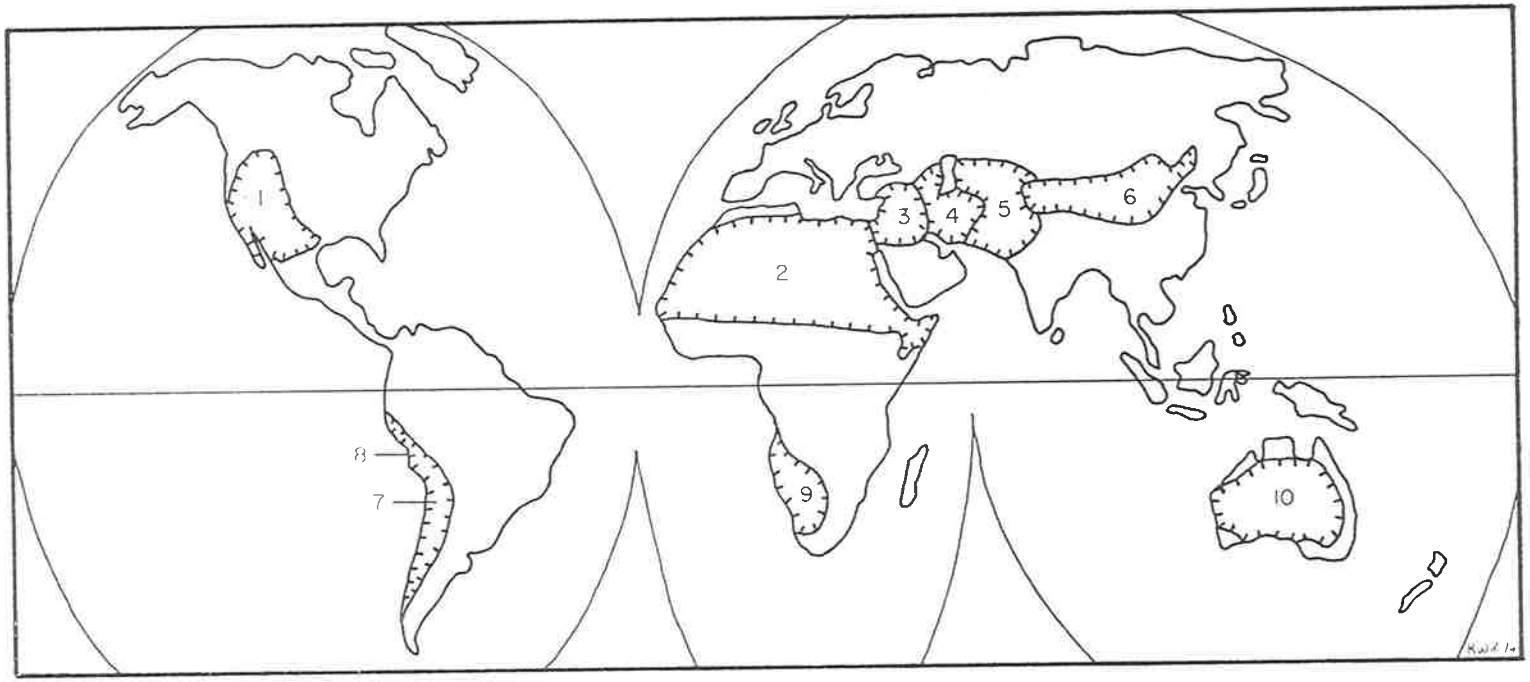

FIG. 2. The ten regions defined for the study of lichen distributions. (1) North America, (2) North Africa, (3) Western Asia, (4) Southwestern Asia, (5) Central Asia, (6) Eastern Asia, (7) South America (Atacama), (8) South America (fog oases), (9) Southern Africa, and (10) Australia.

Thornthwaite (1948), which is a complex index based on both rainfall and temperature regime, and used the descriptive terms "extreme arid", "arid" and "semi-arid". These terms are equivalent of extreme desert, desert and steppe or semi-desert respectively, and are used synonymously throughout this study. Hot arid or semi-arid lands have been interpreted as any region in which the mean temperature of the warmest month exceeds 20°C. This means that areas such as the Mongolian Altai with very low winter temperatures and which might also be considered a cold desert, are included in the study.

Around the world in the band between latitude 15° and 40° is found a band of arid and semi-arid lands in both hemispheres. Notable areas in the northern hemisphere are the Sahara in North Africa; the Negev, Arabian and other western Asian deserts; the Thar in India; the Gobi in central Asia; and the Mohave of North America. In the southern hemisphere there are extensive arid areas in western and central Australia, South America and South Africa (Fig. 1). Characteristically these areas have few low trees with sparse ground cover and, as a result, large areas of bare earth or rock pavement. The environment is harsh. Rainfall is low and erratic, usually less than 250 mm per annum, and in places it is less than 100 mm per annum. Because cloud cover is low, insolation is high; atmospheric temperatures in excess of 40°C and soil surface temperatures in excess of 65°C are commonplace (Rogers, 1971). Because of low cloud cover, night temperatures fall rapidly and temperatures below 0°C are common. Such conditions lead to considerable atmospheric turbulence resulting in strong winds (Geiger, 1950), and since so much of the soil is bare, sand-blasting of the vegetation results. Because many arid regions are far from the moderating influence of the sea, seasonal climatic variation can also be extreme, compounding the diurnal variation. No area, with the possible exception of the tundra, offers such a variable and inhospitable environment.

II. Distribution

A. World Patterns

1. The Regions Examined

There have been a great number of studies which have listed the lichens found in arid lands. After a preliminary survey of this literature, the arid lands of the world have been divided into the ten geographical regions indicated in Fig. 2. Since the vast bulk of literature refers to the Asian land mass, Asia has been treated as four regions, namely: western Asia (Israel, Syria, Iraq), including the Negev and Syrian deserts; south-western Asia (Iran, southern U.S.S.R. and the Azerbaijan S.S.R.), including the Dasht-i-Kavir and Dasht-i-lut; central Asia (Afghanistan, the Kazahk S.S.R., Turkmen S.S.R. and Uzbek S.S.R.), including the Kara-kum and Kyzyl-kum deserts; and eastern Asia (Mongolia, Sinkiang and Inner Mongolia), including the Gobi and part of the Taklamakan deserts. The deserts of North Africa, North America and Australia are each considered as single, separate entities. The deserts of South Africa (the Kalahari and Namib) are treated as a unit, but very little information is available. From South America a little information is available about the Atacama desert, but none from the desert regions of Brazil and Argentina. However, a great deal of information is available about fog oases; as a result two geographic units have been defined for South America, the fog oases in the Atacama desert and the remainder of the Atacama desert itself.

TABLE I.

Number of species and genera recorded in the literature surveyed for each of the regions considered.

Region	No. of Species	No. of Genera
North America	155	39
North Africa	191	40
Western Asia	262	40
South western Asia	147	33
Eastern Asia	292	35
Central Asia	122	31
South America (Atacama)	27	9
South America (fog oases)	139	55
South Africa	46	23
Australia	66	29

The number of species and genera recorded for each region is shown in Table I. A discussion of the sources of information (see also Appendix A, pp. 437) for each region follows.

(*a*) *North America.* The lichen flora of North America is fairly well known, many desert species being recorded in Fink (1935). Information in such a compilation is not easily accessible, nor can it be decided with certainty which species do in fact occur in deserts. Similarly, while many of the species listed by Bouly de Lesdain (1932), Imshaug (1956), Shushan and Anderson (1969) and Weber (1963) are probably from arid regions, insufficient information is given to be certain which are arid, which are from unusually sheltered locations and which are alpine. For biogeographic studies, consideration is limited to those reports which deal with lichens which are known to be from deserts. A number of primarily ecological studies involving soil-surface species (Looman, 1964a, b; Shields, 1957; Shields *et al.*, 1957) list species from desert and semi-desert areas, and have been included in the sources used to compile a list of species from North American desert and semi-desert regions. Some primarily taxonomic papers have also been of value (Darrow, 1950; Fink, 1909a, b; Herre, 1911; Rudolph, 1953; Rundel *et al.*, 1972; Wetmore, 1970) and have therefore been abstracted.

(*b*) *North Africa.* Lichens from North Africa have been of interest to European taxonomists for a long time. The work done on lichens from the Algerian Sahara has been summarized by Faurel *et al.* (1953). Additional sources consulted include species lists by Flagey (1901), Müller (1880b, 1884b), Romano (1914), Steiner (1895) and Werner (1966).

(*c*) *Western Asia.* The western Asian region is probably the most intensively studied of all. Numerous studies covering the Negev have been published (Alon and Galun, 1971; Galun, 1963, 1970; Galun and Reichert, 1960). Werner (1954, 1955, 1956, 1957, 1958, 1959, 1963, 1966) has produced a series of studies on lichens from Syria and Lebanon, some of them from desert and semi-desert lands. Other works examined to prepare a species list for the area include Müller (1884a), Santesson (1942) and Steiner (1921).

(*d*) *Southwestern Asia.* The basic reference for lichens from southwestern Asia is Szatala (1957). This work apparently follows the tradition established by Magnusson (1940, 1944) in that it has a very narrow species concept. Other references consulted included Lamb (1936) and Steiner (1896).

(*e*) *Central Asia.* A single work dominates the information from this area: Poelt and Wirth (1968) compiled an extensive account of the lichens from northern Afghanistan. Other sources include an ecological discussion of some Afghanistan lichens by Jacquemin-Roussard and Kilbertus (1971) and accounts of species from the U.S.S.R. by Keller (1930), Elenkin (1901a) and Steiner (1919).

(*f*) *Eastern Asia.* Although Schubert and Klement (1971) have produced an account of the lichens of Mongolia, reports by Magnusson (1940, 1944) dominate work on the lichens of eastern Asia. Magnusson's exhaustive descriptions of very narrowly circumscribed species have, however, probably greatly inflated the lichen flora of the area. The above works record many species collected from desert areas, as does the report by Klement (1966). Climatically the eastern Asian desert is rather unlike any other desert, with the possible exception of central Asia. Mongolia is a land of extreme heat and cold, and could possibly be considered as a cold desert.

(*g*) *Australia.* Information concerning lichens from the Australian deserts is based primarily on a compilation by Rogers (1970). Additional sources include ecological and floristic studies by Rogers and Lange (1972) and Rogers (1974), species lists presented by Johnson and Baird (1970) Willis (1951), and an account of central Australian lichens by Müller (1893).

(*h*) *South America.* Apart from the fog oases on the Chilean coast, very little information is available concerning the lichen species of South American deserts. Zahlbruckner (1925) listed a few species from the Atacama desert, and Follmann (1965) some more. Dodge (1966), Follmann (1967b) and Follmann and Redón (1972) have produced accounts of the lichens from fog oases (see Section IV). Thomson and Iltis (1968) produced similar information concerning a fog oasis in Peru. South American data is therefore segregated into two portions, the fog oases and the Atacama desert.

(*i*) *South Africa.* Even less information is available about lichens from the South African deserts than from South America. A paper by Zahlbruckner (1926) lists some species from the Namib, and Mattick (1970) lists a few more. Further information has been extracted from the list of South African lichens compiled by Doidge (1950).

2. *Composition of the Lichen Flora*

The literature searched revealed a desert lichen flora of 947 species in 111 genera; representing about 5% of the world's lichen flora of some 20,000 species [estimates from Zahlbruckner (1922–1940) and Lamb (1963)].

Table II shows the ten genera with the largest number of species occurring in arid lands, the percentage of species in each of those genera recorded in arid lands, the percentage contribution to the total number of

TABLE II.

The ten largest genera of lichens in arid lands.

Genus	% of Genus in Arid Lands	% Arid Flora	% World Flora
Lecanora	10	13	7
Caloplaca	15	10	3
Acarospora	16	8	3
Lecidea	3	6	8
Buellia	10	5	2
Verrucaria	7	4	3
Heppia	36	4	<1
Dermatocarpon	30	4	<1
Rinodina	21	3	1
Parmelia	3	3	5
		60%	33%

The ten genera of lichens with the largest number of species occurring in arid lands, listed in order of species numbers in arid lands. The first column shows the percentage of the total number of species in the genus that occur in arid lands, the second column shows the percentage of species in each genus known to occur in arid lands and the third column indicates the percentage of the total world lichen flora in each genus.

TABLE III.

The ten largest genera of lichens on a world basis.

Genus	% of Genus in Arid Lands	% Arid Flora	% World Flora
Lecidea	3	6	8
Lecanora	10	13	7
Parmelia	3	3	5
Bacidia	<1	<1	4
Pertusaria	1	1	3
Caloplaca	15	10	3
Verrucaria	7	4	3
Acarospora	16	8	2
Usnea	<1	<1	2
Buellia	10	5	2
		50%	39%

Columns as in Table II.

species in the arid lands each genus makes, and the percentage of the world's lichen species in each genus. Table III shows the same information for the ten genera with the largest number of species on a world basis. It is notable that seven of the ten biggest genera in the world are amongst the ten biggest in arid lands.

Some genera show a much greater development in arid lands than in the rest of the world. Whereas arid lands have only 5% of the world's lichen species, if the genera with more than ten species in the arid lands are considered, two (*Heppia* and *Dermatocarpon*) have 30% or more of their species in arid lands, two (*Xanthoria* and *Rinodina*) have 20% or more in arid lands, three (*Endocarpon*, *Acarospora* and *Caloplaca*) have 15% or more of their species in arid lands, and four genera (*Toninia*, *Diploschistes*, *Buellia* and *Lecanora*) have 10–14% of their species in arid lands. These named genera thus make a disproportionate contribution to the floristic richness of arid lichen floras and so may be regarded in that sense as characteristic of arid lands. The large genera *Bacidia*, *Pertusaria* and *Usnea* are markedly under-represented in arid lands.

3. Relationship between Regions

Because of the great disparity in the intensity of study in the various zones, comparisons at the species level are difficult. It appears from Table I that knowledge of the genera in the regions is more uniform than knowledge of species, most regions having 30–40 genera recorded. Genus concepts are perhaps more stable than are species concepts in relatively poorly known regions, hence problems with synonymy rarely arise.

The similarity between floras of the various regions at a genus level was computed using the Jaccard coefficient (Jaccard, 1912) and the results presented as a dendrogram in Fig. 3. This shows that there are striking similarities in the genera present in North Africa and throughout Asia. The lichen genera in the deserts of North America are also similar to those of Asia and Africa. The floras of Australia and South Africa are more like each other than other regions, but still show a considerable likeness to those of the northern hemisphere desert regions. The South American floras, however, are apparently distinctive.

The differences may be accounted for in part by the relative intensities of study in the various regions. The information available from the South American deserts (as distinct from the fog oases) is so slight as to preclude a high similarity; the floras of Australian and South African deserts differ from the northern hemisphere area mainly in the absence of records for genera, rather than the presence of distinctive genera.

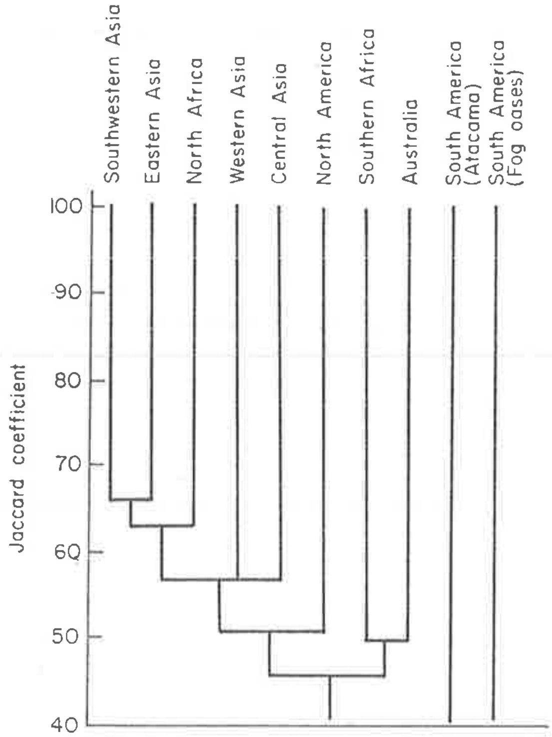

FIG. 3. Dendrogram formed by linking regions in descending order of Jaccard coefficients. The lower the level of linkage, the less similar the composition of the flora.

While comparisons at the species level are less reliable than comparisons at the genus level, some items of interest emerge from such a study. Table IV lists 18 species which occur in five or more regions. One species, *Lecidea decipiens*, is recorded in all desert regions except those in Chile where Follmann (*in litt.*) asserts it does not occur. The information in Table IV reinforces the concept of a single desert lichen flora for most of the world at the genus level. The similarities between Eurasia and America have been commented on by Weber (1963) and Looman (1964b). Rogers and Lange (1972) commented on the similarities in desert soil-surface lichens around the world and Rogers (1974) noted the similarity between an Australian arid lichen flora and other arid lichen floras, particularly those of North America. The South American flora alone appears distinctive.

The erratic *Parmelia* species are of special interest biogeographically, as they present a number of well documented disjunctions. Follmann (1967a) pointed out that *P. vagans* is known from Chile and Asia, but not North America, where *P. chlorochroa* is widespread (Looman, 1964a). Mattick

TABLE IV.

Some species widespread in arid lands.

Region	1	2	3	4	5	6	7	8	9	10
Acarospora bella	+	+		+			+	+		
A. cervina	+	+	+	+	+					+
A. strigata	+	+	+		+	+				
Aspicilia calcarea	+	+	+	+	+	+				+
A. esculenta		+	+	+	+	+				
Buellia subalbula		+	+	+					+	+
Caloplaca cerina	+	+	+	+	+	+		+	+	
C. saxicola	+	+	+	+	+	+				+
Dermatocarpon hepaticum	+	+	+	+						+
D. miniatum	+	+	+	+		+				
Diploschistes scruposus	+	+	+	+	+					+
Fulgensia bracteata			+	+	+	+				+
F. fulgens	+	+	+		+				+	
Lecanora muralis	+	+	+	+	+	+	+			
Lecidea decipiens	+	+	+	+	+	+			+	+
Parmelia conspersa	+		+			+			+	+
Squamarina lentigera	+	+	+	+	+	+				
Toninia coeruleonigricans	+	+	+	+	+					+

Species of lichens, which according to the literature surveyed, occur in at least five of the ten regions studied. The regions are: (1) North America, (2) North Africa, (3) Western Asia, (4) Southwestern Asia, (5) Central Asia, (6) Eastern Asia, (7) South America (Atacama), (8) South America (fog oases), (9) South Africa, and (10) Australia.

(1970) reported *P. convoluta* from Namibia and Rogers and Lange (1972) reported its wide distribution in Australia.

The disjunction of *P. convoluta* and *P. amphixantha* from South Africa to Australia, and of *Chondropsis semiviridis* and *Parmelia reptans* from Australia to New Zealand (Rogers, 1971; Baker *et al.*, 1973) suggests the possibility of dispersal of desert lichens with the westerly flow of the earth's air masses in the southern hemisphere.

Rogers and Lange (1972) have discussed the possibility of long-range dispersal of desert lichens, and conclude that such dispersal is possible. The reports of fertile apothecia on desert lichens not previously known to produce spores (Filson, 1967; Kappen and Schulze, 1972) coupled with reports of long-range fungal spore dispersal (Hirst and Hurst, 1967) support such an argument. Looman (1964b) inferred continental drift as

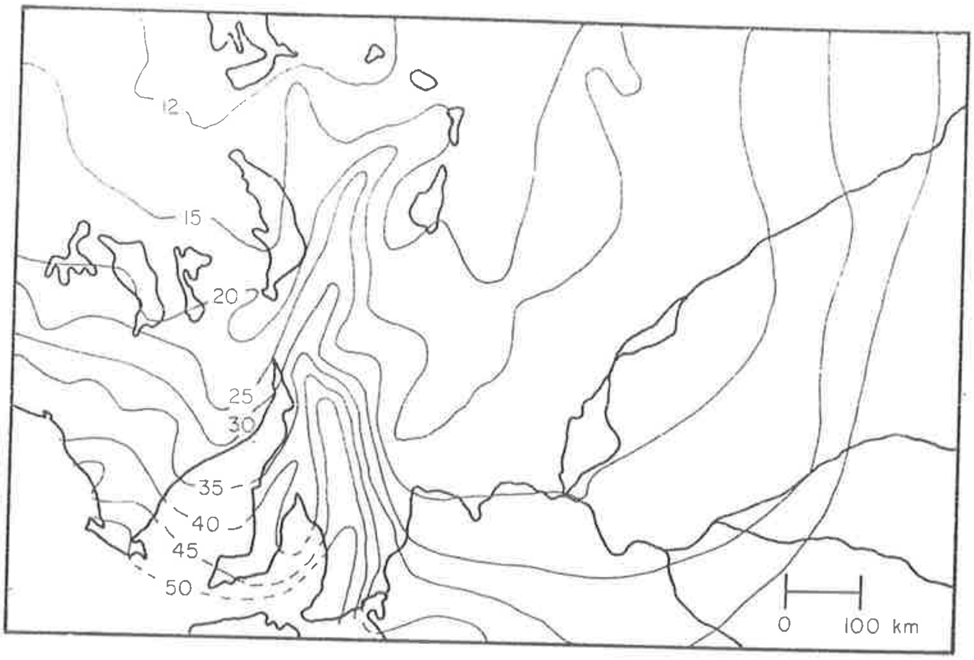

FIG. 4. Mean annual rainfall isohyets (cm) for the part of South Australia studied by Rogers (1972a).

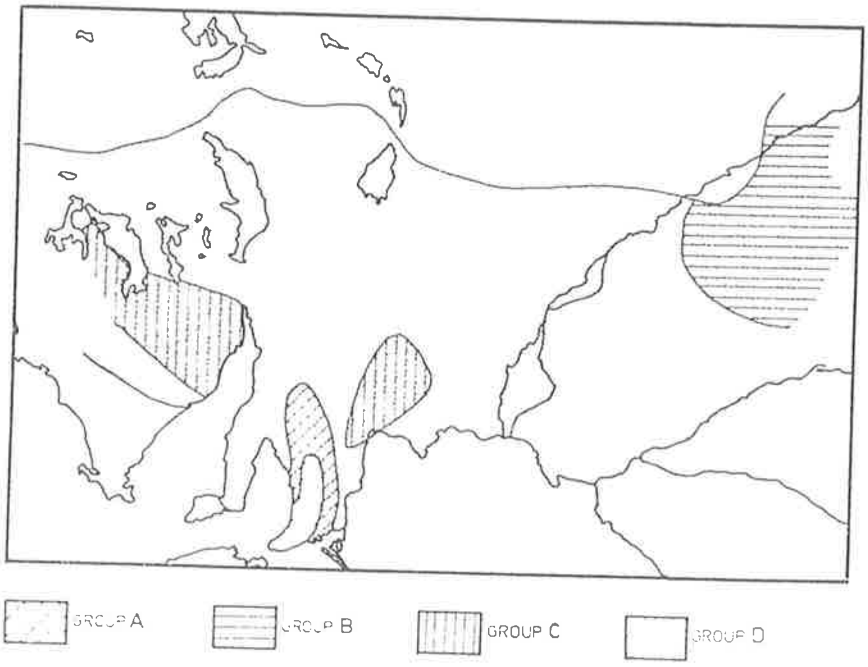

FIG. 5. Distribution of four species groups of soil-surface lichens in arid and semi-arid southeastern Australia. (Reproduced from Rogers, 1972a, by permission.)

an explanation for the close similarities of the lichen floras of steppe and semi-desert of North America and Asia. Such an argument is satisfactory for species showing special disjunctions between two continents, but cannot explain the distribution of species which occur widely in deserts of both hemispheres (Table IV).

It must be remembered, however, that critical taxonomic studies in the lichen floras of arid lands are badly needed. Until consistent studies have been completed embracing taxa across the world, biogeographic findings must be treated as tentative.

B. Regional Patterns

There have been very few studies on the distribution of lichens within desert and semi-desert regions. The most detailed are those by Rogers (1972a,b) which deal only with soil-surface lichens. Since these studies essentially support opinions expressed by other workers, they are useful as a basis for discussion.

An area of about one million square kilometres in southeastern Australia was studied. Most of the area was either arid or semi-arid (Fig. 4), and within this region 42 lichen taxa were reported from soil surfaces. These taxa were arranged into five species groups by consideration of their mutual occurrence and distribution patterns: one group contained only three rare species, so could not be discussed in a geographic context; the other four groups, however, showed an interesting pattern (Fig. 5). Species in group A were confined to humid areas, rarely penetrating to semi-arid regions. Species of group D were widespread through the desert and semi-desert regions, not occurring commonly, however, in the most extreme desert regions, nor in humid regions. In semi-arid regions, species groups B and C formed regional elaborations to the background flora provided by group D species. As the rainfall decreased below 200 mm per annum, so too did the number of species found on the soil surface. Similarly, if the rainfall rose above 300 mm per annum, the soil-surface lichen flora decreased in species richness (Fig. 6).

This demonstrates that there are, at least for soil-surface lichens, distinct arid and semi-arid floras. It is also apparent that arid lands are distinguished from semi-arid lands by the absence of species, rather than by the presence of species. This is perhaps typified by comparing the distribution of *Diploschistes ocellatus* and *D. scruposus* (semi-arid lichens) with *Lecidea decipiens* (a lichen of arid and semi-arid lands) in southern Australia (Fig. 7). It is apparent from Fig. 7 that *D. ocellatus* is confined to the arid–semi-arid margin, mostly in the 200–250-mm annual rainfall band, whereas *D. scruposus* has a wider tolerance (150–200-mm annual rainfall),

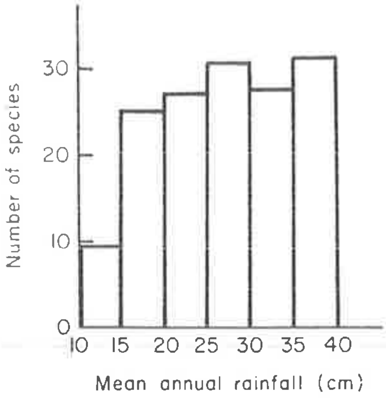

FIG. 6. Histogram showing the decreasing number of soil-surface lichen species with decrease in annual rainfall in southeastern Australia (data from Rogers, 1970).

but is rare below 200-mm rainfall. *Lecidea decipiens,* however, occurs throughout the arid and semi-arid region.

Similarly, Faurel *et al.* (1953) also found that the delimitation of the desert in Algeria was marked by the disappearance of lichens. Reichert (1937a,b, 1940) believed that steppe could be differentiated from desert by the presence of *Diploschistes* in the former. Keller (1930) and Reichert (1937a,b) also suggested that the presence of erratic lichens (see p. 230) indicated an area to be steppe (semi-arid) rather than desert (arid). Galun (1963), however, did find that some saxicolous species in the Negev were characteristic of desert regions, while some were present in both steppe and desert but none were confined to the steppe. Galun also found that there were no soil-surface species characteristic of the desert, whereas there were some which occurred only in steppe regions.

Little published information is available concerning corticolous and lignicolous species. My own studies in Australian arid lands show that the corticolous flora in desert and semi-desert regions is a simplification of that found in adjoining humid or subhumid areas. Of the eleven corticolous species recorded for the Koonamore Vegetation Reserve in South Australia (Rogers, 1974), all but three are known from humid regions of the state. Darrow (1950) made similar observations on the corticolous and lignicolous flora of southeastern Arizona, observing that the species encountered in the desert shrubland and grassland were mostly cosmopolitan.

There appears, therefore, to be a distinctive soil-surface lichen flora in arid and semi-arid regions, the arid zone having a simplified form of the semi-arid flora. The saxicolous lichen flora is apparently distinctive in arid

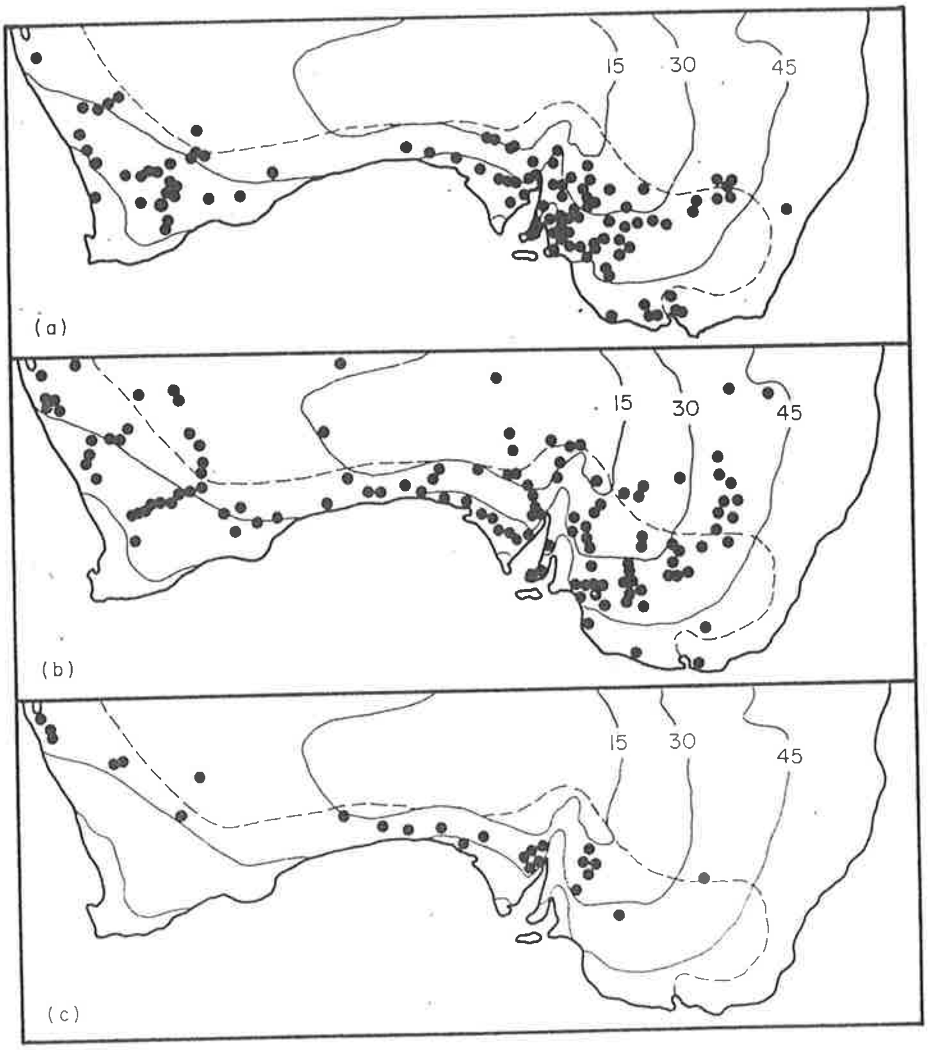

FIG. 7. The distribution of (a) *Diploschistes scruposus*, (b) *Lecidea decipiens* and (c) *Diploschistes ocellatus* in Australia, south of latitude 25°S. The broken line represents the northern and eastern limits of the area with a seasonal maximum of rainfall in winter; the solid lines are rainfall isohyets in cm.

regions but not the semi-arid regions, and the corticolous lichen flora of arid lands is essentially cosmopolitan.

Phytosociological studies of desert lichens have been few. Some workers have, however, formally proposed lichen associations. The earliest work has been summarized by Klement (1958) in his review of lichen associations proposed to that date. The studies of Riemers (1951a,b) and Klement (1955) are pertinent to Europe and Asia, the study by Looman (1964b) refers in part to arid and semi-arid North America, and a study by Mattick

(1970) describes associations from southern Africa. Follmann (1961, 1962, 1965a, 1967a,c) has described and analysed desert lichen associations from South America.

Schubert and Klement (1971) placed a number of desert lichens from Mongolia not in lichen associations, but in associations with phanerogams. Other workers, e.g. Galun (1963) and Rogers (1972a), have discussed lichen communities, but have not introduced syntaxal names. Until taxonomic problems are sorted out and further phytosociological studies undertaken, no comparison of the sociology of arid zone lichens is feasible.

III. Adaptive Response to Aridity

A. Morphological

1. Some General Adaptations

(*a*) *Life-form.* When considering morphological adaptation to arid conditions, it is appropriate to consider first the life-form spectra of lichen populations from various parts of the world. The significance of the ratio of crustose : foliose : fruticose lichens has been noted by a number of writers. Renaut *et al.* (1968) studied the value of this ratio in assessing microclimatic conditions. Others (Fink, 1909b; Herre, 1911; Magnusson, 1940, 1944; Galun, 1963; Rogers, 1974) have commented on the dominance of crustose species in desert regions. It is generally accepted that the reduced surface area of crustose species is an adaptation which permits survival in arid conditions. It cannot be argued that the crustose growth form is a response to arid conditions: the crustose growth form appears also in rainforests where loss of water by evaporation is not a real problem for the lichens. The desert climate, however, does not permit other growth forms to develop. Table V contains life-form spectra compiled from a number of sources for arid and semi-arid areas, with comparative values shown for South Australia and the United States.

(*b*) *Coloration.* Some writers have ascribed adaptive value to variations in coloration. Fink (1909b) noticed an abundance of black spots and lines over the thallus; these he believed to protect the algae from intense insolation. However, Herre (1911) found such spots to be no more common than in other areas, and also that algae were not particularly aggregated there, as they might have been if the pigmentation was protective. Contrasting with Fink's observation, Galun (1963) noted that desert species tended to be light in colour, and hence highly reflective, darker-

TABLE V.

Life-form spectra.

Location	Source	Crustose	Foliose	Fruticose	Climate
Skhrirate	Renaut *et al.* (1968)	60	20	20	S.H.
Jbel Mouch	Renaut *et al.* (1968)	63	26	10	S.H.
EnJemra	Renaut *et al.* (1968)	62	28	9	S.A.
Souk Jemaa	Renaut *et al.* (1968)	78	17	4	S.A.
Skour des Rehamma	Renaut *et al.* (1968)	73	19	7	A.
Mongolia	Magnusson (1940)	98	1	1	A.
Koonamore	Rogers (1974)	58	42	0	A.
Reno	Herre (1911)	91	9	0	A.
Negev	Galun and Reichert (1960)	91	6	3	A.
Sahara	Faurel *et al.* (1953)	97	3	0	A.
Arid South Australia	Rogers (1970)	75	23	2	A.
Semi-arid South Australia	Rogers (1970)	57	35	8	S.A.
Temperate South Australia	Rogers (1970)	37	41	22	S.H.
All of South Australia	Rogers (1970)	45	36	19	—
All of the United States	Fink (1935)	73	16	12	—

The percentage crustose, foliose, and fruticose species at each location are shown along with the climate indicated as S.H.—subhumid, S.A.—semi-arid, A.—arid. For comparative purposes, spectra for South Australia and the United States are included.

coloured species usually having a coating of light-coloured pruina. Follmann and Follmann-Schrag (1964) also noted the bright, reflective nature of "Fensterflechten" in Chile.

(*c*) *Cortical Anatomy*. Anatomical adaptations suggested include a generally parenchymatous thallus, which tends to reduce evaporation (Fink, 1909b; Herre, 1911) and a thickened upper cortex (Blum, 1974; Zukal, 1895). Observations on *Chondropsis semiviridis* show, however, that the thickness of the upper cortex (about 87 μm) is essentially the same in arid and semi-arid sites in South Australia as it is in a subalpine location in New Zealand (R. W. Rogers, unpublished). Another variation in the nature of the upper surface noted by Galun (1963) was the presence of a thick amorphous layer over the surface of *Buellia canescens* from Israel, but not over specimens from Scandinavia. Discussing "Fensterpflanzen" from the southern African deserts, Vogel (1955) considered the thickness of the upper cortex, and produced figures indicating that temperate-zone lichens from sunny habitats have an upper cortex varying from 20–45 μm thick, whereas the desert lichens he studied had an upper cortex from 175–200 μm thick, except *Heppia* (30 μm) and *Eremastrella tobleri* (600–1500 μm). It appears that, as a rule, lichens which occur in deserts have a thicker protective upper cortex than other lichens, although the thickness may be more or less constant for any one species throughout its range.

A thick, cellular upper cortex acts in three ways to protect the thallus. It reduces light intensity, frequently becoming opaque as it dries (Vogel, 1955; Ertl, 1951), and, because of the high water potential that may be developed (Vogel, 1955; Barkman, 1958; Follmann and Follmann-Schrag, 1964), reduces evaporative loss and also permits direct absorption of water vapour from drier air.

A study of *Chondropsis semiviridis* (R. W. Rogers, unpublished) shows that although the thickness of the cortex cannot be related to environment for that species, the breadth of the lobes may (Fig. 8). It is apparent that in desert areas this species has a thallus so much more robust than in semi-desert areas, that the two extremes have been described as varieties (Bibby, 1955). The more robust form may be better suited to the battering such a thallus must take during wind-storms.

2. *Specialized Growth Forms*

(*a*) *Succulence.* Galun (1963) considered that "succulence" as shown by the homiomerous lichens (e.g. *Collema* and *Psorotichia*) was an adaptation to desert conditions, the thalli absorbing much water, and then slowly releasing it. That gelatinous species occur commonly on the driest of desert soils (Rogers, 1972b) suggests they are indeed well adapted to such places, although Fink (1909b) believed they occurred only in the most protected parts of the desert. The gelatinous species do absorb a great deal of water (Smith, 1962), but have virtually no cortical development and will therefore lose water quite as rapidly as any gel. The adaptation of gelatinous species probably results not from succulence, but from the extreme resistance of the phycobiont (a blue-green alga) to adverse environmental conditions.

(*b*) *Inverted Thalli.* A bizarre adaptation described by Vogel (1955) from South Africa, was a *Buellia* species which partially reversed its thallus

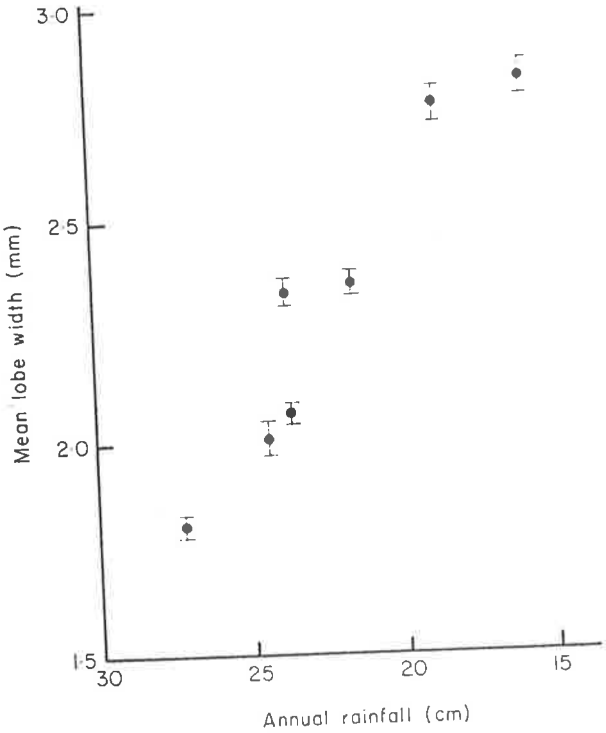

FIG. 8. The increase in width of lobe at the penultimate dichotomy of *Chondropsis semiviridis* for locations in South Australia as rainfall decreases. Scale marks represent one standard deviation each side of the mean.

structure. The thallus grows above soil level on translucent quartz pebbles, with the algal layer close against the quartz, and the medulla and cortex over it, and apothecia on the outside. The algal layer is illuminated not through the cortex as is normal, but by indirect light through the quartz pebble, getting about 10% of incident solar radiation, so reducing heat and water stress on the algal layer of the thallus.

(*c*) "*Fensterflechten*". Vogel (1955) first described the "window lichens" ("lichens with periscopes" according to Follmann and Follmann-Schrag, 1964) as minute squamulose thalli of 2-mm diameter, with only the upper cortex visible, the rest being sunk into the earth. They have a thick upper cortex and algal layer, and very long (5 mm) and extensive rhizoids. Such species are known for southern Africa (Vogel, 1955) and South America (Follmann, 1965b; Follmann and Follmann-Schrag, 1964). They show the ultimate reduction of surface area, only the upper surface being exposed like a window in the soil. They are usually highly reflective, and their thick cellular upper cortex limits light and heat penetration, restricts water loss, and strongly absorbs water from the air. The extensive rhizoidal system must allow them to absorb water in appreciable quantities from the soil. All of these characteristics favour survival in a desert.

(*d*) *Hygrochasic thalli. Chondropsis semiviridis* from Australian semi-arid lands is an extreme example of the lichen variation discussed by Kappen (1974) in which thalli curl up when dry, and uncurl when wet. *Chondropsis* rolls up very tightly in a ball when dry, but when wet rolls out flat on the surface (Rogers, 1971). It has a thick upper cortex (80 μm) which is opaque when dry, and a very thick (200 μm) medulla which is white below. When rolled up, it reduces the surface area exposed to insolation, protects the algal layer behind the thick, reflective lower surface, or, should light fall on a portion of the normal upper surface, the thick opaque cortex protects it.

(*e*) *Erratic thalli.* A growth form which appears characteristic of arid and semi-arid areas is the erratic or unattached lichen ("Wanderflechten" of German authors). Lichens of this form are reported from every continent. From the description cited in Eversmann (1831) it appears that Pallas, a noted naturalist–explorer and prolific writer in late eighteenth century Russia, was the first to describe such forms. *Aspicilia esculenta* was first collected by him from the Kirgiz steppes. Eversmann (1831) discussed this and a number of related species, with an appendix to his paper by Nees van Esenbeck which included details of the chemistry of *Aspicilia esculenta.* Elenkin (1901b) has reviewed the early history of this species.

After examining specimens that descended in an unusually severe hail storm, Errera (1893) suggested that *Aspicilia esculenta* may have been the manna of biblical reports which rained down on the Jewish tribes wandering on the Sinai Peninsula. Analyses showing a calcium oxalate content of 60–70% (Nees van Esenbeck, 1831; Errera, 1893), however, throw doubt on this suggestion (cf. Chapter 5). Smith (1921), Harrison (1951) and Cloudsley-Thompson (1976) have discussed this subject further.

Elenkin (1901c) surveyed the erratic lichens of North Africa, the Middle East and western Asia. He recorded *Aspicilia esculenta* and *A. affinis*, each with a number of varieties, as well as *Parmelia vagans* (*sub. P. molliuscula*) and *P. ryssolea* from Russia, and *Aspicilia esculenta* from Africa.

Hale (1974) noted the wide distribution of erratic forms of *Parmelia* on desert soils, apparently referring all the unattached forms to *P. camtschadalis*, originally from Kamchatka and Nepal (Mereschkovsky, 1918). Hale reported this species as present in Russia, North America, Australia and Africa. Other writers, however, record other species from those areas: Looman (1964a) reported the North American form as *P. chlorochroa*; Rogers and Lange (1971) noted *P. australiensis* and *P. convoluta* in

Australia; Follmann (1967a), in his study of the erratic lichens of Chile, reported *P. vagans*; and Mattick (1970) reported *P. convoluta* from Namibia. Follmann (1967b), in his study of Chilean fog oases, discussed two other erratic species, *Roccella cervicornis* and *Tornabenia ephebaea.* Under similar climatic conditions in Baja California, Rundel *et al.* (1972) found unattached colonies of *Desmazieria pulchribarbara*.

It is apparent that many of the erratic forms are simply detached fragments of normally attached species (Smith, 1921). For example, Magnusson (1940) noted that the normally epiphytic *Teloschistes brevior* "descended onto the soil" in Mongolia and became erratic. *Tornabenia ephebaea*, normally epiphytic, was found unattached by Follmann (1967a) on soil and rocks in South America. *Aspicilia esculenta* is known from both erratic and attached specimens. Whether the various *Parmelia* species discussed above are obligately erratic or are detached portions of thalli which also grow attached to substrates is uncertain. However, *Chondropsis semiviridis* which is widespread in semi-arid regions of Australia (Rogers, 1971) is obligately erratic. It is devoid of all organs of attachment, and is found only on soil surfaces. Other obligately erratic forms appear to be *Roccella cervicornis* (Follmann, 1967a) and *Desmazieria pulchribarbara* (Rundel *et al.*, 1972).

Erratic forms are not confined to semi-arid areas, as Smith (1921) recorded their presence in England, and Meyer (1825) described their formation in Germany. They are, however, especially well developed in semi-desert areas. The erratics are usually of such a form that they can be blown about, and because they are so convoluted or are filamentous, photosynthetic surfaces are always exposed. Perhaps the most striking erratic form is the Australian *Chondropsis semiviridis*. This species is not convoluted, but rather rolls up neatly into a ball when dry, such that when wetted it unrolls onto the soil, virtually always with its photosynthetic surface exposed to the sun. The adaptive significance of the erratic form is possibly that it allows the colonization of soil surfaces which are too unstable to support attached forms.

3. Environmental Modification and Taxonomy

The taxonomy of desert lichens, which are essentially crustose species, is bedevilled by the description of many narrowly defined species. This is partly the result of poor collections from those areas, and partly a lack of understanding of deserts by some taxonomists dealing with material sent to them.

Collections of lichens from deserts have usually been made incidentally by those interested in phanerogams—or even by non-botanists. The lichens collected on one major Australian desert expedition of last century were collected by the expedition's anthropologist! This has often resulted in fragmentary collections, unrepresentative of the areas. Terricolous material has usually been little collected, or returned as a disintegrated dust heap. Saxicolous materials collected have been those specimens on pebbles small enough to take intact, or on parts of outcrops easily broken off: both producing atypical samples. Because the collectors' main interests have been in other subjects, those lichen collections made have usually been few and show an incomplete range of the variation to be found in the field. The need for extensive and deliberate collecting of lichens from desert regions is no less acute today. The need for taxonomists to study material in the field, especially in totally unfamiliar environments, cannot be stressed too much. W. A. Weber, one of the few lichenologists to have collected extensively in deserts himself, discusses these problems in Chapter 2. Modifications caused by the desert environment have also been noted by Galun (1963, 1970), especially in respect of the astonishing plasticity of soil lichens, and these have been discussed briefly by Poelt (1974).

B. Physiological

The two prime physiological stress factors acting on organisms in a hot desert are heat and drought. The effect of low rainfall is reinforced by the intensity of incoming solar radiation, which rapidly evaporates water from surfaces, and tends to heat the thallus.

1. Water Relations

The water relations of lichens have been the subject of a number of studies. The more significant studies include those of Jumelle (1892), Goebel (1926), Kolumbe (1927), Stocker (1927), Smyth (1934) and Butin (1954). Smith (1962) and Blum (1974) have produced extensive reviews on the topic. Essentially, it has been demonstrated that lichens absorb water over the whole thallus, the thallus acting like a hygrophilic gel. Water content varies from 1–15% of the dry weight under drought conditions, up to 350% when saturated, with the homiomerous (gelatinous) lichens reported to have a saturated water content up to 36 times their dry weight.

Barkman (1958) calculated that lichen thalli have a water potential of −300 to −1000 atm (−30,300 to −101,000 kPa), probably due largely to the walls of the hyphae and gelatinous algal walls, not to the cytoplasmic contents of the cells. Water can therefore be absorbed directly from the air as well as from dew and rain. Since the humidity is commonly quite high in arid lands in the early morning hours (dew often forming), it is likely that water absorbed this way is ecologically significant.

Very little physiological study was actually carried out on desert prior to the important investigations of Lange and his co-workers (Lange, 1969a,b; Lange and Bertsch, 1965; Lange *et al.*, 1970a,b). This group studied a variety of fruticose and crustose species from the Negev. At about the same time Rogers (1971) made an eco-physiological study of *Chondropsis semiviridis*, a foliose species from the Australian desert. Lange and Bertsch (1965) showed that *Ramalina maciformis* could absorb about 40% of its saturation water content from the air. At that water content, carbon dioxide uptake reached 70% of the level at optimal water content (about 80% of saturation content). Below 20% of saturation content respiration exceeded photosynthesis. Lange *et al.* (1970a) demonstrated that *R. maciformis* could absorb sufficient water from an atmosphere with a relative humidity of 80% to reach the photosynthetic compensation point. Such humidities are common occurrences overnight in arid areas, as the temperature falls rapidly at night. They also showed that short-term drying did not affect photosynthesis, but that after longer terms of dehydration inhibition was proportional to the duration of drought. Even after 51 weeks with a water content of 1% that of saturation, *R. maciformis* regained its initial photosynthetic capacity. They concluded therefore that damage by drought was improbable in the natural habitat.

The study also showed that at low temperatures (2°C) the light saturation intensity was 20,000 lx, rising to 48,500 lx (equivalent to full sun) at 20°C. At 48,500 lx, the optimal temperature for photosynthesis was 20°C. This figure is lower than the optimal temperature recorded by Rogers (1971) for *Chondropsis semiviridis* (25–30°C), but is still a relatively high temperature in comparison with other lichens (Table VI). While a temperature optimum for assimilation of 20°C is low for desert plants as noted by Lange (1969a), it does not suggest that *Ramalina maciformis* is in this respect specially adapted for desert existence, at least not more so than are other lichens.

In a remarkable field study, Lange *et al.* (1970a) confirmed their hypothesis concerning *R. maciformis*: they demonstrated (Fig. 9) that an early morning dew provided sufficient moisture to allow some 3 h of photosynthesis after dawn. This burst of photosynthesis was more than adequate to compensate for the respiratory losses during the night. They found that 1·32 mg CO_2 (g dry weight)$^{-1}$ day^{-1} was incorporated, that 0·78 mg CO_2 g^{-1} day^{-1} was lost by respiration, leaving a net gain of 0·54 mg CO_2 g^{-1} day^{-1} or, 0·146 mg C g^{-1} day^{-1}. The precise amount while varying through the year was sufficient in their estimation to allow a 5–10% growth rate per year. *Teloschistes lacunosus* behaved in an essentially similar manner.

TABLE VI.

Optimal temperatures for photosynthesis.

Species	Reference	Optimal Temperature	Habitat
Platismatia glauca	Stalfelt (1939)	1°C (19°C)	Alpine
Parmelia corei	Lange (1953)	5°C	Antarctica
Hypogymnia intestiniformis	Lange (1953)	8°C	Alpine
Letharia vulpina	Lange (1953)	8°C	Alpine
Cladonia foliacea	Lange (1953)	8°C	Alpine
Stereocaulon alpinum	Lange (1953)	8°C	Alpine
Cetraria islandica	Stalfelt (1939)	3–14° (18°C)	Alpine
Lasallia pustulata	Stalfelt (1939)	11°C (15°C)	Subalpine
Cladonia elongata	Lange (1953)	12°C	Alpine
C. "sylvatica"	Stalfelt (1939)	14°C (18°C)	Cool temperate
Usnea "dasypoga"	Stalfelt (1939)	14°C (18°C)	Cool temperate
Cora pavonia	Lange (1953)	15°C	Tropical
Cladonia rangiferina	Bliss and Hadley (1964)	15°C	Alpine
Cetraria islandica	Bliss and Hadley (1964)	15–20°C	Alpine
C. nivalis	Bliss and Hadley (1964)	15–20°C	Alpine
Ramalina farinacea	Stalfelt (1939)	18°C (22°C)	Temperate
R. fraxinea	Stalfelt (1939)	19° (19°C)	Temperate
Parmelia pachyderma	Lange (1953)	20°C	Tropical
P. magna	Lange (1953)	20°C	Tropical
Ramalina maciformis	Lange (1969a)	20°C	Hot desert
Diploschistes scruposus	R. W. Rogers (unpublished)	20–25°C	Hot desert
Chondropsis semiviridis	Rogers (1971)	25–30°C	Hot desert

The optima, which are arranged in ascending order, are generally in accord with the habitat from which the lichen was taken.

Lange *et al.* (1970b) have extended the study to cover crustose and foliose species (*Caloplaca ehrenbergii*, *C. aurantia*, *Lecanora farinosa*, *Xanthoria isidioidea*, *Squamarina* cf. *crassa*, *Diploschistes steppicus*) and an endolithic species as well. Like the fruticose species, it was found that these were all able to photosynthesize after sunrise following dewfall. These species were also able to absorb sufficient moisture from the air to permit a short period of photosynthesis after sunrise even if no dew formed. If the thalli were wet during the day at normal temperatures (36–40°C), respiratory losses occurred (Fig. 10). This loss was explained in terms of high respiration at high temperatures, and was taken to indicate

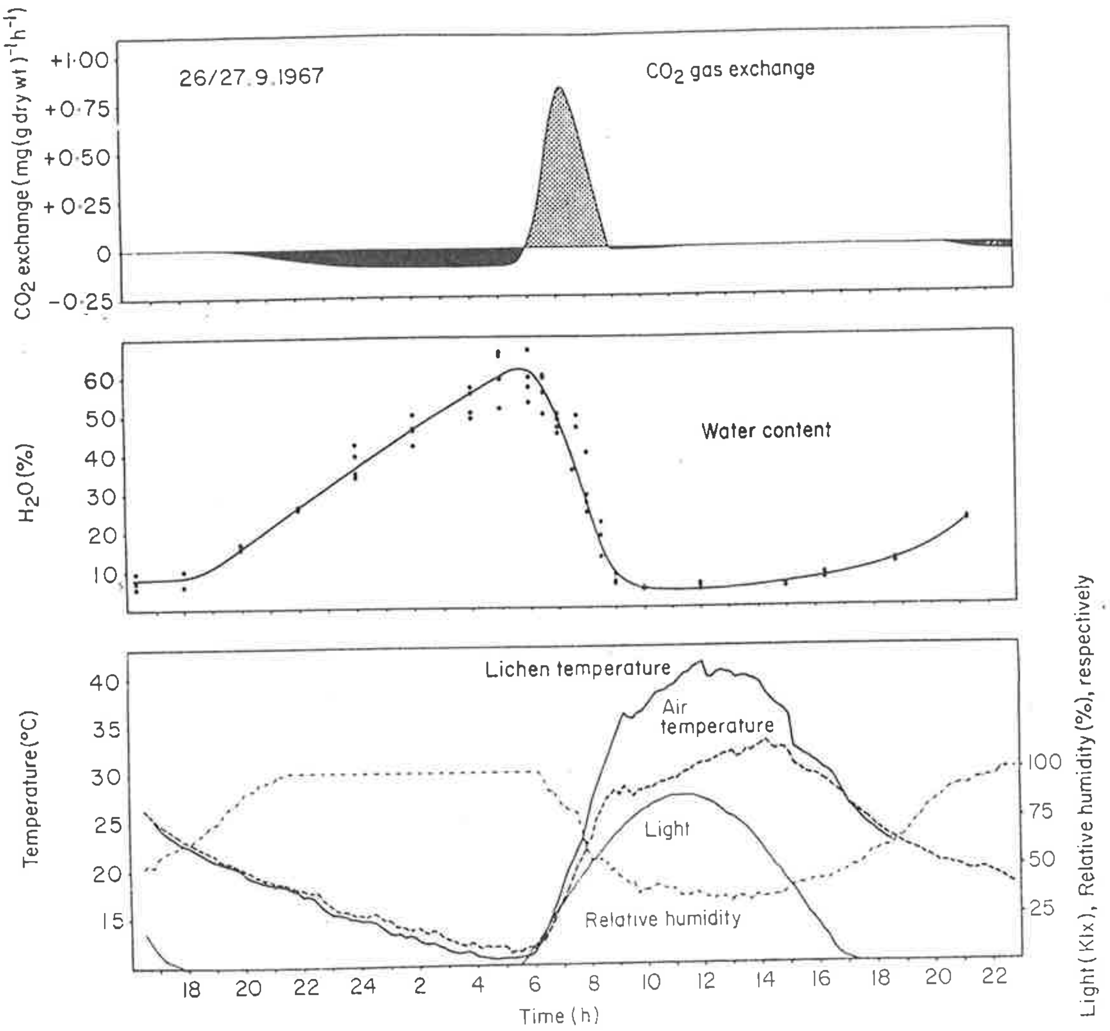

FIG. 9. Carbon dioxide exchange (top) and water content (middle) of *Ramalina maciformis* in the Negev desert. Lower graph shows thallus temperature, light intensity and relative humidity. Note the burst of photosynthesis after sunrise as the thallus dries out. (Reproduced from Lange *et al.*, 1970a, by permission.)

adaptation to low temperatures, since no such loss could be detected if the thalli were kept at a relatively low temperature (19°C).

In the eco-physiological studies of *Chondropsis semiviridis* in Australia (Rogers, 1971), high humidity was suggested as a factor limiting the distribution of the species, as the thallus did not unroll and expose the photosynthetic surface unless liquid water in the form of dew or rain was applied. Apart from this qualification, the findings of that study agreed with those of Lange and his co-workers in terms of rapid response to water, and in the finding that the respiratory surge following wetting was not of great

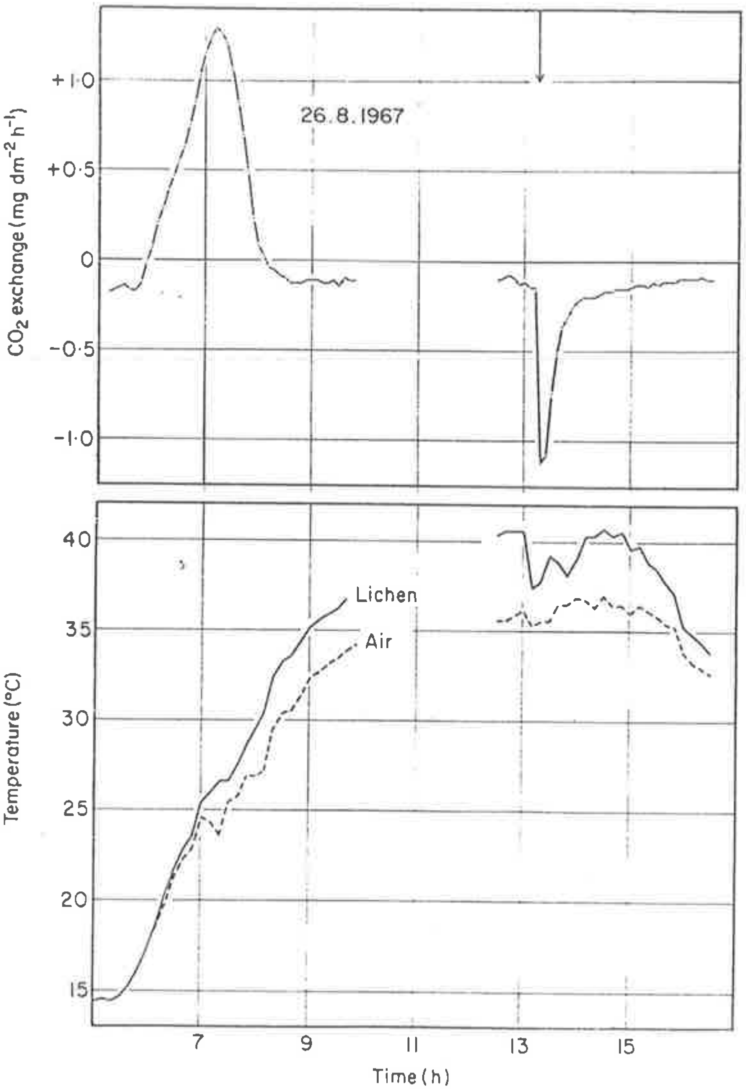

FIG. 10. Carbon dioxide exchange (top) of an endolithic lichen in the Negev desert, showing the respiratory surge caused when the thallus was wet in full sun (arrowed). The lower graphs show air and thallus temperatures. (Reproduced from Lange *et al.*, 1970b, by permission.)

ecological significance. Like *Ramalina maciformis*, *Chondropsis semiviridis* survived prolonged drought apparently without permanent damage.

It appears, therefore, that desert lichens are adapted to use dews to provide short bursts of photosynthesis in the cool of the morning, and that frequency of dew formation is likely to be a significant factor in determining their distribution. Crustose species on soil surfaces may also avail themselves of the upward movement of water in desert soils at night, demonstrated by Rose (1968). It is possible that under desert conditions dew could form within the soil even if it did not form on the surface. This would help explain the extensive development of crustose lichens on desert soil surfaces.

Because of the varying conditions of light and temperature under which optimal water content of thalli for carbon assimilation has been determined, it is not possible to compare results from study to study. Something of a debate has developed as to whether the optimum is saturation level, or lower. Ellee (1939), Smyth (1934) and Lange (1969a) all found saturation conditions optimal, whereas Jumelle (1892), Stocker (1927), Ried (1960) and Kershaw (1972) found optima at lower levels. The precise optimum will vary according to prevailing conditions, lower optima being expected of low light intensities because while light may be the limiting factor in photosynthesis, it will not greatly influence respiration rate. It appears that xeric species under identical conditions do have lower optimal water contents for assimilation. Kershaw and Harris (1971) showed a cline across England in *Parmelia caperata*, a lichen of more mesic conditions, from an optimum at 88% of saturation water content in wet regions in Devon to only 28% of saturation in drier regions of Norfolk. Kershaw (1972) demonstrated this relationship for a number of species in Canada, *Xanthoria fallax* showing a marked shift in optima depending on its origin (Fig. 11). It is likely, therefore, that desert species will reach optimal assimilation rates at lower water contents than will temperate species.

2. *Temperature*

Lange (1953) reviewed the effect of high temperatures on lichens, and tested a great number of species after exposure to a 30-min period at various temperatures. As a rule, lichens are not easily damaged by high temperature if air-dry, but are sensitive when wet. Photosynthesis is more sensitive to high temperature than is respiration. Lange noted a general tendency for the temperature resistance of lichens to correspond with the conditions likely to prevail in their environment.

Lange (1969a) found that after 30 min at 60°C, air-dry *Ramalina maciformis* thalli were virtually unaffected. Similarly, Rogers (1971) found that *Chondropsis semiviridis* thalli were resistant to high temperatures (60°C) when dry, but when wet a temperature of 40°C for 30 min caused severe damage. Temperatures in excess of 60°C do occur on desert soils (Rogers, 1971), so it appears that while the heat resistance of dry thalli is usually sufficient to withstand the conditions encountered, some heat damage may occur. In some semi-desert areas where summer rains are not infrequent it is possible that wet thalli will reach quite high tempera-

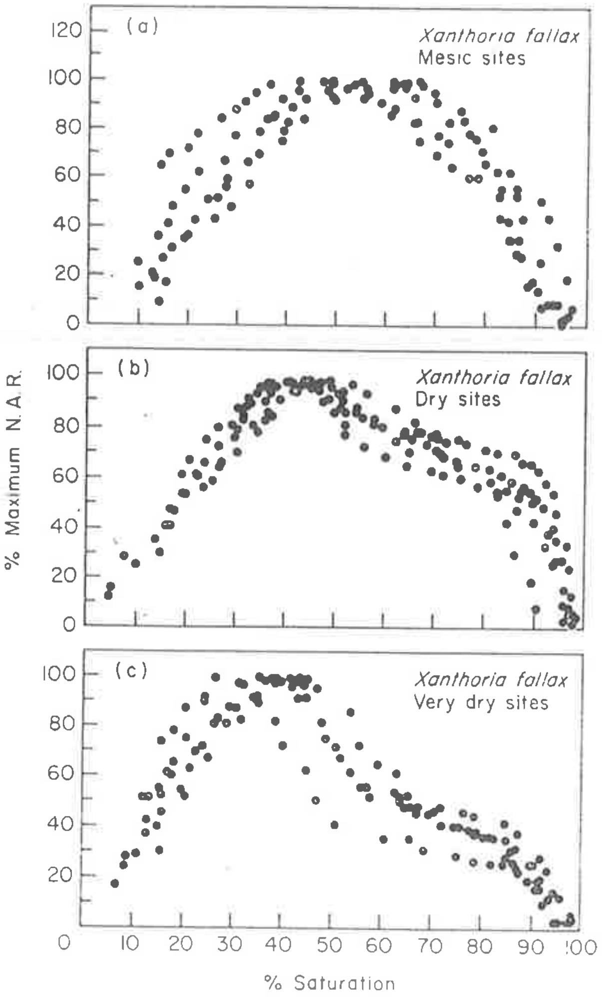

FIG. 11. Relationship between net assimilation rate (N.A.R.) and thallus saturation for *Xanthoria fallax* from various sites in Canada. Note the reduced saturation level at which material from various sites reaches maximal assimilation. (Reproduced from Kershaw, 1972, by permission of the National Research Council of Canada.)

tures and so suffer severe damage. Rogers suggested that this controlled the distribution of *Chondropsis* in eastern Australia, as *Chondropsis* only occurred in desert areas within which winter rainfall predominated.

It is apparent that lichens from hot deserts are better adapted to high temperature than other lichens. Lange (1969a) observed that the optimal temperature of 20°C for assimilation by *Ramalina maciformis* was low for a hot-desert plant, and may represent an adaptation to allow maximal photosynthesis in the cool of the morning. While this is so, an optimum of 20°C is a high temperature optimum amongst the lichens studied (Table

VI). The hot-desert lichens studied do have higher temperature optima for photosynthesis than other lichens. From Table VI it is apparent that species from warm areas tend to show higher optimal temperatures than those from cold areas, an apparent adaptation to environmental conditions. It is notable that with the exception of an unnamed lichen species from Florida (Gannutz, 1968) which has its optimum in the range 20–32°C, hot-desert lichens have the highest optimal temperatures recorded.

IV. Factors Controlling Distribution

It is apparent from the preceding discussion on the morphological and physiological response of lichens to aridity, that high temperatures and drought are important factors in their evolution. These factors are also important considerations in explaining the distribution of lichens within desert regions.

The assertion that lichens are able to survive a far longer drought than they meet in nature (Lange, 1953) was based on measurements of respiration. It is apparent that studies based on photosynthetic response show a lesser drought resistance. However, it is not so much drought resistance as the total number of hours during which a lichen may photosynthesize that will determine whether or not it survives. Studies by Lange *et al.* (1970a,b) and Rogers (1971) show how small is the margin by which a desert lichen survives. A reduction of a few hours per year in photosynthesis—a few less occasions when the thallus is wet—and respiration might well exceed photosynthesis. Thus, it is not unexpected that lichen distribution so closely parallels rainfall patterns, especially on the dry edge of the distribution range.

It is likely that inability to compete with other organisms, especially for light, limits the development of desert lichens in areas of high rainfall, although they would be expected to occur in dry, exposed sites in such places. Thus, the distribution of desert lichens is largely explained in terms of rainfall and its seasonal distribution.

However, not only must climate be suitable for a lichen to develop, but so must the substrate (Brodo, 1974). Rogers (1972a) has documented the distribution of soil-surface lichens on a variety of arid zone soils. The frequencies of 32 species were examined with respect to soil pH, extractable soil calcium and sodium, and soil-surface type. Some species were restricted to the acid-neutral soils (pH 6·4–7·2) while others were restricted to alkaline soils, but most occurred across a wide range of soil pH, six species occurring across the entire range surveyed (pH 6·4–8·8). The relationship between soil calcium and species range is similar to that between pH and species range, except that no species is confined to soils with high (> 6·4 mmol/g soil) extractable calcium. Studies on the relationship between extractable soil sodium and species range produced the surprising result that while *Collema coccophorum* was most frequent on the more saline soils ($> 10^3$ μmol Na/g soil), most species occurred over a wide range of sodium concentrations. It was found that the lichens were most common on soils with a fine texture which either crusted or was hard-setting. Lichens were rare on self-mulching clays, sands and gravels. Galun (1963) observed that the pattern of soil-surface lichen distribution in the Negev was in accord with the soil pattern of the area.

Saxicolous lichens are often quite substrate specific. Galun (1963) found that where flint and chalk stones occurred together each had distinctive lichen communities, although the environment was otherwise identical. She observed, however, that *Buellia subalbula* var. *fuscocapitellata* occurred on both substrates, although it formed only small thalli 2–3 cm in diameter on flint, but thalli as large as 10 cm in diameter on limestone.

It is also true that corticolous and lignicolous species in deserts may be substrate specific; for example Darrow (1950) found that *Caloplaca astrosanguinea* was confined to the bark of *Prosopis juliflora* var. *velutina* in the desert shrublands of Arizona. Such specificity is probably uncommon, most species apparently growing on a number of substrates, but more frequently on some than others. It is, however, the rarity of bark and wood surfaces in some deserts that prevents the development of corticolous and lignicolous species in them—Galun and Reichert (1960) found only one corticolous lichen in the Negev, *Caloplaca luteoalba* growing on *Acacia tortilis*.

In broad terms, lichens and phanerogams are distributed in response to climatic factors, so it is not surprising to find that within deserts they often show similar distribution patterns. This similarity has been referred to by Reichert (1937b,c), Faurel *et al.* (1953), Looman (1964b), Schubert and Klement (1971) and Rogers (1972b). Faurel *et al.* (1953) and Rogers (1972b) suggested that the lichen flora conveniently divided arid lands into two portions, depending on the severity of aridity.

The similarity in distribution patterns can be judged by comparing the distribution of *Kochia sedifolia*, a desert perennial shrub, with that of *Diploschistes ocellatus* (Fig. 12). This pattern will, however, only hold where the lichen and phanerogam are subject to the same stress. In the Negev, for instance, both soil lichens and phanerogams are distributed as the soils, both being sensitive to soil variations. However, rock-inhabiting lichens are sensitive to the nature of the rock, which the phanerogams are not. Hence, various lichen communities occur within the same phanerogamic community when flint and chalk pebbles are mixed (Galun, 1963).

Fog oases are a striking departure from the general principle. Because of differences in water relations, phanerogams absorb water almost exclusively

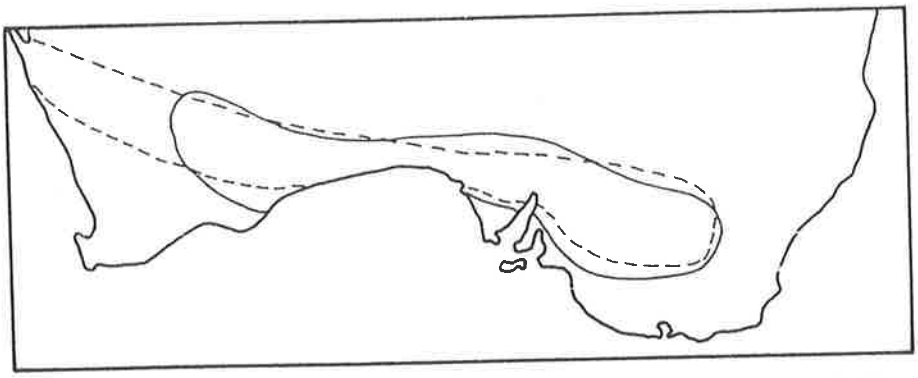

FIG. 12. Distribution of the shrub *Kochia sedifolia* (based on data of Hall *et al.*, 1964) (solid line) and *Diploschistes ocellatus* (broken line) in southern Australia.

from the soil, whereas lichens absorb water quite readily from the air. Regions with low rainfall but where fogs or high humidity are common would thus be dry for phanerogams, but humid for lichens. There are reports of such locations in South America (Follmann, 1967b; Thomson and Iltis, 1968; Follmann and Redón, 1972), North America (Rundel *et al.*, 1972) and South Africa (Mattick, 1970). In all these areas the desert sweeps down to tropical coasts, and fogs frequently roll in over them from the sea.

The lichen growth in these areas is quite unlike that found in other desert regions, genera such as *Usnea*, *Ramalina*, *Heterodermia* and *Arthonia* dominating. The species list for the Cerro Moreno region in Chile (Follmann, 1967b) reads like a list from a rainforest. The affinity of the flora is in fact with the wet tropics. The floras reported from Peru by Thomson and Iltis (1968) and Baja California by Rundel *et al.* (1972) were essentially of terrestrial species which formed extensive mats over the soil. Those discussed by Follmann (1967b) and Follmann and Redón (1972) from subtropical Chile are more diverse, having corticolous and foliicolous, as well as saxicolous and terricolous, species. In this region even the spines of arborescent cacti are festooned with *Usnea* and other fruticose genera. Further regions where fog oases are likely to be found, therefore, include the coast of Mauritania in North Africa and the coast of north-western Australia in the vicinity of Exmouth Gulf.

The uniformity of desert lichen floras around the world relative to the diversity of phanerogamic floras, and the relative lack of endemics, has caused comment (Thomson, 1961; Weber, 1962; Looman, 1964b; Rogers and Lange, 1972). Thomson (1961) observed that vegetative reproduction would limit endemism, but would cause any new mutation that did arise to develop a uniform population rapidly, as back-crossing may not occur. This apparently had occurred, but only rarely, in *Physcia* in North America.

It has long been held that the desert environment provides a strong stimulus to evolutionary change and to speciation. Stebbins (1952) accounted for this by hypothesizing a series of minor climatic changes which alternately isolated small populations allowing them to develop separately, then brought them together so they hybridized. To explain the distribution of cosmopolitan desert lichens it is necessary to assume that recombination occurs at least rarely. This assumption is compatible with the evidence for a slow rate of evolution. Hence ecological sifting of available gene combinations is probably more important than the evolution of new combinations for the development of desert lichen communities.

V. Lichens in Arid Ecosystems

In arid lands lichens are ecologically significant: their resistance to extremes of heat and drought enables them to occupy habitats unavailable to phanerogams, and nowhere is this more striking than on the soil surface. The ability of crustose, squamulose and sometimes foliose lichens to completely cover the soil surface in desert regions has an important impact on soil stability, hydrology and fertility.

Erosion of desert soils by wind and water is a critical problem. However, lichen crusts retard such erosion to a marked extent, their thalli preventing raindrop impact on to the soil, and their rhizoids binding the usually friable desert soil particles. Cameron and Blank (1966) found lichen crusts capping uneroded soil pedestals up to 10 cm higher than the surrounding eroded areas. Weber (1962, 1967) also noticed the ability of lichens to retard soil erosion. Examination of quadrats used to study revegetation of bare soil on the Koonamore Vegetation Reserve in South Australia showed, however, that lichen crusts only develop on areas of soil that are protected from erosive forces (Rogers, 1974). On that reserve a shrub layer of *Atriplex vesicaria* or *A. stipitata* appears on eroded areas before lichen crusts form. It appears that the first stage in stabilization of the soil surface is protection from wind erosion, the surface being then bound by fragile algal filaments, the lichens growing only slowly on this temporarily stabilized surface. It is apparent on these quadrats that once the shrub cover dies and decays, a well developed lichen crust is able to resist erosive forces for a considerable time.

Lichen crusts have a marked effect on the hydrology of arid lands. The rate of infiltration of water into a sandy soil at Koonamore was 7 cm h^{-1} in an area with a lichen crust, but almost 14 cm h^{-1} in a nearby area on a similar soil without a lichen crust (Hall and Specht, personal communication). Crusting of soil surfaces is generally expected to reduce infiltration and thus increase run-off (Jackson, 1958), so increasing the likelihood of erosion by flowing water. Soil-surface lichen crusts are, however, markedly vesicular, frequently having a microtopographic amplitude of 1–2 cm. Such a microtopography would tend to retain a great deal of the water which could not infiltrate into the soil, and would so reduce flow rates as to limit any erosion that might have been caused.

Lichen-stabilized soil crusts contribute significantly to the fertility of desert soils and, presumably, to growth of vascular plants. Shields (1957) and Shields *et al.* (1957) showed the nitrogen content of soils with a lichen crust to be 2–7 times higher than soils without a lichen crust. Similarly, they found the organic carbon levels in lichen-stabilized soils to be higher than that in other desert soils. These differences were presumably due to biological fixation by both free-living and lichenized algae in the soil surface. The only records of nitrogen fixation by desert lichens are those of Rogers *et al.* (1966). However, it is to be expected that any lichen containing an heterocystous blue-green alga will be capable of nitrogen fixation.

It is striking how few seedlings germinate in lichen-encrusted areas after rains compared with nearby areas without lichens. It is possible that this is simply due to the physical nature of the soil surface, but it is also possible that lichen acids are involved. Rondon (1966) and Pyatt (1967) have shown that lichen extracts inhibit seed germination, and Huneck and Schreiber (1972) have shown that at low concentrations some lichen substances promote growth of vascular plants. Other organisms may also be affected: the antibacterial effects of lichen acids have been discussed by Stoll *et al.* (1947), and Malicki (1967) showed that whereas usnic acid inhibited bacterial decomposition of cellulose, it did not inhibit nitrogen fixation by *Azotobacter*. While such effects may not be significant in most ecosystems, in a desert where the entire soil surface is carpeted with lichens these factors deserve examination.

Lichens on soil and rock surfaces undoubtedly provide habitats for a complex microfauna, of the type described by Wood (1970) from arid soils in Australia. There is little sign that insects browse on desert lichens in Australia, and no record of such from other arid lands. The impact of lichens on animal communities must, therefore, generally be indirect through their impact on the other plants.

VI. The Impact of Man

The impact of man on lichens in deserts and semi-deserts has been chiefly through the introduction of grazing herds. There can be no doubt that the soil-surface lichens have been destroyed or damaged over an area measured in millions of square kilometres.

The extent of damage has been partly documented by Rogers (1972) for Australia. From this study it is apparent that in large areas of Australia there has been an almost complete destruction of the lichen crusts on the soil following low intensity grazing by sheep. This has occurred in little more than 100 years. Damage in the Old World must be very much more extensive indeed. Detailed studies by Rogers and Lange (1971) around sheep-watering places in arid South Australia showed that different species respond differently to trampling by sheep. While all are reduced in frequency, the reduction is less marked in *Collema* and *Endocarpon* than in any other genera. *Lecidea decipiens* and *Heppia lutosa* showed reduced frequencies at distances as great as 800 m from watering places (Fig. 13).

Recovery from damage caused to soil-surface lichens by sheep is slow. On the Koonamore Vegetation Reserve, some areas ungrazed by sheep since 1925 were still not showing a development of soil-surface lichens in 1969, although areas adjacent to them did.

The destruction of soil surface lichen populations by trampling animals is likely to have far-reaching effects. Once the crust is destroyed, the surface soil which contains most of the soil nutrients is easily blown away. The soil texture changes when the crust is damaged and the living conditions for the soil microflora are radically changed. This will in turn affect the growth of phanerogams especially by alteration of seed-bed characteristics.

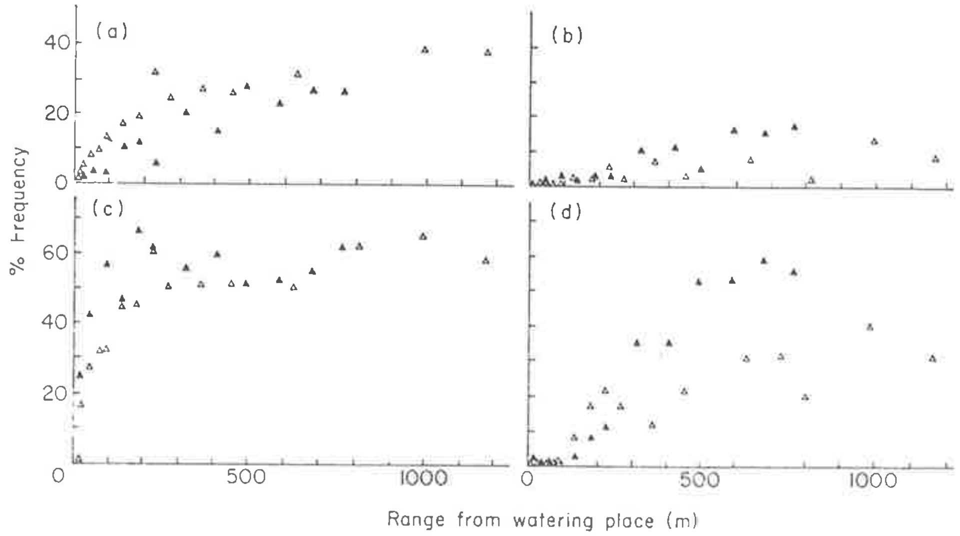

FIG. 13. Relationship between percentage frequency and distance from a sheep-watering place for soil-surface lichens in arid South Australia. (a) *Heppia lutosa*, (b) *Dermatocarpon lachneum*, (c) *Collema coccophorum*, and (d) *Lecidea decipiens*. Open triangles and solid triangles represent two nearby sites. (Reproduced from Rogers and Lange, 1971, by permission.)

It is likely, then, that by the time the soil-surface lichen crust is destroyed by trampling livestock, far-reaching and perhaps irreversible changes have been initiated in the system.

The impact of industrial activity on desert lichens is relatively limited. The principal non-pastoral industries in arid lands are mining and tourism; disturbance to lichen communities is probably due to mechanical damage caused by machinery. This situation is different from that in cold deserts (tundra) discussed by Schofield and Hamilton (1970).

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PROCEEDINGS OF THE SYMPOSIA ON LICHENOLOGY AT THE XIII INTERNATIONAL BOTANICAL CONGRESS,
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PART 2
Compiled by L. KAPPEN and R. W. ROGERS

XIII INTERNATIONAL BOTANICAL CONGRESS SYMPOSIUM: LICHENS OF ARID REGIONS

INTRODUCTION

L. KAPPEN[1] AND R. W. ROGERS[2]

Until the middle of this century there had been few studies on desert lichens. The earliest work concerned western Asia, North America and North Africa. The number of papers in the field has now risen to a few hundreds (Hawksworth, 1977) but our knowledge of taxonomy and floristics is still very incomplete. Very little is known of the lichen flora in the deserts of southern Africa and southern Asia. Vast areas of some deserts are apparently without lichens, for instance in the Sahara, the Atacama and in parts of Australia, however, in some deserts intensive studies have shown the lichen flora to be more diverse than the phanerogams. The ability to utilise moisture in the air is important in this respect in southern Peru (Thomson and Iltis, 1968) and in the fog oases in Chile (Follmann, 1965) and locally in Antarctica (Schofield and Ahmadjian, 1972).

There have been some studies on desert lichen phytosociology in Eurasia, North Africa and South America. However, these papers are relatively few – about 50 in total to the present.

Fink (1909) and to a lesser extent Herre (1911) attempted the earliest ecophysiological interpretations of lichen distribution. In the last 20 years, however, some definitive studies on the ecophysiology of desert lichens have been conducted, with some 75 papers produced. It is now possible to generalise concerning lichen ecology in desert areas, based mainly on studies in western Asia, western North America, southern Australia and the Antarctic.

There are, in deserts, a number of cosmopolitan species. On the other hand,

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[1] Botanisches Institut der Christian-Albrechts Universität, Olshausenstrasse 40–60, 2300 Kiel 1, West Germany

[2] Department of Botany, University of Queensland, St. Lucia 4067, Queensland, Australia.

there is a number of genera which tend to characterise deserts – *Dermatocarpon*, *Heppia*, *Squamarina*, *Psora*, *Collema*, *Acarospora*, *Aspicilia*, *Buellia* and *Rinodina* (Rogers, 1977; Friedmann and Galun, 1974). A high level of endemism is reported for Central Asia and South America, and to a lesser degree for Australia, North America, the Sahara and southern Africa. Many morphological variations in crustose and fruticose lichens have been demonstrated (Weber, 1962; Friedmann and Galun, 1974; Kappen, 1973; Lindsay, 1977; Rundel, 1982), some of the morphotypes being so different that they appear to be like different species.

The physiological responses of the desert lichens may be less variable than their morphology. Cyanophilic lichens are apparently better adapted to extremely arid conditions than those with a eucaryotic phycobiont (Galun et al., 1982). One common physiological pattern seems to be for photosynthesis to be restricted to the cool periods after sunrise when humidity is still high. Lichen occurrence in deserts is restricted to the habitats where suitably moist microclimates occur: as a response to the limited sites available the life form spectra of lichens in deserts tend to be similar. Crustose species grow closely to the rock surfaces and can thus make optimal use of water condensation from the air; fruticose species with a large surface area are able to catch the suspended water droplets in fog; erratic lichens may accumulate in temporarily wet depressions. 'Window Lichens' are forms characteristic of deserts in two different manners, being either thalli on the under surface of translucent pebbles, which is the window, or alternatively, terricolous with a thick cortex (window) and anchored by long rhizines. The function of the rhizines is not known, and it has not yet been demonstrated significantly that the thick cortex besides protecting the lichen does also conserve water.

The ecophysiological limitation of desert lichens becomes apparent when it is observed how their distribution is restricted to places where water from rain, fog, dew or snow is preserved for a longer time – on the shady side of pebbles, under pebbles, in depressions etc. Further comparative studies will show to what extent our present knowledge can be satisfactorily generalised.

It was intended that the papers which follow should present an over-view of the floristics, vegetation and ecology of lichens in the arid regions of the world. It will be apparent from the contributions that there are still large gaps in our knowledge.

The first four papers deal with general aspects of the physiological and morphological adaptations of lichens to desert conditions. This is followed by a review of the current state of knowledge concerning the lichens in desert regions of each of the continents including the arid parts of the mediterranean area in which lichenology has been extensively studied.

The information available is uneven. There is no report from southern Africa and little from arid areas outside of Chile in South America.

Perhaps the incompleteness of the survey will in itself stimulate activity to close the gaps demonstrated.

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LICHENS OF ARID AUSTRALIA

R. W. ROGERS[1]

INTRODUCTION

The Australian continent is dominated by land which can be described as desert or semi-desert. Between latitudes 20° S and 33° S only the narrow strip of the eastern highlands and the extreme south-west are adequately watered. The south and east of the continent receive appreciable rains in the winter, whereas the north and east receive their rains in the summer, the remainder receives no appreciable seasonal rainfall (see Fig. 1a). Although there is some dry sub-alpine land in south-eastern Australia, there is no portion of Australia which could be considered a cool or cold desert: the Australian deserts are all warm to hot.

There have been few studies undertaken on the lichens of arid Australia. The first report to detail a significant number of Australian desert lichens was prepared by Müller Argoviensis (1893), who worked on lichens collected by Richard Helms, travelling with the Elder exploring expedition to central and western Australia. A few small collections were made and reported on in the following years, but not until 1971 did any further significant works on Australian desert lichens appear. Commencing that year Rogers published on soil surface lichens in arid south eastern Australia (Rogers 1971, 1972a, 1972b, 1974; Rogers & Lange 1971, 1972). It is not only desert lichens which are poorly known in Australia: it was not until 1979 that the first modern handbook to the lichens of an Australian region was produced (Filson & Rogers 1979), and that is an incomplete account of the relatively depauperate (and largely desert) flora of South Australia. A discussion of some lichen distribution patterns in Australia, including desert species, can be found in Rogers & Stevens (1981).

FLORISTIC RICHNESS

The lichen flora of Australian arid lands is imperfectly known . In all of arid South Australia Filson & Rogers (1979) recorded a total of 89 species of lichens – a total which is by no means complete. In a relatively homogenous area of 390 hectares at Koonamore in arid southern Australia Rogers (1974) found 38 species of lichens: Johnson & Baird (1970) reported a lichen flora of 12 species from Forrest and in a small area a few kilometres west of Morgan in South Australia a brief inspection showed a lichen flora in excess of 26 species. Desert soils bearing a lichen flora of 15 or more species are known from a number of locations in both south-eastern and south-western Australia. The southern, winter rainfall, arid lands thus appear to support a quite diverse flora.

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[1] Department of Botany, University of Queensland, St. Lucia, 4067, Australia.

The situation in northern arid lands is apparently very different, although very little direct information is available. A thorough search by the author in the vicinity of Mt. Isa failed to find any lichens at all. This search included quartzite rocks, granites, soil surfaces and tree trunks. Geologists working in the area who were asked to look for lichens eventually produced very poor specimens of an indeterminate *Peltula* like thallus and of *Acarospora schleicheri* (Ach.) Mass. from siliceous rocks in an overhung river bed. Botanists working in tropical and subtropical arid western Queensland have also found remarkably few lichens – a total of not more than ten

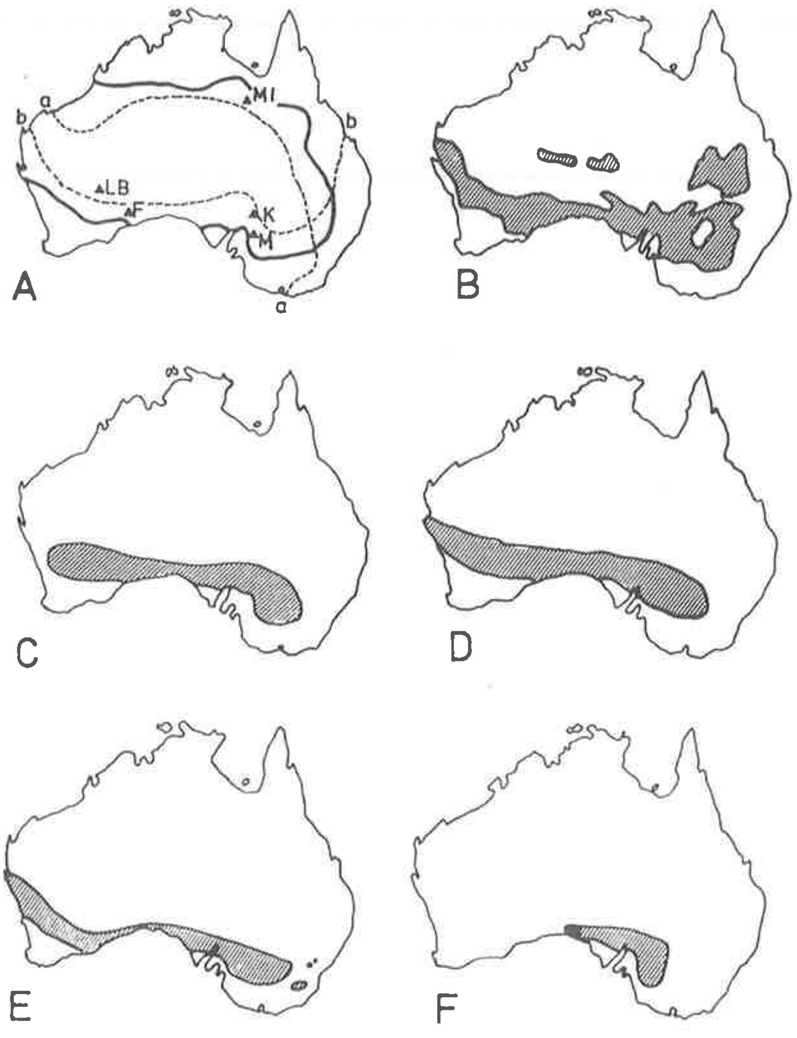

FIG. 1. A. Deserts in Australia. The heavy line indicates limit of desert lands. The broken line a–a represents the southern and western limit of areas receiving appreciable summer rainfall, and the broken line b–b areas reciving appreciable winter rainfall. LB – Lake Barlee, F – Forrest, K – Koonamore, M – Morgan, MI – Mt. Isa. B. Distribution of soil surface lichen crusts. C. Distribution of *Diploschistes ocellatus*. D. Distribution of *Psora crystallifera*. E. Distribution of *Chondropsis semiviridis*. F. Distribution of *Xanthoparmelia convoluta* (hatched) and *X. australiensis* (black).

species having been found to this time. The evidence indicates a very limited lichen flora in the tropical and subtropical arid lands, when compared with that known from the southern (mediterranean type) arid lands. However, lichens are known to be very sensitive to heat when the thallus is wet. It appears that lichens from arid regions are adapted to photosynthesizing in the cool early morning when wet from dew formation, and are normally dry by the time temperatures start to rise during the day. In north-eastern arid Australia the summer is both very hot and humid, with occasional heavy rains. In such a region where temperatures in excess of 40°C are commonplace with simultaneous high humidities, it seems likely that lichens would be exposed to fatal conditions quite often.

COMPOSITION OF THE LICHEN FLORA

The lichen flora of arid southern Australia is especially rich in *Xanthoparmelia*. Of the 89 lichen species reported by Filson & Rogers for arid South Australia, 28 species are in the genus *Parmelia sens. lat.*: of these 22 are *Xanthoparmelia*, 4 saxicolous or terricolous *Melanoparmelia*, one a yellow-green corticolous species, and one a grey corticolous species. Other frequent genera include *Acarospora*, *Aspicilia*, *Buellia*, *Caloplaca*, *Chondropsis*, *Collema*, *Dermatocarpon*, *Diploschistes*, *Endocarpon*, *Fulgensia*, *Psora*, *Peltula*, *Physcia*, *Toninia* and *Xanthoria*.

The presence of soil surface lichen crusts is a striking feature of enormous areas of southern arid Australia. Rogers (1972b) reconstructed the probable pre-European settlement distribution of these continuous crusts over the entire southern half of the continent, extrapolating from data from south-eastern Australia only. Subsequent work in south-western Australia has shown that the area was under-estimated, as some extensive areas of earthy sands and red earths in that region supported a well developed lichen crust (Fig. 1b). These crusts are fragile, and very easily damaged by trampling sheep (Rogers & Lange 1971).

DISTRIBUTION PATTERNS

By assembling the distribution data from Rogers (1970), and collections made by Noy-Meir, Rogers & Sammy, Bratt, Elix and Filson, it has been possible to define the distributions of a number of arid zone lichens from southern Australia. The species with distributions which can be defined are mostly widespread along the southern margin of the arid lands. This pattern is well illustrated by *Psora crystallifera* (Tayl.) Müll. Arg. (Fig. 1c) and *Diploschistes ocellatus* (Vill.) Norm. (Fig. 1d). An interesting variant is shown by *Chondropsis semiviridis* F. Muell. ex Nyl. (Fig. 1e) which has disjunct populations in the dry subalpine grasslands of the Snowy Mountains and some other high and relatively dry mountain peaks in the south-east of the continent as well as in New Zealand.

Some evidence of difference between the eastern and western arid floras exists. It is apparent that *Xanthoparmelia convoluta* (Kremp.) Hale, which is a distinctive vagant species of eastern Australia does not occur in Western Australia. In Western Australia the genus *Haematomma* differs from that genus in eastern Australia in that there are two endemic species, both occurring in dry inland regions, whereas none occur in the eastern desetrs. There is also a distinctive undescribed *Xanthoparmelia* widespread and common on soil in the north of the arid region of Western Australia which has not been reported from eastern Australia.

There are few cases of apparent narrow endemism known. *Xanthoparmelia australiensis* (Cromb.) Hale, which is sympatric with the morphologically very similar but chemically different *X. convoluta*, is restricted to a small area on the Nullabor Plain (Fig. 1f). One of the two western *Haematomma* species is apparently restricted to a small area near Lake Barlee.

FUTURE WORK

There is no current or projected program especially for the study of Australian desert lichens. However, there is growing interest in lichens in Australian botanical institutions and as a result data on species distribution is being accumulated, and the taxonomy of some genera being clarified for arid lands in the context of the whole continent. This situation appears likely to continue. Areas which may repay examination are parts of the coast of the Great Australian Bight and the coast of Western Australia north of the tropic where fog oases may possibly occur. An expedition into the tropical arid areas searching for lichens is unlikely to make many collections, but would resolve the question of whether the apparent absence of lichens in the area reflects the infrequency of collectors or the absence of lichens. There is a general need for systematic collection of saxicolous and corticolous lichens throughout the entire Australian desert.

The significance of lichens on Australian desert soils as soil binders and as modifiers of the seed bed, two very important environmental and economic factors, also deserve more attention than has been given to them in the past.

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SUCCESSION AND SURVIVAL STRATEGIES IN LICHEN POPULATIONS ON A PALM TRUNK

By R. W. ROGERS

Botany Department, University of Queensland, St Lucia 4067, Australia

SUMMARY

(1) Lichen populations on a palm trunk in Brisbane were treated as a chronosequence for which ages could be estimated. The effects of succession and environmental stress on species cover were examined.

(2) Growth rates of five foliose lichens were estimated and, using a morphological index, these species were located in a triangular ordination with the poles representing competitive, stress-tolerating and ruderal survival strategies. Using data from this study and other published sources, the place of lichens in such a triangular ordination in relation to herbaceous plants is examined and lichens are shown to be extreme stress tolerators.

(3) During a twenty-eight year succession the mean strategy of the population shifts from a relatively ruderal to a more competitive nature. This shift occurs more slowly on the more strongly irradiated and therefore drier aspects of the trunk.

INTRODUCTION

Studies on the ecology of lichens have included relatively few accounts of successions or examinations of survival strategies. Many of the studies have been unsophisticated, consisting of little more than lists of species at different locations. Studies in tropical and subtropical environments are particularly limited. Because of their small size and simple architecture, lichens ought to offer significant opportunities for detailed ecological studies, and investigations of ecological theory. This study concerns the succession of lichens on the trunks of palm trees in Brisbane, Australia.

Succession studies

The longevity of the surface of the trunk of *Oreodoxa regalis* H.B.K. (the Royal Palm) allows the observation of a chronosequence from top to bottom of the trunk. This situation is similar to that studied by Yarranton (1972) in which he concluded that the sequence of lichens observed on a *Picea mariana* (P. Mill.) B.S.P. trunk could be interpreted as a succession, and is in contrast to the case of *Juniperus scopulorum* Sarg. in which the flakiness of the bark was the factor determining the lichen flora (Peard 1983). The chronosequence is complicated to some extent by differential shading of the trunk by the canopy during the day. However, during the early morning when the lichens are most likely to be wet and hence photosynthesizing, the canopy does not shade the trunk. A further complication to the chronosequence is that the lower parts of the trunk are likely to benefit from stem flow after rain to a greater extent than the upper parts.

Chronosequence theory assumes that the environment experienced by the organisms is unchanging. In a large city like Brisbane, however, attention must be paid to changes in air quality as SO_2 concentrations are particularly important in lichen ecology (Hawksworth & Rose 1976). Examination of available records for air quality in the Brisbane area (Anonymous 1966–86) shows that SO_2 concentrations in the vicinity of the study area rose from about 30 $\mu g\ m^{-3}$ in the earliest records (1966) to 45 $\mu g\ m^{-3}$ in 1977, and then fell to about 15 $\mu g\ m^{-3}$ in 1983. Similar patterns are evident in fallout of particles, lead, and oxides of nitrogen. The levels of pollution are low, falling within the lowest and second lowest of the ten categories used by Hawksworth & Rose (1976) in their study of lichens in relation to pollution in the British Isles. One factor which may be of importance is the flooding of the area in 1974, during which the trunk studied was submerged for four days, although the lichen flora did not appear to suffer serious damage.

Stress gradients

In the summer, all of the palm trunk is shaded by the crown at midday; consequently, the east and west faces receive the most direct sunlight during the hottest time of the year, but mainly during the relative cool of the morning and afternoon. The southern face, on the other hand, almost completely escapes direct sunlight. It is probable that photosynthesis in the early morning after deposition of dew is significant in the economy of lichens on these trunks and (by analogy with the results of Lange, Schulze & Koch 1970b) that the eastern face which is directly exposed to the drying heat of the sun in the morning will be less suited to lichen growth than the western face. Because the northern face is exposed to more direct solar radiation than the southern face, it might be expected that the southern face will have a greater lichen development than the northern face. A moisture gradient is thus to be expected around the trunk, with more favourable conditions for growth on the south and west, and less favourable conditions on the north and east. This could be shown in total lichen cover, in the species present, in growth rates, and in successional sequences of lichens.

Ecological strategies

Grime (1977) proposed the use of triangular ordinations to display the relative difference in survival strategies between sets of plants. Such ordinations of species with respect to the three primary strategies normally requires estimation of the maximum relative growth rate (R_{max}), and an estimate of competitive ability. Such an analysis has not been presented previously for lichen species, although Topham (1977) has attempted a modification of this for some lichen communities in Great Britain, and Rogers & Barnes (1986) have speculated about the strategies displayed by lichens growing on leaves in Queensland rain forests.

Estimating R_{max} for flowering plants is not a simple matter, although attempts to do so under sets of standard conditions are accepted as reasonable (e.g. Grime & Hunt 1975). Estimating R_{max} for a lichen, however, is fraught with difficulty. While it is reasonable to expose a flowering plant to constant high levels of moisture and nutrients, such conditions result in the death of lichens which require alternating wet and dry periods. It appears that field measurement is the only available method for estimating lichen growth, and that selection of the highest recorded field estimate of relative growth rate for a species (R_{field}) is the nearest approximation to R_{max} available for lichens.

Estimates of R_{field} are clearly flawed, as they are estimated in unstandardized conditions, and use thalli of unknown age and of complex and usually unrecorded history. However, if values for the smallest thalli available are selected and the highest relative growth rate calculated for a species is taken, these problems will be minimized. This method has one advantage: it uses the growth rate of species under conditions in which they can occur naturally, whereas a set of standardized conditions may well be more suited to some species than to others.

Because all the lichens in this study are adnate to the trunk, and all form a complete mat over the substratum, growth of one thallus over another inevitably results in reduced productivity or death of the overgrown individual, a competitive interaction discussed by Armstrong (1982). This allows a direct estimate of competitive ability in terms of the frequency with which one species grows over the other, so blocking it from the light. It is also possible to apply the morphological index proposed by Topham (1977) for lichens, or to modify it to suit the particular group of lichens involved in the present study.

METHODS

A trunk of *Oreodoxa regalis* in the grounds of the University of Queensland (27°30′S, 153°01′E) not closely shaded by any other tree, and with a well developed lichen flora was selected for study. The trunk was 54 cm diameter at breast height, and 360 cm tall. From a 1962 photograph the height of the trunk at that time was determined. Because the palm had reached its mature girth in 1962 it was presumed to be growing linearly and annual height increments were calculated on this basis, allowing the age of the trunk to be estimated at any point.

Lichen growth rates

In order to determine lichen growth rates the trunk was examined along four vertical lines on the cardinal compass points. In a strip 30 cm wide centred on each of these lines, the identity, dimensions and position of each distinguishable foliose lichen thallus was recorded. These data allowed thallus size to be related to estimated age of the trunk at that point. A selection of thalli was carefully measured to allow an estimate of their surface area, removed from the trunk, dried and weighed. A regression relating area to dry weight was developed for each species.

Data concerning the distribution of thalli of various sizes were pooled for 50-cm vertical segments of the trunk, and the largest thallus in each segment noted and its dry weight estimated. Data for thalli at points further down the trunk than that of the maximum thallus size were excluded from further analysis on the grounds that they could not contribute to an estimate of R_{field}. Topham (1977) suggested that lichens show initial exponential growth lasting about ten years. Armstrong (1976) also demonstrated that an exponential function most adequately described lichen growth; relative growth rates were therefore estimated by fitting an exponential curve.

Cover

Lichen cover was estimated from transects parallel to the ground and 20 cm long at 10-cm intervals from the top of the trunk down to ground level. The species of lichen present at 1-mm intervals were recorded. These data were pooled into sets of five transects for analysis, resulting in a single cover estimate for 50-cm intervals on the trunk, each based on the observation of 1000 points.

Competitive ability

The frequency with which one species overtopped another was used as an indication of competitive ability. To determine this a series of transects were run down the trunk of several palms and at each intersection of one thallus with another it was noted which (if any) thallus was overtopping the other; simple abuttment was not considered. In order to find interactions between all species, a number of trees had to be examined. These data were pooled to estimate an index of aggression for each species.

RESULTS

In 1985 the trunk of the palm was 360 cm tall to the base of the leaf sheath while in 1962 it was only 90 cm tall, a mean growth of 11·7 cm per year that was very close to the 10·5 cm apparent growth in the previous year. This correspondence suggested there was no need to seek a more complex relationship between distance from the top of the trunk and age of the surface.

Lichens on the trunk belong to at least twenty-one taxa. Twelve of these taxa arc foliose: *Candelaria concolor* (Dicks.) Stein, *Canoparmelia texanum* (Tuck.) Elix & Johnson, *Dirinaria applanata* (Fee) Awasthi, *D. confluens* (Fr.) Awasthi, *Heterodermia obscurata* (Nyl.) Trevisan, *H. speciosa* (Wulf.) Trevisan, *Hyperphyscia adglutinata* (Floerke) Mayrhofer & Poelt, *Parmotrema austrosinense* (Zahlbr.) Hale, *P. crinitum* (Ach.) Choisy, *P. tinctorum* (Nyl.) Hale, *Pyxine pugens* Zahlbr. and *Pyxine subcinerea* Stirton. Eight crustose taxa were identified: *Candelariella* sp., *Haematomma similis* Bagl., *Lecanora leprosa* Fee, *Lepraria* sp., *Opegrapha* sp., *Pertusaria* sp., *Rinodina dissa* (Stirton) Mayrhofer, ?*Arthonia* sp. One endolignic (i.e. with its thallus immersed in wood) species *Trimmatothele* sp. was identified.

Growth rates

Growth was approximately exponential for the species examined (Table 1). Deviations from exponential growth were greatest for *Hyperphyscia adglutinata* which may have grown more slowly on older parts of the trunk (Table 1), but even in this case r^2 for the regression of maximum thallus size on estimated age is 0·648 ($P<0{\cdot}01$). R_{field} values (Table 1) ranged from $1{\cdot}5\times10^{-3}-10{\cdot}0\times10^{-3}$ g g^{-1} week^{-1} (values are expressed in g g^{-1} week^{-1} to facilitate comparison with Grime 1977).

Cover

Cover values of the various taxa and groups of taxa are shown in Figs 1–3. Lichen cover on the palm trunk ranged up to 93%, this value being reached on the north face of the trunk in the segment 160–200 cm from the top. Cover on the north face, however, consisted mostly of crustose species, especially *Trimmatothele* (Fig. 3). Foliose species are most developed on the southern face, from 160 cm down, and on the east and western face from 210 cm down (Fig. 2). The loosely adnate foliose taxa (*Parmotrema austrosinense*, *P. crinitum* and *Canoparmelia texanum*) were well developed on the south face (Fig. 1), with *Parmotrema austrosinense* the only loosely adnate species sufficiently common to be

TABLE 1. Estimated R_{field} in g g^{-1} week$^{-1}\times10^3$ of some lichens on a palm trunk in Brisbane, Australia, with the coefficient of determination of the regression from which R_{field} was derived ($P<0{\cdot}01$ in each case).

Species	R_{field}	r^2
D. applanata	9·6	0·932
D. confluens	7·7	0·888
H. adglutinata	1·5	0·648
P. austrosinense	10·0	0·798
P. subcinerea	6·1	0·880

mapped (Fig. 2). The closely adnate taxa reached a higher value of cover than the loosely adnate taxa, and were not so much restricted to the south face (Fig. 1). Several species were sufficiently well developed for their cover distribution to be mapped (Fig. 2). The crustose species, however, were relatively poorly developed on the south face (Fig. 3), and the epilignic (i.e. with a thallus on the surface of wood) crustose species had only low cover mostly on the north face. The single epilignic species sufficiently common to be mapped was *Rinodina dissa. Trimmatothele* formed extensive patches on the upper and mid sections of the trunk except on the south side, having a more developed cover on the north face than the east and west.

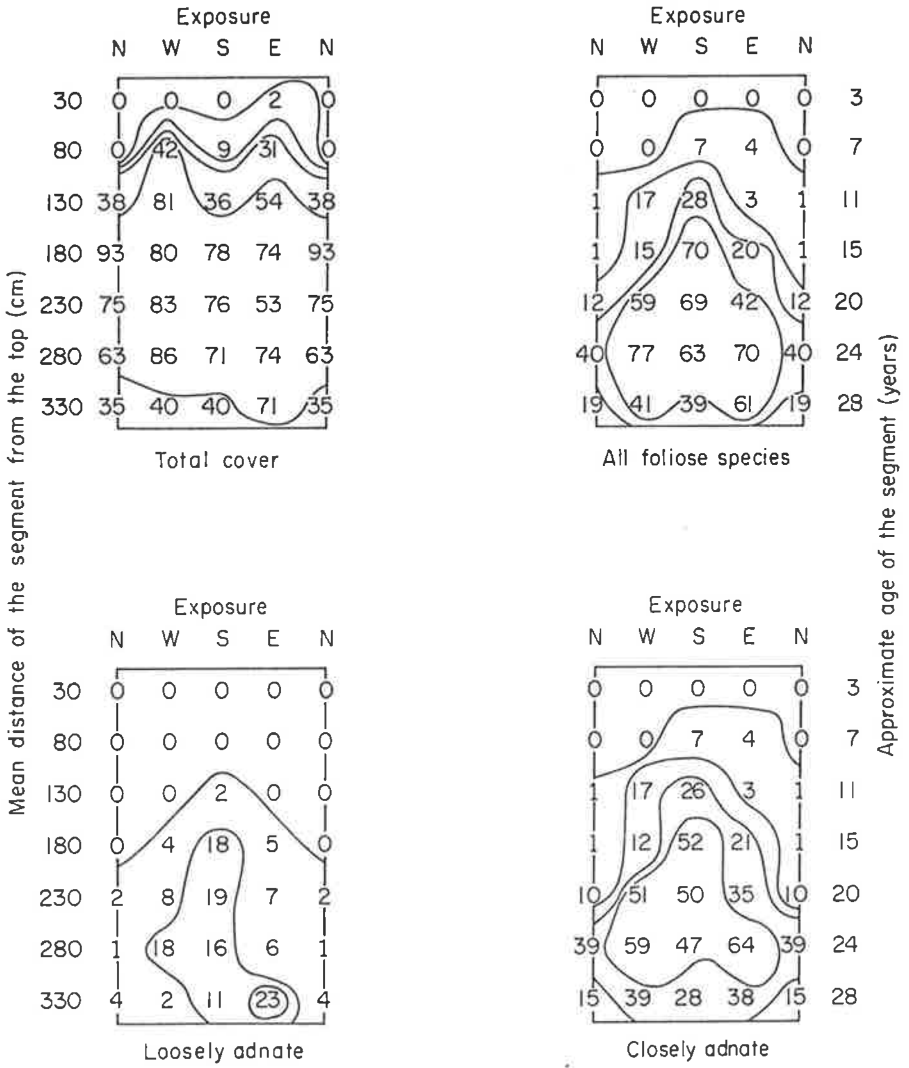

FIG. 1. Maps showing the distribution of cover of all lichen species, of all foliose species, loosely adnate foliose species and closely adnate foliose species on a palm trunk in Brisbane, Australia. To prepare these figures the palm trunk has been treated as a simple cylinder unrolled onto a plane. Mean percentage cover for a set of 1000 points is indicated at the midpoint of the sector studied. There are no anomalous values within the isolines. N,W,S,E, indicate the compass exposure of the trunk.

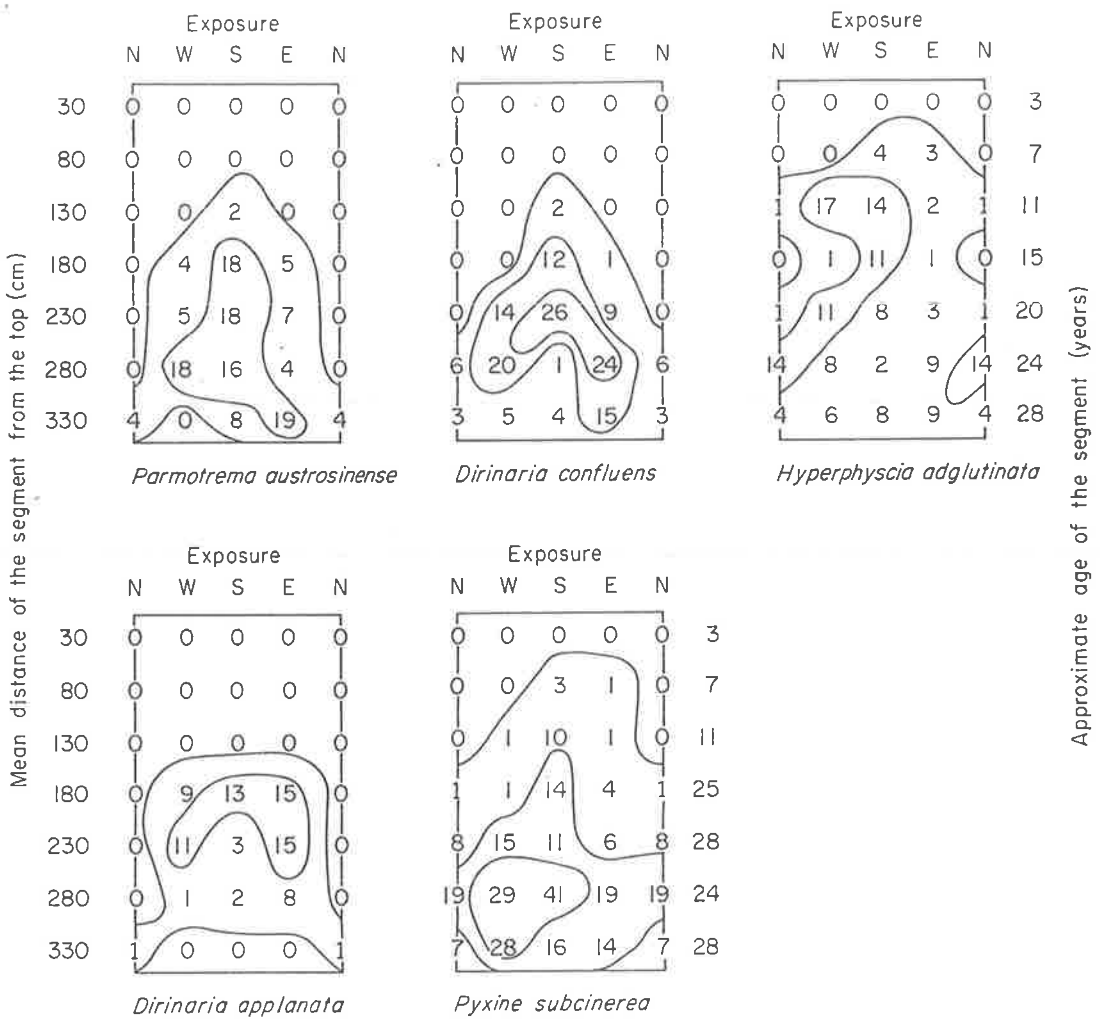

FIG. 2. Maps showing the distribution of cover of the foliose lichen species *Parmotrema austrosinense*, *Dirinaria confluens*, *Hyperphyscia adglutinata*, *Dirinaria applanata* and *Pyxine subcinerea* on a palm trunk in Brisbane, Australia. For detailed explanation see Fig. 1.

Sequence of colonization

Small thalli of *Pyxine subcinerea* and *Hyperphyscia adglutinata* occurred as close as 30 cm from the top of the palm trunk (i.e. a surface about 3 years old), with *Candelaria concolor* appearing just a little below them, except on the east face where no *C. concolor* was found. Somewhat lower on the trunk *Dirinaria applanata, Parmotrema austrosinense, D. confluens* and *Pyxine pungens* appeared on the trunk with *Parmotrema crinitum* and *Canoparmelia texanum* appearing after the other foliose species. In general, the crustose species (except *Trimmatothele*) occurred only low on the trunk. The general order of succession was therefore from the small closely adnate foliose species to the larger but still closely adnate foliose species. The large and loosely adnate foliose species followed with the crutose species appearing last amongst the morphological groups. The one striking exception to this pattern is *Parmotrema austrosinense* which appeared among the closely adnate foliose species.

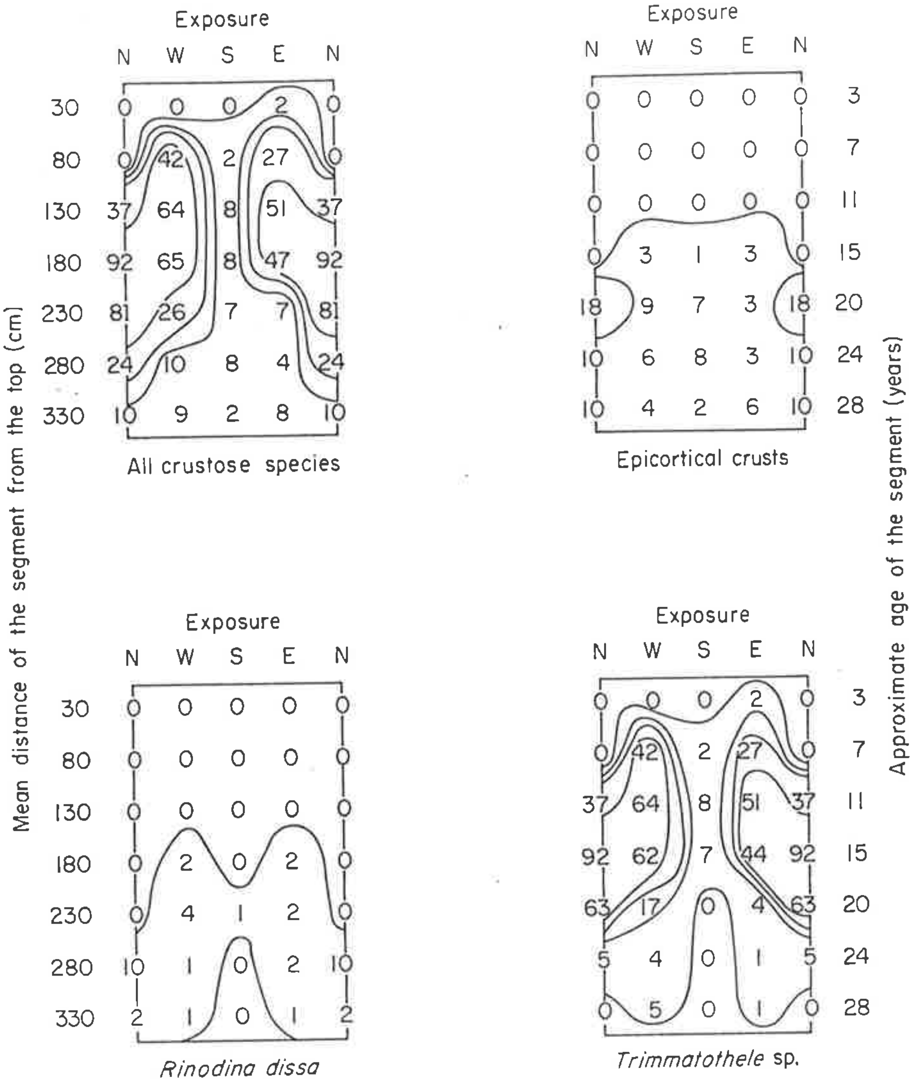

FIG. 3. Maps showing the distribution of cover of all crustose species, all epicortical crusts, and of the crustose species *Rinodina dissa* and *Trimmatothele* sp. on a palm trunk in Brisbane, Australia. For detailed explanation see Fig. 1.

Population structure

Different species showed different patterns of colonization and different thallus size distributions (Figs 4–8). *Dirinaria applanata* populations were best developed on the west and east faces, with the largest populations found on the segment of the trunk with a mean age of twenty years, after which populations fell rapidly. *Dirinaria confluens* showed an essentially similar pattern.

Parmotrema austrosinense reached its maximum population size on the segments with mean ages of 20–24 years, with the largest populations on the western face. *Pyxine subcinerea* formed large populations on all faces, reaching maxima on segments seven years old on the south face, eleven years on the west face, twenty years on the north face, and a dual peak at eleven and twenty years on the east face.

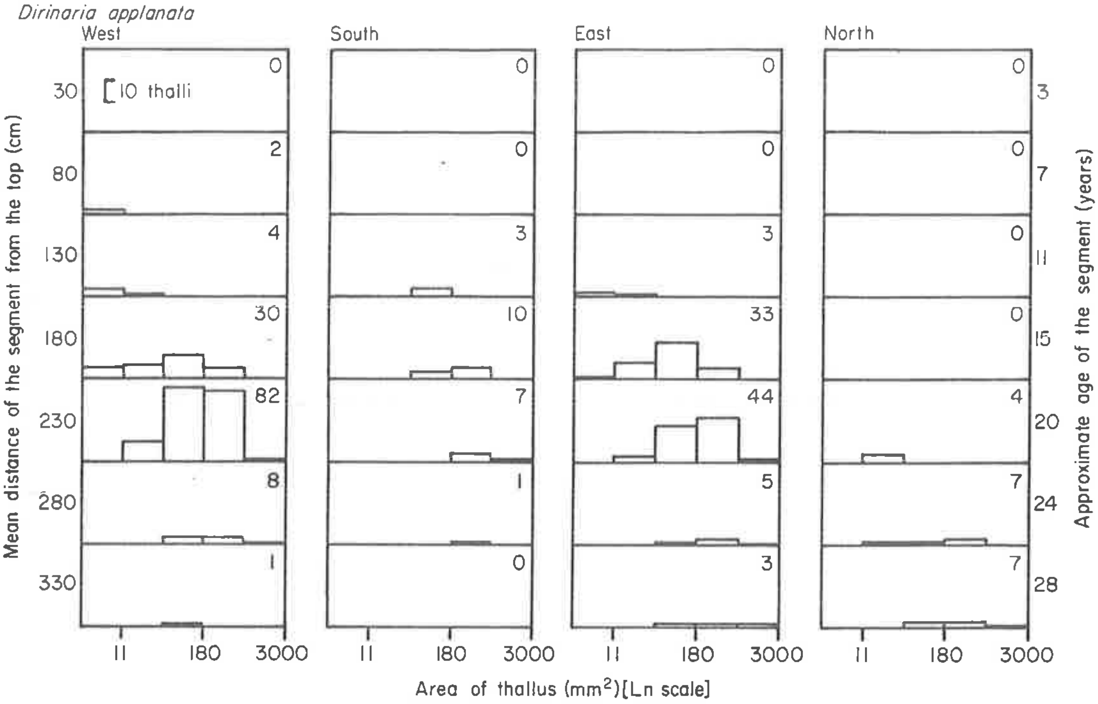

FIG. 4. Histograms showing the frequency with which *Dirinaria applanata* thalli of the indicated size-classes occur on segments on a palm trunk 75 cm long in a transect 30 cm wide placed along the cardinal compass points. Size of thallus is in mm^2 (note the logarithmic scale). A scale bar representing ten occurrences is incorporated in the histograms for the western aspect. The figure in each compartment indicates the total population on that segment. Mean distance (cm) of the segment from the apex is indicated on the left, and approximate age (years) of the segment on the right.

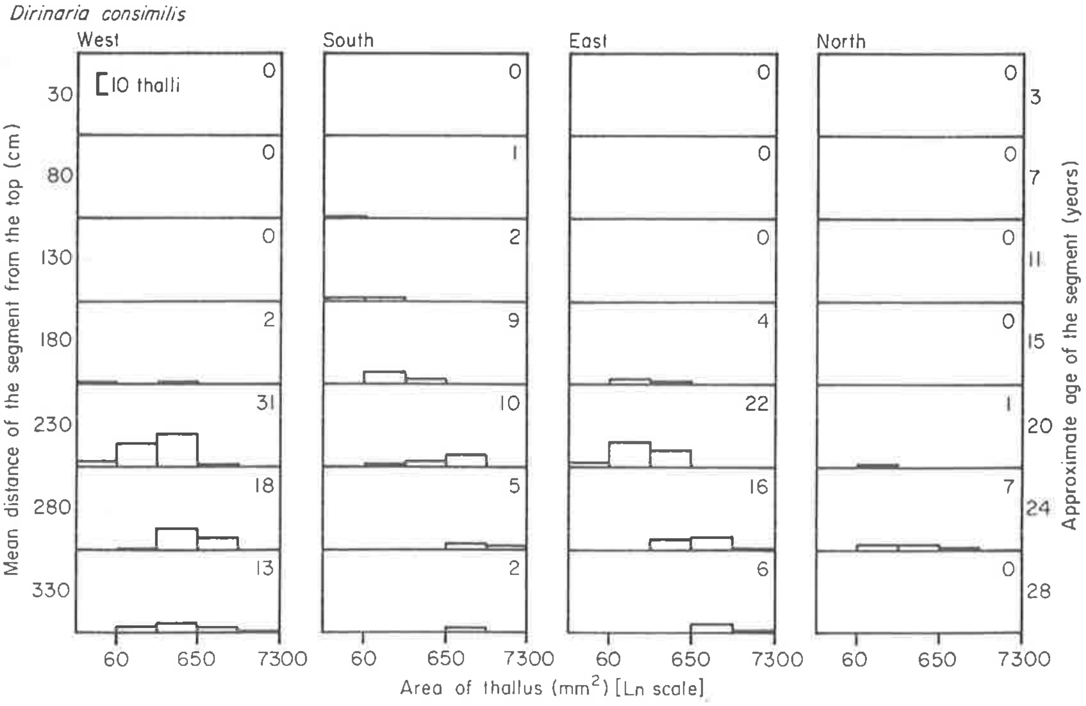

FIG. 5. Histograms showing the frequency with which *Dirinaria consimilis* thalli of the indicated size-classes occur on segments of a palm trunk 75 cm long in a transect 30 cm wide placed along the cardinal compass points. For detailed explanation see Fig. 4.

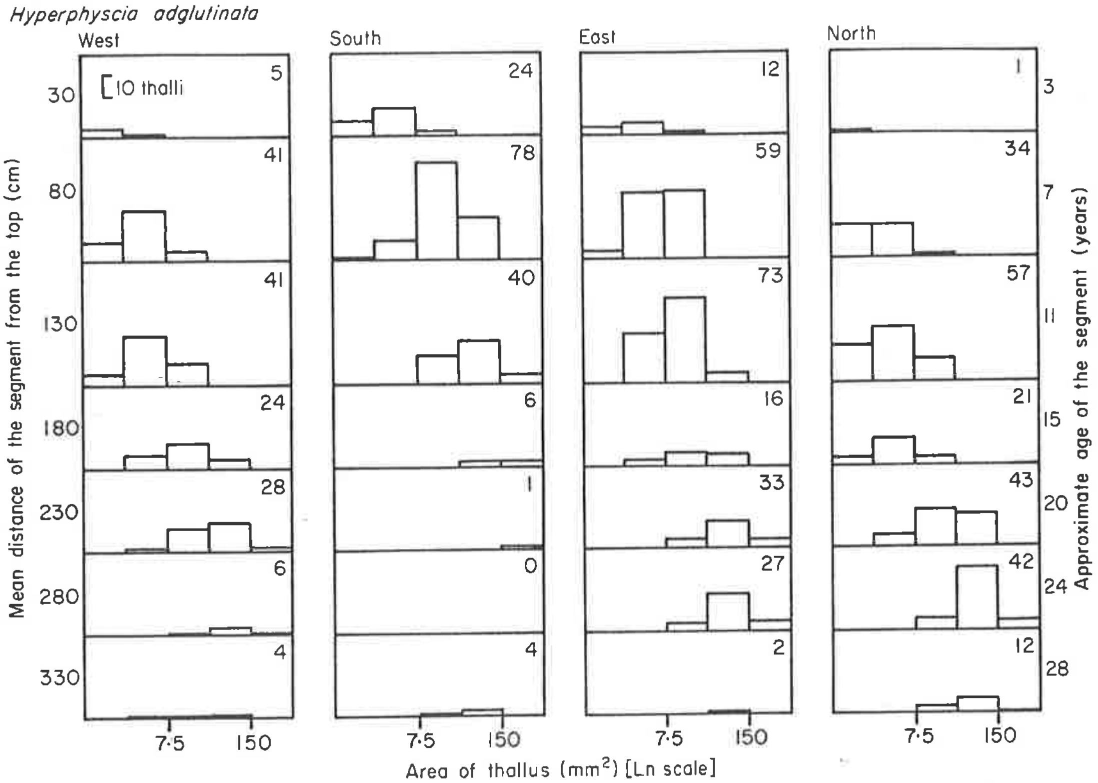

FIG. 6. Histograms showing the frequency with which *Hyperphyscia adglutinata* thalli of the indicated size-classes occur on segments of a palm trunk 75 cm long in a transect 30 cm wide placed along the cardinal compass points. For detailed explanation see Fig. 4.

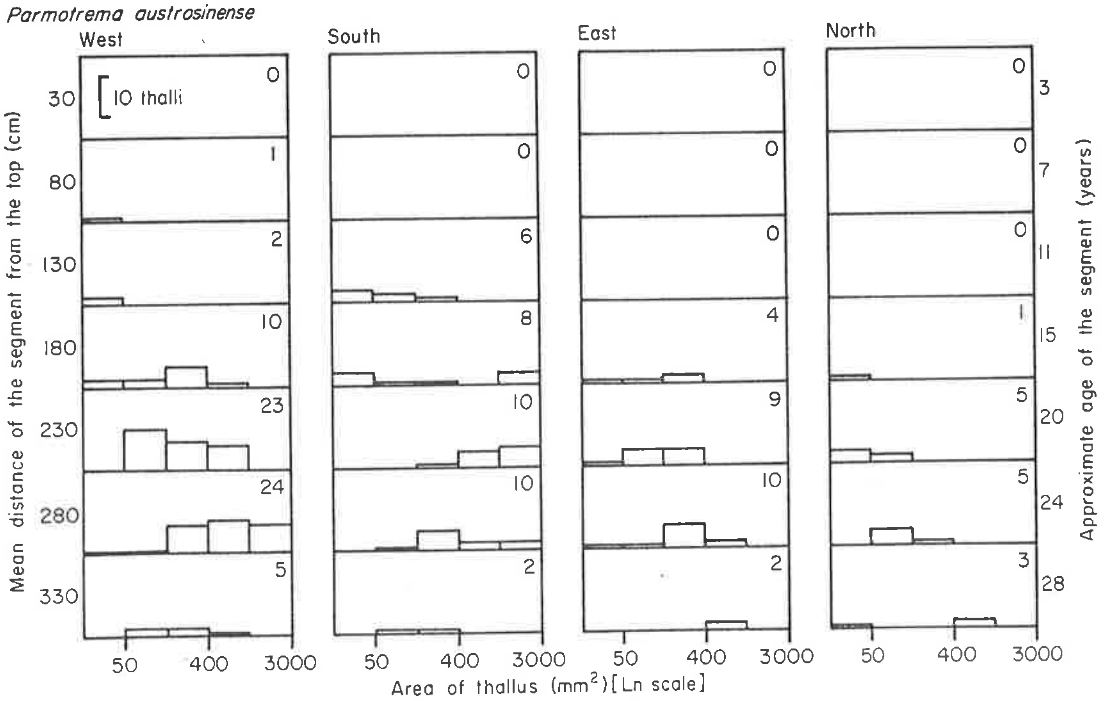

FIG. 7. Histograms showing the frequency with which *Parmotrema austrosinense* thalli of the indicated size-classes occur on segments of a palm trunk 75 cm long in a transect 30 cm wide placed along the cardinal compass points. For detailed explanation see Fig. 4.

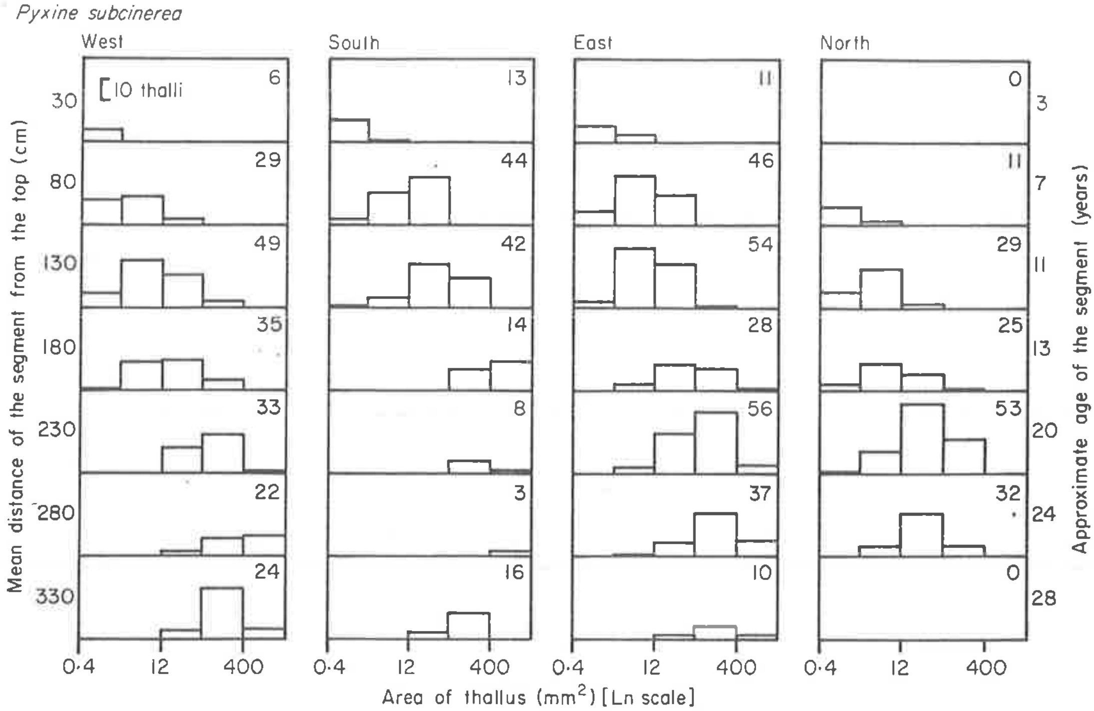

FIG. 8. Histograms showing the frequency with which *Pyxine subcinerea* thalli of the indicated size-classes occur on segments of a palm trunk 75 cm long in a transect 30 cm wide placed along the cardinal compass points. For detailed explanation see Fig. 4.

Hyperphyscia adglutinata reached its maximum population on the segment seven years old on the south face, seven and eleven years on the west face, eleven years on the east face, and eleven and twenty years on the north face. On all faces there is a marked population decline between the eleven and fifteen years-old segments, with an increase on the twenty years old segment on all faces except the south. This pattern was also evident to some extent for *Pyxine subcinerea.*

TABLE 2. Competitive ability defined in terms of overgrowth of thalli. Index of aggression is the proportion of all interactions in which the species indicated in the heading overtops others. The figures in the body of the table show the proportion of interactions in which a species indicated in the heading of the table overtops the one indicated in the margin. Pc = *Parmotrema crinititum.*

Species	Pc	Pa	Ct	Pb	Hs	Dc	Da	Ps	Ca	Ha	Rd	Ll	Ar
Index of aggression	0·89	0·88	0·88	0·78	0·70	0·58	0·47	0·41	0·15	0·10	0·02	0	0
Parmotrema austrosinense	0·50												
Canoparmelia texanum	0·50	0·71											
Pyxine berteriana	1·0	1·0	—										
Heterodermia speciosa	0·66	0·66	0·71	0·44									
Dirinaria confluens	1·0	0·89	0·86	0·66	1·0								
Dirinaria applanata	0·80	0·88	1·0	0·83	1·0	0·80							
Pyxine subcinerea	1·0	1·0	1·0	1·0	1·0	0·66	0·69						
Candelaria sp.	1·0	1·0	1·0	1·0	1·0	1·0	1·0	0·75					
Hyperphyscia adglutinata	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0				
Rinodina dissa	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	—	1·0			
Lecanora leprosa	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	—	1·0	1·0		
Arthonia sp.	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0	—	

There were apparent systematic shifts in thallus size down the trunk, progressively larger thalli dominating the older segments, and small thalli becoming quite rare.

Competitive ability

There were clear differences in the competitive ability of the species (Table 2). When the species are arranged in descending order of overall aggressivity there is generally a simple relationship in which species with a higher index of aggression overgrow all those with a lower index.

DISCUSSION

Population structure

Lichen colonization of the palm trunk takes place over an extended period for each species, and the populations then grow at differing rates, producing a more or less normal population distribution in terms of thallus size. The general absence of small thalli near the base of the trunk indicates a failure of later colonization.

The substantial fall in the number of thalli shown on some segments of the trunk by most species may be due to competitive interactions, or may reflect a finite life span for the species concerned. There was some evidence in the field for both of these explanations. *Hyperphyscia adglutinata* and *Pyxine subcinerea*, for example, were commonly overgrown by other species. *Dirinaria* and *Pyxine* species were found to become more convoluted and less firmly attached as the thallus grew larger, and on occasions it was clear that a large part of a *Dirinaria* thallus had fallen off, leaving a clear area behind. The resurgence of *Hyperphyscia adglutinata* and *Pyxine subcinerea* populations on the lower parts of the trunk may be related to the spaces left empty in this way.

The apparent bimodality of population sizes at lower points on the trunk in both *Pyxine subcinerea* and *Hyperphyscia adglutinata* can be dated to a section of trunk formed about 1970, a segment which would have been colonized by large numbers of very small thalli of these species in 1974 when a major flood inundated the area for several days. It seems likely that this flood killed many young thalli of these species and, from the distribution of thallus sizes, that there was little further opportunity for recolonization.

The low populations generally found on the bottom 50 cm of the trunk may be related to environmental peculiarities including gardening practices in the University and the effect of dog urine.

Nature of the succession

The pattern of species changes down the trunk (Fig. 9) more closely resembles the classic seral ('Clementsian') model of succession than the other models proposed (e.g. by Noble & Slatyer 1981). This is in contrast to the gradual competitive exclusion of species from the initial flora which Conran & Rogers (1983) observed in a succession of lichens on long-lived rainforest leaves.

It appears that lichen colonization begins after a period during which the trunk is weathered, making sites suited to colonization available. Lichens, however, produce secondary substances which can change the chemistry of their substratum, and repeated wetting and drying of thalli firmly fixed to the substratum produces changes in its physical fabric (Brightman & Seaward 1977; Syers & Iskandar 1973). The succession is, therefore, probably the result at least in part of facilitation by the first colonizers which weather and leach the palm trunk making suitable microsites for further lichen establishment. Just as

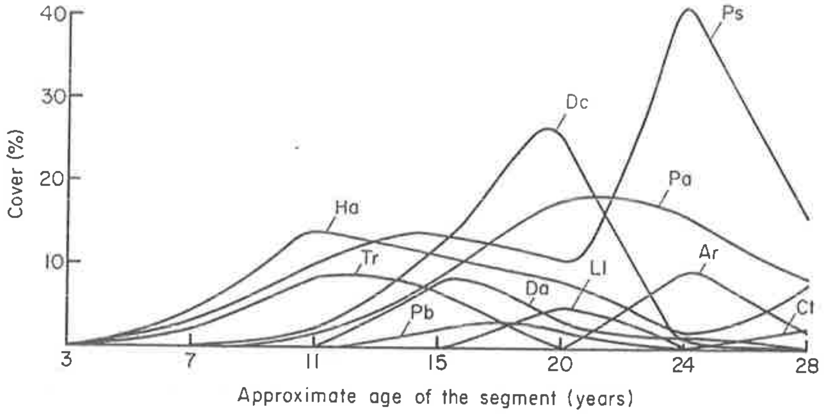

FIG. 9. Change in cover of the more common species of lichens on the south face of a palm trunk in Brisbane, Australia. This illustrates the apparently seral nature of the succession, with species appearing and disappearing over a period. Symbols: Ar, *Arthonia* sp.; Ct, *Canoparmelia texana*; Da, *Dirinaria applanata*; Dc, *D. complanata*; Ha, *Hyperphyscia adglutinata*; Ll, *Lecanora leprosa*; Pa, *Parmotrema austosinense*; Pp, *Pyxine pungens*; Ps, *P. subcinerea*; Tr, *Trimatothele* sp.

Finegan (1984) argued that, in forests, facilitation (which does not imply determinism) needed to be maintained as a mechanism for successional development along with tolerance, inhibition and allogenesis, so the same range of mechanisms, including facilitation, influences lichen succession.

Growth rates

Values of R_{field} for a number of lichen species have been estimated from literature reports. Regressions relating relative growth rate (RGR) to thallus size for *Caloplaca aurantia* reported by Farrar (1974) were projected back to a thallus size of 0·1 cm^2, and RGR at that thallus size treated as R_{field}. The highest RGR reported for *Phaeophyscia orbicularis*, *Parmelia glabratula* var. *fuliginosa*, *P. saxatilis* and *Xanthoparmelia conspersa* by Armstrong (1973), and of *Lobaria oregana* by Rhoades (1977), all measured on small thalli, have also been treated as R_{field}. Data of Brodo (1965) for *Melanelia sulcata*, *Flavoparmelia caperata* and *Lecanora caesiorubella* were recalculated assuming that the mean thallus size in his smallest size class was 2-cm diameter, and the RGR, estimated on that basis, treated as R_{field}. Lange, Schulze & Koch (1970a) have estimated a daily production, following dewfall, for the desert fruticose lichen *Ramalina maciformis*, which can be considered a low estimate of R_{field}. Data from Karenlampi (1971) dealing with the growth rates of 2-cm long tips of *Cladina alpestris*, *Stereocaulon paschale* and *Cetraria nivalis* grown under conditions of 3·5 mm rainfall per day have also been treated as estimates of R_{field}. Data of Burrows & Orwin (1971) for the period 1950–60 were used to calculate R_{field} for small thalli of *Rhizocarpon tinei* in New Zealand. These values for R_{field} are presented in Table 3. The R_{field} estimates for the species on palm trunks in the tropical climate of Brisbane (Table 1) are similar to those estimated from other environments (Table 3).

Strategies

An attempted triangular ordination using the axes developed by Topham (1977) proved unworkable, as there was no clear relationship demonstrable between propagule

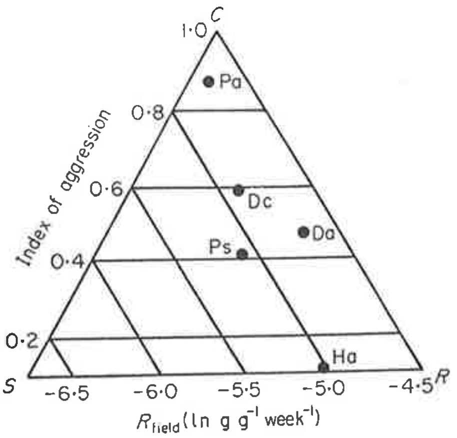

FIG. 10. Triangular ordination of foliose lichen species on a palm trunk in Brisbane, Australia, using R_{field} and index of aggression as axes to demonstrate ecological strategies. Symbols: Da, *Dirinaria applanata*; Dc, *D. complanata*; Ha, *Hyperphyscia adglutinata*; Pa, *Parmotrema australiense*; Ps, *Pyxine subcinerea*.

size and strategy. This relationship is clearly a complex one, not satisfactorily reduced to a single factor (Grime 1979, p. 112).

Figure 10 is the ordination resulting from the use of R_{field} as one axis and index of aggression as the other. Use of a morphological index in which thalli were classified on the basis of thallus size instead of index of aggression resulted in a similar relationship (Fig. 11), and allowed incorporation of data from other studies (Fig. 12).

Figures 10 and 11 show that the foliose lichens found on the palms scatter between the ruderal and competitive poles of the ordination. When the range of lichens treated in Table 3 is considered it is apparent that the lichens on the palms in Brisbane have modest growth rates, although even the slowest growing species, *Hyperphyscia adglutinata*, has a higher growth rate than many of those reported. While Table 3 suggests that growth rates of lichens tend to descend in the order fruticose > foliose > crustose, there are clear exceptions to this.

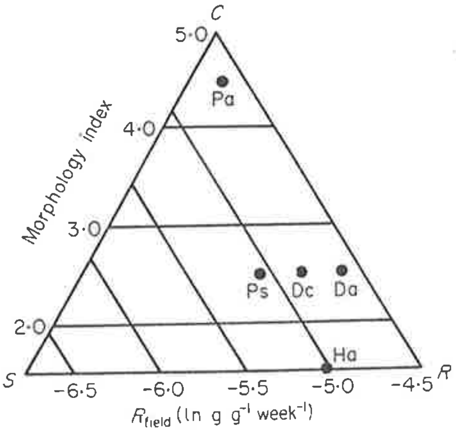

FIG. 11. Triangular ordination of foliose lichen species on a palm trunk in Brisbane, Australia, using R_{field} and a morphology index, M, as axes to demonstrate ecological strategies where $M = T + D/2$. T = thallus thickness (height): < 0·5 mm = 1; 0·5–1 mm = 2; 1·1–2·5 mm = 3; 2·6–10 mm = 4; > 10 mm = 5. D = thallus diameter: < 2 cm = 1; 2–5 cm = 2; 5·1–10 cm = 3; 10·1–25 cm = 4; > 25 cm = 5. Key to species as Fig. 10.

TABLE 3. Estimated R_{field} (g g^{-1} $week^{-1} \times 10^3$) of some lichens.

Species	Source	R_{field}	Thallus	Habitat
Cladina alpestris (L) Nyl.	5	45·0	Fruticose	Subarctic
Stereocaulon paschale (L) Fr.	5	42·0	Fruticose	Subarctic
Cetraria nivalis (L) Ach.	5	42·0	Fruticose	Subarctic
Rhizocarpon tinei (Tornab.) Runem.	6	15·0	Crustose	Cool temperate
Xanthoparmelia conspersa (Ach.) Hale	1	9·2	Foliose	Cool temperate
Phaeophyscia orbicularis (Neck.) Moberg	1	6·1	Foliose	Cool temperate
Parmelia glabratula ssp *fuliginosa* (Fr. ex Duby) Laundon	1	5·4	Foliose	Cool temperate
Melanelia sulcata (Tayl.) Essl.	2	4·5	Foliose	Cool temperate
Parmelia saxatilis (L) Ach.	1	4·4	Foliose	Cool temperate
Flavoparmelia caperata (L) Hale	2	4·4	Foliose	Cool temperate
Caloplaca aurantia (Pers.) Hellb.	3	4·0	Crustose	Hot desert
Ramalina maciformis (Del.) Bory	4	2·8	Fruticose	Hot desert
Lecanora caesiorubella Ach.	2	0·8	Crustose	Cool temperate

Sources: 1, Armstrong (1973); 2, Brodo (1965); 3, Farrar (1974); 4, Lange, Shulze & Koch (1970a, b); 5, Karenlampi (1971); 6, Burrows & Orwin (1971).

Because a strategic ordination is relative rather than absolute in its basis, many data are needed for meaningful comparison of strategies of different species. From the literature it is possible to estimate a morphology index for all of the species listed in Table 3, and to prepare a triangular ordination for a range of lichen growth forms from a range of environments. This is presented in Fig. 12. In this ordination *Parmotrema austrosinense* is clearly a competitive lichen, falling just outside the triangle, near its competitive apex. It is likely that the measurements made on the palms in Brisbane include longer unfavourable periods than were experienced by the other clearly competitive species, the studies of Karenlampi (1971) in particular being restricted to the summer growing period. Compensation for this would tend to bring *Parmotrema austrosinense* back into the

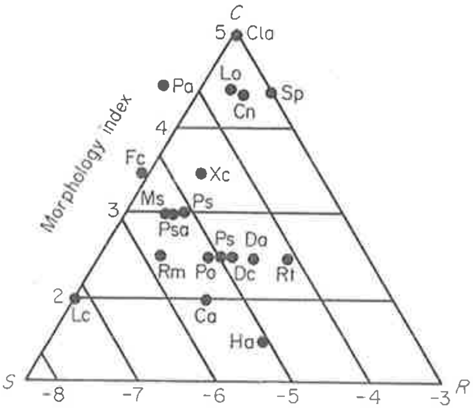

FIG. 12. Triangular ordination of lichens from various habitats using R_{field} and a morphological index as axes. R_{field} data are from Tables 1 and 2. The morphological index is as for Fig. 11. Symbols: Ca, *Caloplaca aurantia*; Cla, *Cladina alpestris*; Cn, *Cetraria nivalis*; Da, *Dirinaria applanata*; Dc, *Dirinaria complanata*; Fc, *Flavoparmelia caperata*; Ha, *Hyperphyscia adglutinata*; Lc, *Lecanora caesiorubella*; Lo, *Lobaria oregana*; Ms, *Melanelia sulcata*; Pg, *Parmelia glabratula* var. *fuliginosa*; Psa, *Parmelia saxatilis*; Pa, *Parmotrema austrosinense*; Po, *Phaeophyscia orbicularis*; Ps, *Pyxine subcinerea*; Rm, *Ramalina maciformis*; Rt, *Rhizocarpon tinei*; Sp, *Stereocaulon paschale*; Xc, *Xanthoparmelia conspersa*.

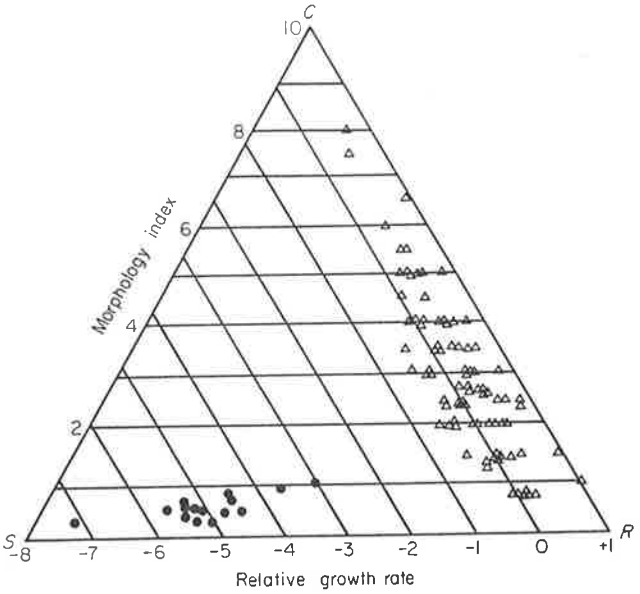

FIG. 13. Triangular ordination of herbaceous plants (from Grime 1979) and lichens (from Table 2). The morphology index is that of Grime (1977) except that for lichens a maximum index of 0·1 has been assumed, and the morphology index in Table 2 rescaled on a 0–0·1 basis. Relative growth rate is R_{field} (●) for lichens, and R_{max} (△) for herbs.

triangle. *Dirinaria applanata*, *Dirinaria complanata* and *Pyxine subcinerea* are apparently competitive stress-tolerant ruderal lichens (*sensu* Grime 1979). *Hyperphyscia adglutinata* can be considered a stress-tolerant ruderal.

To set lichens in a context amongst other photosynthetic organisms, the data of Grime (1979, p. 74) have been rescaled and lichens incorporated (Fig. 13). R_{max} and R_{field} have been treated as if identical, and the morphology index has been derived on the basis that a large fruticose or foliose soil surface lichen (e.g. *Cladina* spp., *Cladonia* spp., *Peltigera* spp.) have similar size and habit to small flowering plants, making a maximum morphology index for a lichen of 0·1 on Grime's scale appropriate. Figure 13 shows that lichens are extreme stress tolerators as suggested by Grime (1977), but are separated from herbaceous angiosperms by a very large gap. R_{field} values used for lichens are not identical with R_{max} for the herbaceous plants, but even if the growth rate of lichens is a tenfold underestimate, their growth rate is less than that for the herbs.

Differences in survival strategy with time and stress

In order to examine the change in strategy of the lichens making up the community during succession and on faces of the palm subject to differences in moisture availability, ln mean R_{field} and a mean morphology index were calculated for successive 50-cm vertical segments on each aspect of the trunk, using values from Table 1 and weighting the contribution of each species according to the proportion of the total cover it provided in that segment of the trunk. For these calculations it was assumed that all crustose species had a value of ln R_{field} of $-5{\cdot}52$ (the same as that of *Caloplaca aurantia*, Table 2), the median value reported for a crustose lichen. A morphology index (cf. Fig. 11) of 1·0 was applied for the endolignic species, and 1·5 for the epilignic species. Figures 13 and 14 present the outcome of these calculations in the form of triangular ordinations for each face of the palm and for all faces at differing ages.

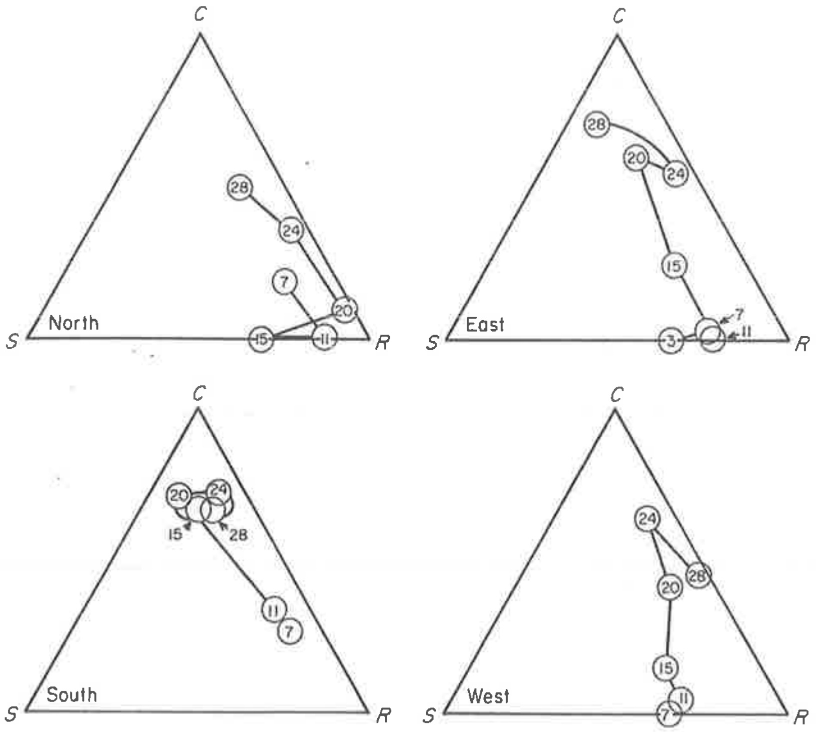

FIG. 14. Triangular ordination of lichen populations on different aspects of a palm trunk showing changes during succession on each face. Approximate age of populations is indicated in years.

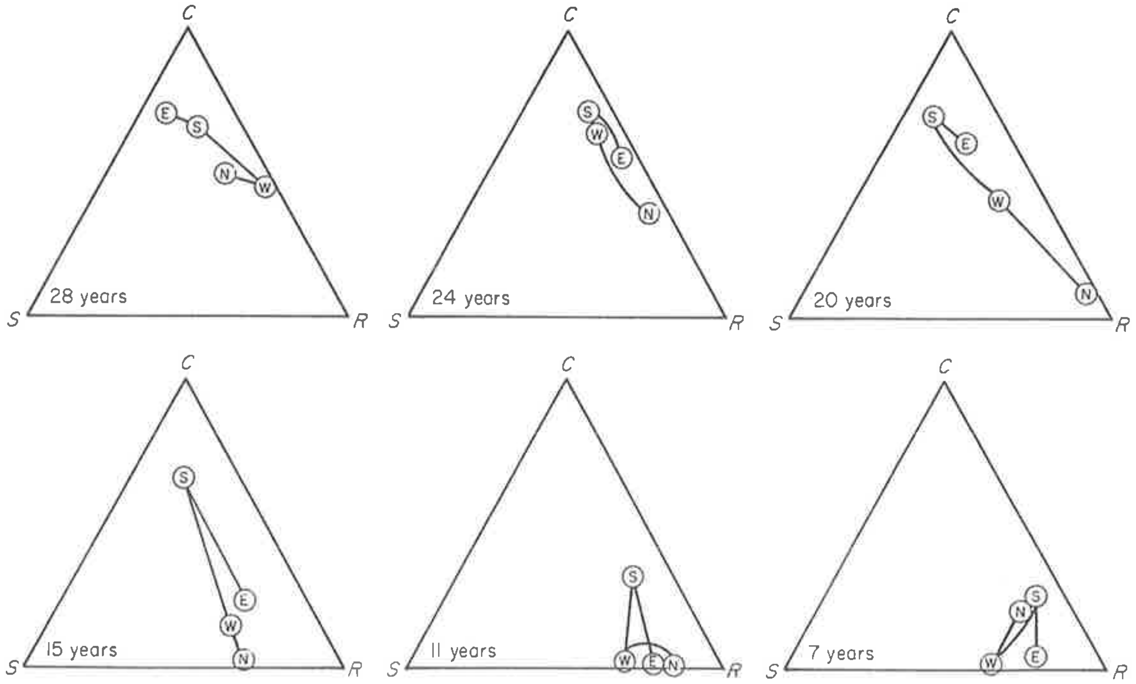

FIG. 15. Triangular ordination of lichen populations on a palm trunk at different ages showing differences between aspects at the same age.

In general terms, succession moves from the ruderal towards the competitive pole. Succession progresses most rapidly on the relatively wetter south face for 15 years (Fig. 15), after which time the east and west faces catch up, followed eventually by the north face. The older parts of the trunk have a substantially more competitive flora on the south and east faces than on the north and west. These trends are consistent with the data of Topham (1977), and follow the pattern of succession postulated by Grime (1979). Because lichens gain their nutrients from the rain and from the air (which can be treated as renewable resources for this purpose), there seems little reason to expect that the nature of the population will tend to move substantially towards a more stress-tolerant composition. Such a move was postulated by Grime for plants exploiting the non-renewable nutrient resources of the soil.

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Lichen Succession on Leaves of *Wilkiea macrophylla* in Southeast Queensland

J. G. Conran and R. W. Rogers
Botany Department, University of Queensland, St. Lucia, Queensland 4067, Australia

Abstract. *The leaves of* Wilkiea macrophylla *provide an environment on which succession in foliicolous lichen species can occur. The pioneer species are* Tricharia albostrigosa *and* Sporopodium xantholeucum *which appear to grow best as isolated thalli. These are gradually replaced by spreading species such as* Porina epiphylla, Porina impressa, *and by discrete but apparently competition-resistant species such as* Mazosia melanophthalma. *Where leaf damage has occurred,* Strigula subtilissima *and* Strigula complanata *are present around the wound margins.* Tricharia albostrigosa *and* Strigula complanata *are new records for Australia.*

Foliicolous lichens are those lichens that grow epiphytically on leaves, generally on upper surfaces. Most are microlichens, although some foliose species are known. Supracuticular taxa are most abundant, however subcuticular species have been reported, associated with damage to the leaf cuticle (Santesson 1952).

Foliicolous lichens are taxonomically diverse, and can also occur on varied substrates. They are found in a wide range of humid habitats, and are especially well developed in tropical and subtropical regions. Obligately foliicolous species were monographed by Santesson (1952) and this work was an essential resource for the identification of the taxa observed. Much of the Australian material in that work was collected by DuRietz in 1927. While some work (Filson 1965) exists on the taxonomy of Australian foliicolous lichens, there are no currently published accounts of their successional ecology.

Wilkiea macrophylla (A. Cunn.) A. DC. is a shrub or small tree common in the understory of rainforests in southeastern Queensland. The leaves of this shrub are large (10 × 4 cm), and opposite, and appear to persist for four growing seasons. Successive growth segments, separated by bud scars, commonly have two pairs of leaves. Thus leaf pairs along *Wilkiea* stems represent an age sequence. A characteristic leaf is illustrated in Fig. 1.

METHODS

Collections of over 200 *Wilkiea macrophylla* leaves with lichens growing on them were collected from rainforests at Mt. Glorious (27°19′S, 152°56′E); Imbil (26°28′S, 152°39′E); Jimna (26°42′S, 152°25′E) and Lamington Plateau (28°13′S, 153°08′E). The leaves were examined under a dissecting microscope and the lichens identified using the accounts in Santesson (1952) and Rogers (1981). Sterile thalli were determined by comparison with fertile specimens found either on other host species, or, if no fertile material was available, by comparison with the descriptions and illustrations of Santesson.

The lichen floras on leaves of increasing age along stems were examined in situ on plants growing near O'Reilley's Guest House, Lamington Plateau. Leaf pairs were numbered sequentially from the apex of the branch, and leaf scars were counted so that leaves distal to the leaf scar were numbered as if a leaf had been present. Fifty stems (bearing a total of 577 leaves, excluding scars) were examined in this way, and the lichens present recorded.

The occurrence of each species at each leaf pair position was recorded, and species frequency calculated. The weighted percentage of occurrence for each species at each leaf pair position was then

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calculated by standardizing the species frequency data to allow for variation in the number of leaves at each leaf pair position (age class number) using the following formula:

$$\text{Weighted \% lichen occurrence} = \frac{\text{\% lichen occurrence at age class number}}{\text{total number of leaves at that age class number}}$$

Hence, in terms of the original measurements, the weighted percentage lichen occurrence could be calculated directly as:

$$W_{xi} = \frac{100N_{xi}}{T_i \cdot T_x}$$

W_{xi} = weighted percentage lichen occurrence for species x at age class number i.
N_{xi} = number of occurrences of species x at age class number i.
T_i = total number of leaves at position i.
T_x = total occurrence of species x.

Results

Nine species of foliicolous lichens were identified in this study, and, of these, eight were found to be so readily distinguishable in the field as to allow immediate ecological study. A further four species reported from leaves of *W. macrophylla* at various localities in southeast Queensland (Santesson 1952) were not found in this study, but were included in the following key to foliicolous lichens known from *W. macrophylla* in this region.

Key to Foliicolous Lichens on *Wilkiea macrophylla* in Southeastern Queensland

1. Thallus subcuticular 2
1. Thallus supracuticular 4
  2. Spores 3-septate ..... *Strigula complanata* (Fée) Mont.
  2. Spores 1-septate 3
3. Thallus with a distinct black border ..... *Strigula subtilissima* (Fée) Müll. Arg.
3. Thallus without a distinct black border ..... *Strigula elegans* (Fée) Müll. Arg.
  4. Fruiting body a perithecium 5
  4. Fruiting body not a perithecium 8
5. Base of perithecium markedly constricted ..... *Porina semicarpi* Vain.
5. Base of perithecium spreading 6
  6. Spores 1-septate ..... *Porina obducta* (Müll. Arg.) Schilling
  6. Spores more than 1-septate 7
7. Spores 7-septate ..... *Porina epiphylla* (Fée) Fée
7. Spores 3-septate ..... *Porina impressa* R. Sant.
  8. Apothecia immersed in the thallus 9
  8. Apothecia sessile, constricted at the base 11
9. Thallus smooth ..... *Mazosia phyllosema* (Nyl.) A. Zahlbr.
9. Thallus verrucose 10
  10. Spores muriform ..... *Gyalectidium filicinum* Müll. Arg.
  10. Spores transversely septate only ..... *Mazosia melanophthalma* (Müll. Arg.) R. Sant.
11. Thallus with prominent white hairs ..... *Tricharia albostrigosa* R. Sant.
11. Thallus without hairs 12
  12. Margins of apothecia prominent, thick, white ..... *Sporopodium xantholeucum* (Müll. Arg.) A. Zahlbr.
  12. Margins of apothecia not prominent, thin, yellow ..... *Sporopodium phyllocharis* (Mont.) A. Massal. var. *flavescens* R. Sant.

Of those species present at the study sites, *Tricharia albostrigosa* and *Strigula complanata* are new records for Australia. Although it was found in the course of the study, *Gyalectidium filicinum* was difficult to identify reliably in the field, and was not used in the succession studies. The number of taxa present at each leaf pair shows an increase in

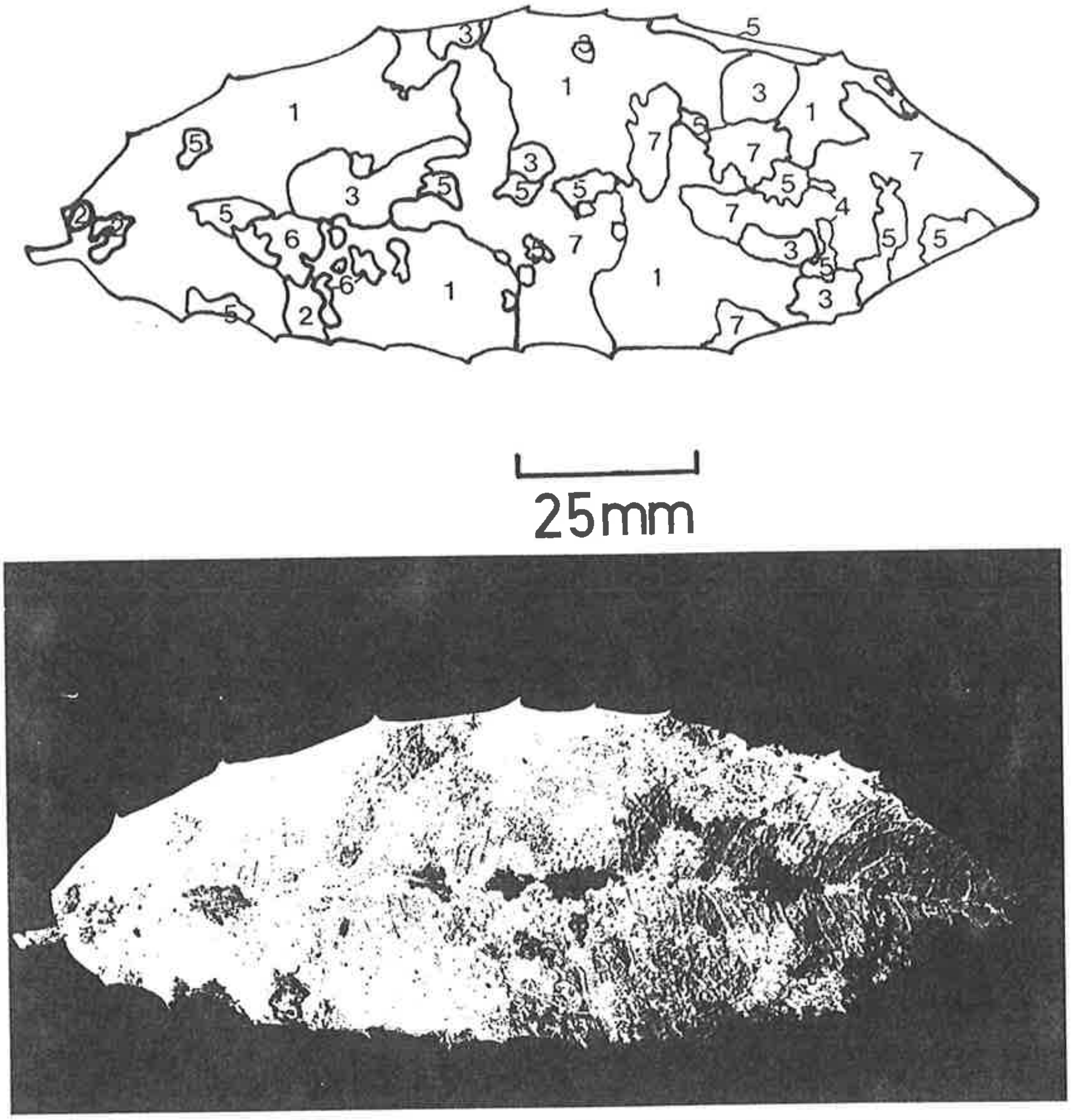

FIGURE 1. Lichens on a leaf of *Wilkiea macrophylla*. 1. *Porina epiphylla*. 2. *Strigula complanata*. 3. *Mazosia melanophthalma*. 4. *Strigula subtilissima*. 5. Fungal fruiting body commonly associated with *Strigula*. 6. *Gyalectidium filicinum*. 7. Unlichenised leaf surface.

species diversity up to the third leaf pair from the branch apex, then all species are present until the eighth leaf pair (Fig. 2A) where *Sporopodium phyllocharis* var. *flavescens* is absent. Past the eighth leaf pair succession was terminated by leaf abscission.

The weighted percentage occurrence for each species at each leaf position shows a number of patterns (Fig. 2B). *Sporopodium xantholeucum* and *Tricharia albostrigosa* show an early increase but then decline in frequency prior to leaf abscision. *Porina epiphylla*, *Mazosia phyllosema* and *M. melanophthalma* all show increasing frequency with leaf age, however, the rate of increase starts to level off by leaf position five. *Strigula subtilissima* and *S. complanata* both appeared later than the other species and were still increasing in frequency at the eighth leaf position. *Sporopodium phyllocharis* var. *flavescens* was a rare

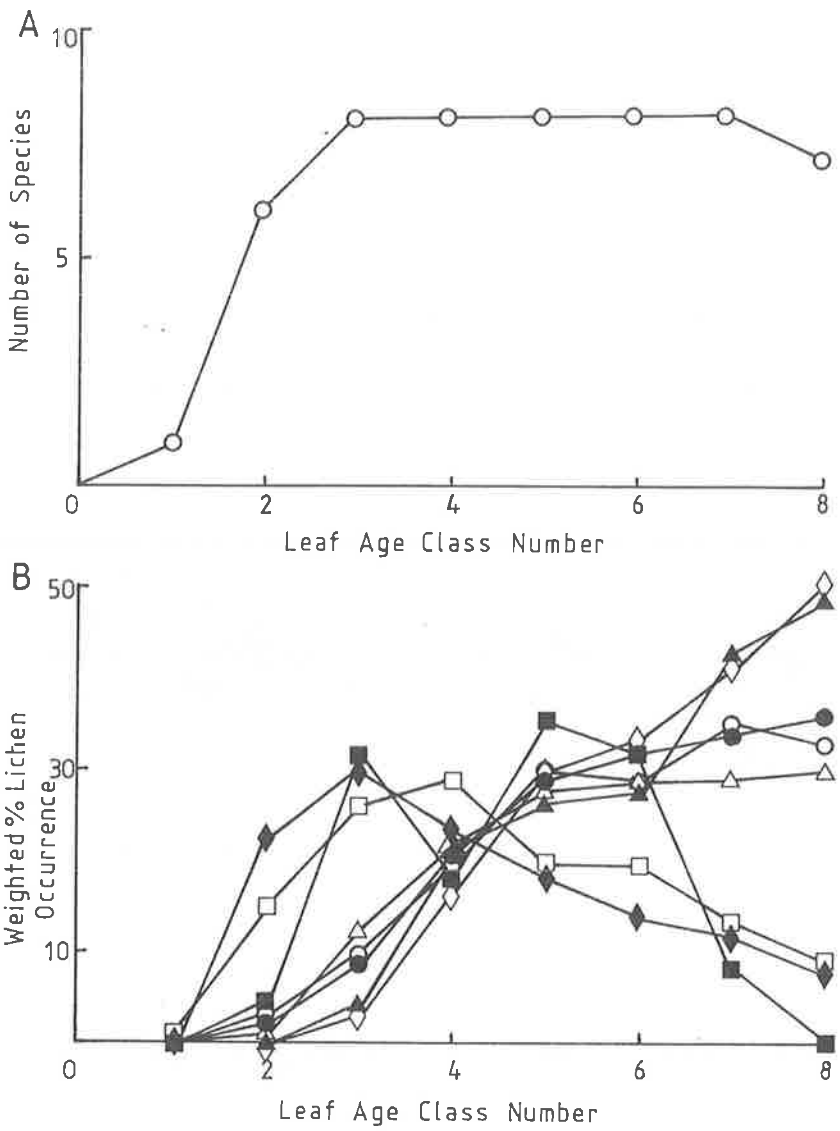

FIGURE 2. **A.** Number of lichen species for each leaf pair number of *Wilkiea macrophylla*. **B.** Weighted Percentage Lichen Occurrence for each leaf number of *Wilkiea macrophylla*. ○ *Porina epiphylla*; ● *Mazosia melanophthalma*; △ *Mazosia phyllosema*; ▲ *Strigula complanata*; □ *Sporopodium xantholeucum*; ■ *Sporopodium phyllochoris* var. *flavescens*; ◇ *Strigula subtilissima*; ◆ *Tricharia albostrigosa*.

species, with Fig. 2B suggesting a late arrival and early decline. Four species groups are apparent: I. *Strigula subtilissima* and *Strigula complanata*; II. *Porina epiphylla, Mazosia phyllosema* and *M. melanophthalma*; III. *Sporopodium xantholeucum* and *Tricharia albostrigosa*; IV. *Sporopodium phyllocharis* var. *flavescens*.

When the correlation coefficients (r) between species occurrences were calculated, strong correlations were obtained between the species within each of groups I–IV (significant at 0.001 confidence level). The species in group I showed significant correlations with group II (0.001 confidence for *Strigula complanata* and *Mazosia melanophthalma*; 0.01 confi-

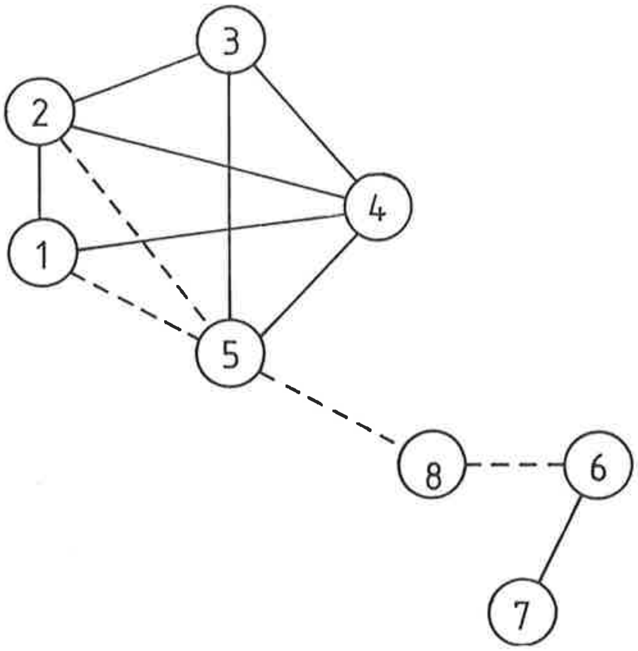

FIGURE 3. Association diagram of the foliicolous lichens on *Wilkiea macrophylla*—solid lines: $p < 0.001$; dotted lines: $0.05 > p > 0.001$. 1. *Strigula subtilissima.* 2. *Strigula complanata.* 3. *Mazosia melanophthalma.* 4. *Porina epiphylla.* 5. *Porina impressa.* 6. *Sporopodium xantholeucum.* 7. *Tricharia albostrigosa.* 8. *Sporopodium phyllocharis* var. *flavescens.*

dence for *M. phyllosema*). *Porina impressa* showed significant correlation (0.05 confidence) with *Sporopodium phyllocharis* var. *flavescens*, and the latter also correlated at the 0.05 confidence level with *Sporopodium xantholeucum.* There were no significant correlations between the species of group III and those of groups I and II.

The correlation associations between species at the 0.001 and 0.01 confidence levels (Fig. 3) reveal three broad groups corresponding to groups I–II, III and IV. Within the group containing groups I and II, species in groups I (species 1 and 2) are less closely associated with group II species (3, 4 and 5) than they are with each other. However, the whole group still shows high correlation at the 0.01 level for the species in groups I and II.

DISCUSSION

The lichen population on leaves of *W. macrophylla* could be determined by one or several of the following processes: (1) random colonization; (2) conditions at the time of initial colonization; (3) succession of species as the leaves age. The implications of each of these can be considered and compared with results obtained.

1. *Random colonization:* Since there are clear patterns in the frequency of all species (except possibly *Sporopodium phyllocharis* var. *flavescens*, whose rarity makes frequency trends difficult to interpret) and significant correlations between most species, the idea that the lichen distributions are the result of random colonization must be rejected.

2. *Conditions at the time of initial colonization:* This hypothesis assumes that the environment in which the host plant grows is undergoing steady changes in climate, or is markedly seasonal, so that the conditions at the time when the oldest leaves were initially

colonized were different from those of leaves being currently colonized. Such an hypothesis would result in repeating patterns of species dominance indicating climatic or seasonal cycles. With leaf maturation, death of some short-lived species could occur resulting in some decline in species frequency. This hypothesis is tenable if it is assumed that cycles are longer than the time that leaves remain on the stems. There are no observed repeating patterns of changes in species composition. A seasonal pattern is also unlikely since leaf production in *W. macrophylla* appears only to occur once a year in spring/summer.

3. *Succession:* Succession is the measurable change in species composition in a community over time and can be divided into a number of different patterns of succession. These are defined by Horne (1976) and the classic "Clementsian" (seral) succession (Clements 1916) in which pioneer species change the environment such that they are replaced by later species that are better adapted to the changed conditions. While workers such as Degelius (1969, 1978) have reported successions on substrates such as twigs where annual growth by the host could be clearly seen, Yarranton (1972) considered that the corticolous epiphytes on *Picea mariana* (black spruce) changed in frequency because of changes due to growth by the host tree and by environmental variation, and thus true succession as defined by Clements (1916) did not occur in these communities. When the pattern of species replacement seen on *W. macrophylla* leaves is compared with the alternative succession theories discussed by Horne (1976), the gradual exclusion of unsuccessful species by other dominant species conforms to the criteria for a competitive hierachy, and it is by this means that we consider succession to occur on *Wilkiea macrophylla* leaves. There are two ways to study populations to see if succession is occurring: one is to study a site over time, and to observe the changes in the flora, another (more commonly used, especially with lichens) is to examine a number of similar habitats of different ages for differences in their floristic components. This latter approach has enabled some workers (Morrison & Yarranton 1974; Orwin 1970; Robinson 1959) to look at probable lichen successions through long time-periods. Santesson (1952) makes brief reference to the nature of successions in foliicolous lichens. Species showing no resistance to competition often occur as the pioneer species, e.g. *Bacidia aphiaca* (Müll. Arg.) A. Zahlbr. and are later replaced. Zahlbruckner et al. (1928) observed that there are many species with apparent particular requirements for substrate, and that establishment occurs best on leaves on which bryophytes are less likely to establish. Although many foliicolous lichens do not reach the size of many other lichens of similar age, they mature more rapidly, producing fruiting bodies on small thalli (Santesson 1952). This characteristic enables these species to survive despite the ephemeral nature of the substrate.

In most lichenological works, successions are considered to go from crustose life forms, through foliose and climaxing with fruticose (Topham 1977). On leaves of *W. macrophylla*, however, succession did not progress beyond crustose species.

The succession observed on *W. macrophylla* is as follows: young leaves are colonized by a number of species but *Tricharia albostrigosa* and *Sporopodium xantholeucum* mature more quickly and show the healthiest development of thalli on leaves on which there are no other species growing in close proximity. Both species showed up clearly as a group in both the weighted percentage frequency and correlation coefficient results. Further down the leaf sequence, species such as *Porina epiphylla, P. impressa* and *Mazosia melanophthalma* began to establish and grow. *Porina epiphylla* and *P. impressa* both showed extensive growth and apparent fusion of thalli so that leaves were frequently covered by one or the other species, with other lichen species surrounded by them. At this stage, *Tricharia albostrigosa* and *Sporopodium xantholeucum* begin to decline in frequency and are generally less healthy, often showing necrosis on portions of the thalli.

Strigula complanata and *S. subtilissima* both appear to be associated with areas of damage to the leaf, and in this genus establishment is known to be associated with cuticle damage. *Strigula subtilissima* was also seen to be frequently associated with a large, dark fungus (possibly Hyphomycetes (Santesson 1952)) and presumably becomes established after the fungal infection damaged the cuticle. As the probability of leaf damage increases with age, it is not surprising to find that the parallel increase in frequencies of both species and their similar habitat requirements are reflected by their highly significant correlation.

Thalli of *Mazosia melanophthalma* were only of moderate size (to 15 mm diam.) and tended to form discrete, rounded patches. They did not show any of the necrosis seen in *Sporopodium* and *Tricharia* when surrounded by *P. epiphylla* or *P. impressa*: the species is therefore probably resistant to competition.

Because of its rarity in the population examined, *Sporopodium phyllocharis* var. *flavescens* is difficult to place in the sequence; however, its correlations with *S. xantholeucum* and *P. impressa* indicates that it establishes itself later than the pioneer species. Its early elimination from the system and the poor condition of thalli on older leaves indicate that it is probably not resistant to competition.

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Leaf demography of the rainforest shrub *Wilkiea macrophylla* and its implications for the ecology of foliicolous lichens

R. W. ROGERS
Botany Department, University of Queensland, St Lucia, Qld 4067, Australia

A. BARNES
Science Faculty, University of Queensland, St Lucia, Qld 4067, Australia

Abstract

A population of leaves of the rainforest shrub Wilkiea macrophylla *was studied for a period of 3 years. Survival curves for three subsamples were constructed. The estimated proportion of leaves initiated during the study that survived for the length of the study period (1150 days) was 79.7% and, by extrapolating in time, their mean half life was estimated to be 6.8 years. Those leaves present at the inception of the programmes but without lichen cover at that time, showed 80.1% survival over the subsequent 1150 days, whereas only 55.2% of those with lichen cover survived for 1150 days. Leaf growth and fall was concentrated in the period September–December, suggesting cool temperate affinities. Leaves of* W. macrophylla *are so long-lived that it cannot be assumed that foliicolous lichens are ruderals: only comparative studies will establish their nature.*

Introduction

The life span of rainforest shrub leaves is not well documented. Bentley (1979) studied leaf loss in a rainforest understorey by examining the survival of five young leaves on one plant from each of 27 different species: 39% of these leaves survived for 2 years. In the case of *Wilkiea macrophylla*, it is apparent that leaves are retained for up to four growing periods (Conran & Rogers 1983). Uncertainty about the frequency of growth periods, however, meant that no attempt could be made to age individual leaves or even to provide an indication of the likely maximum age of a leaf on the shrub. This information is important in the context of studies of successional patterns of lichens occurring on the leaves (foliicolous lichens) of *W. macrophylla*, and the strategies that those colonizing lichens show. One possible hypothesis is that leaves are relatively short-lived, and that lichens occupying such a transient habitat would have evolved ruderal strategies (Grime 1981). To investigate this hypothesis a study was planned to document the demography of leaves on the shrub. Because it has very large leaves (often more than 4 cm wide and 20 cm long) widely spaced on rigid stems, *W. macrophylla*, is well suited to such a study.

The site selected was at Mt Glorious, some 30 km north-west of Brisbane, at an altitude of 600 m. The study site is a complex notophyll vine forest on a ridge top, with *W. macrophylla* shrubs forming a prominent part of the sparse understorey.

The lichens which grow on leaves are, in the large part, highly specialized taxa, some belonging to families which are obligate leaf colonizers (Santesson 1952). It is generally believed that foliicolous lichens are simply epiphytes which do no direct damage to the leaf. The shading effect of the lichen must, however, be significant in at least some cases in such a light-deficient environment as the rainforest floor; in a similar forest on the Lamington Plateau, Bjorkman and Ludlow (1972) measured an average light flux equivalent to 0.5% of that above the canopy.

Methods

Eight shrubs in close proximity were selected for study. On 23 July 1981, all twigs were tagged on four of these shrubs and the individual leaves documented. On the other four, a selection of twigs judged by the absence of lichens on leaves at the tip of the shrub to have made relatively recent growth were tagged and the leaves documented. These shrubs were re-examined at 13 intervals ranging from 30 to 143 days over the following 3 years.

Leaf survival rates were calculated from life tables (Lawless 1982) prepared for three classes of leaf:

(1) those which were initiated after the commencement of the study;

(2) those which were present at initiation of the study but were without lichens; and

(3) those present at initiation of the study which had at least one species of lichen present on them at that time.

These Classes represent an apparent age sequence. Classes 2 and 3 are necessarily older than Class 1; Class 1 leaves are the only ones with a known age. Leaves in Class 3 were assumed to be mostly older than leaves in Class 2 because lichen colonization takes a finite (and at the start of this study quite unknown) time.

Results

One bush clearly began to senesce early in the study and died before the 3 year period ended; data from this individual have been excluded from all analyses. A total sample of 39 twigs with 188 leaves therefore provides the basis for analyses relating to initial populations. Of the 188 leaves present at initiation of the study, 121 had at least one lichen species growing on them and 67 had no lichen. During the observation period 146 leaves were initiated.

New leaves were initially bright pink, remaining that colour until they were fully expanded when they slowly turned green. The process of leaf expansion and chlorophyll production took over 4 months in some of the leaves observed.

From the data on lichen colonization collected in this study, it was apparent that leaves did not develop visible lichen colonies in less than 550 days after leaf appearance, and that by 1000 days only about 10% of the leaves had lichens growing on them.

The survival percentages of leaves in the three classes examined are shown in Fig. 1. Mean daily leaf growth and leaf-fall is shown in Fig. 2. Leaf growth and leaf-fall are clearly seasonal, having marked maxima in the period September–December.

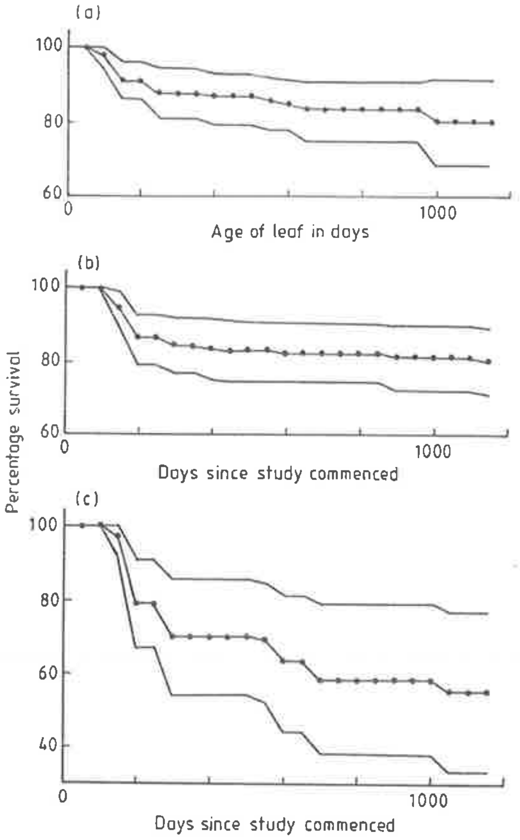

FIG. 1. Percentage survival of three leaf populations of *W. macrophylla* at Mt Glorious (●—●), with estimated standard errors of the mean (—): (a) Class 1; (b) Class 2; (c) Class 3.

From Fig. 1 it is apparent that the rate of survival of new leaves and of the initial population of leaves without lichens is very similar. After 1150 days, 79.7% (95% confidence limits: 68.0% and 91.4%) and 80.15% (95% confidence limits: 71.1% and 89.2%), respectively, of leaves were still alive. Except for the initial 150 days of the study, survival of leaves with lichens was less than that for leaves without lichens. These survival curves diverged as the study progressed and by 600 days (and subsequently) were significantly different from each other ($P < 0.05$). By 1150 days, 55.2% (95% confidence limits: 33.2% and 77.2%) of the leaves with lichens at initiation of the study were still living. These findings must be qualified by the observation that the test of significance and 95% confidence intervals are approximations because standard errors were calculated from leaves which were not fully independent, being obtained from a small number of plants.

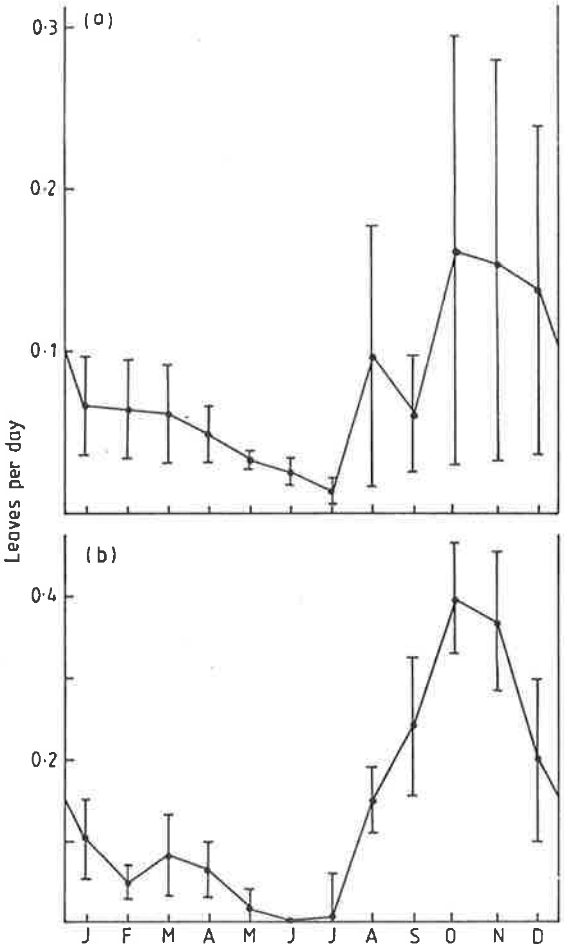

FIG. 2 Mean daily (a) leaf-fall and (b) leaf growth of *W. macrophylla* at Mt Glorious from January to December. Bars indicate standard errors of the mean.

Discussion

As intervals of up to 143 days elapsed between recordings of leaf populations, only leaves which survived this long would have been included in the study. Thus the number of leaves produced will have been slightly underestimated and, consequently, leaf survival over this period will be marginally overestimated. Young shoots of *W. macrophylla* sometimes produce a series of cataphylls before normal foliage leaves are produced and, since these leave scars on the stem when they fall, it is not possible to use leaf scars as a basis for accurate measurements of leaf demography in this species.

That there is a higher death rate initially than later in the life of new leaves is probably a consequence of predation. Leaves of *W. macrophylla* are very tough and leathery when mature, but quite soft when young; this results in susceptibility to predation in young leaves, but immunity from predation in old leaves, a common phenomenon in rainforests (Lowman & Box 1983).

Although there is a suggestion from Fig. 1 that the rate of leaf death over the first 100–200 days of life might be slightly higher than at later ages, the pattern of leaf survival is not markedly different from an exponential curve over the limited age range studied. The similarity in survival rates for new leaves and leaves present at commencement but without lichens suggests that the survival function may be approximately exponential for a considerably longer period than the 3 year time span of this study.

If it is assumed that survival of leaves is an exponential function of age, then the exponential decay rate parameter may be estimated from the data (Lawless 1982). By extrapolating the fitted curve to the time when only 50% of leaves survive a half life, or median survival time, of 2496 days (95% confidence interval: 1432 days and 3159 days) or 6.84 years is calculated for leaves of a known age.

The higher death rate during the study shown by leaves colonized by lichens at commencement of the study suggests that leaf death rates may eventually be more rapid than those predicted by an exponential curve. This higher death rate may be the result of an adverse effect of lichens on the leaves. It has been demonstrated by Bjorkman *et al.* (1972) that plants growing on the floor of rainforests operate at marginal photosynthetic levels and it seems likely that leaves with lichen cover have a less satisfactory light regime than those without lichens and therefore die at a faster rate.

Since lichen colonization takes at least 550 days, and after 1000 days only 10% of leaves have been colonized, it is reasonable to assume a mean age difference of at least 3 years between the leaves present at the beginning of the study with lichens and those without lichens.

Leaf production is concentrated in the period of dry weather in spring and early summer, perhaps triggered by rising temperatures; leaf-fall shows a similar, but less marked, pattern. The restriction of leaf initiation to the late winter–early summer period suggests that *W. macrophylla* has a phenology adapted to the climatic conditions now prevailing in southern Australia, and thus possibly has a southern or cool temperate rather than a northern or tropical origin (Conran 1984; Specht 1981). Since the family Monimiaceae is characteristic of the Southern hemisphere and is common in the forests of the eastern highlands (Victoria and Tasmania), that hypothesis is not unreasonable.

It is clear that the average life-span of a leaf of *W. macrophylla* is comparatively long. A half life of 6.84 years based on the sample of new leaves indicates that a significant proportion of leaves of considerable age might be expected on a bush. The survival curves of the leaves present at the commencement of the study do not alter that expectation.

Long leaf life is characteristic of stressed environments (Grime 1981). Hom and Oechel (1983) found that black spruce needles in the Alaskan arctic survived up to 13 years, and attributed this long life to maximization of photosynthetic return for nitrogen investment. Chapin (1983) advanced a similar argument relating leaf longevity to nutrient deficiency. While it is often thought that rainforests occupy rich soils, Golley (1983) points out that this is not necessarily so, and discusses a number of nutrient conservation mechanisms found in rainforests. These mechanisms include large coriaceous leaves with glossy (non-wetting) surfaces and drip points, all characters of *W. macrophylla* leaves. It is therefore not unreasonable to assume that nutrient conservation has been an important factor in the evolution of *W. macrophylla* with long-lived leaves as one outcome. Such leaves are also clear advantage to a plant which lives in the most marginal of light environments (Bjorkman & Ludlow 1972; Bjorkman *et al.* 1972) and for which the energy investment required to produce a new leaf is a substantial drain on resources. Both light and nutrient stress factors have probably played a role in the evolution of these long-lived leaves.

The evolution of foliicolous lichens is complicated by the tendency of the thallus to reduce the effectiveness of the leaf. If the thallus causes leaf death by reducing photosynthetic efficiency, it curtails its own life. Such a reduction in efficiency might be brought about not only by limiting light penetration to the leaf, but also by increasing the rate at which nutrients are leached from the leaf. Epiphylls tend to increase the rate of nutrient losses from the leaf by prolonging the period for which the leaf surface is wet. Since the epiphylls accumulate nutrients from the leaf leachate and from the atmosphere (Witkamp 1970), nutrient stress is not likely to play a dominant role in the evolution of foliicolous lichens.

Because factors which favour the development of the lichen thallus endanger its continued existence, it may well be that the foliicolous lichens have evolved mechanisms limiting their development, and thus preserving the leaf they grow upon. The very thin thalli of most species may be one such mechanism. Failure of lichens to grow on the anatomical lower surface of a leaf even if the leaf is hanging vertically or is inverted may also be a mechanism limiting the impact of the lichen growth on the leaf.

The factors influencing the evolution of the foliicolous lichens thallus are thus complex. This evolution is probably mostly related to stress, particularly light stress, but also includes some of the special factors normally associated with parasitism.

Given the long life of leaves of *W. macrophylla*, time available for establishment and growth may not be a crucial factor for foliicolous lichens. These lichens cannot, therefore, be considered ruderals (*sensu* Grime 1981) simply on the basis of the assumed evanescence of their substrate. A true understanding of their nature can only come from comparative studies including a range of other lichens.

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Lichen Succession on Leaves of the Rainforest Shrub, *Capparis arborea* (Capparaceae)

R. W. Rogers

Botany Department, The University of Queensland,
Qld 4072, Australia.

Abstract

The lichen flora on leaves of *Capparis arborea* (F.Muell.) Maiden growing in undisturbed rainforest at Mt Glorious, Queensland, Australia was examined. The sequence of colonisation on leaves of increasing age on twigs (a chronosequence) was determined, and, although involving the same lichen species, was found not to be the same as that reported on *Wilkiea macrophylla* in the same forest. Analysis of variance demonstrated that total lichen cover and the cover of the common species *Porina epiphylla* on the leaves was significantly related to both leaf position in a chronosequence and to leaf area, with a significant interaction between the two. The relationship between the cover of lichen species on a leaf and the size and age of the leaf is apparently complex. Frequency of four species was related to position in the chronosequence, and of six species to size of the leaf. Lichen succession is not a simple time-dependent sequence on this host plant species.

Introduction

Lichens colonising the leaves of shrubs within rainforests have been the subject of a number of publications (Schell and Winkler 1981; Conran and Rogers 1983; Rogers and Barnes 1986; Rogers 1989; Rogers *et al.* 1994). Detailed studies, however, have been restricted to the shrub *Wilkiea macrophylla* (A.Cunn.) DC. in the subtropical rainforest of south-eastern Queensland (Conran and Rogers 1983; Rogers and Barnes 1986; Rogers 1989; Rogers *et al.* 1994). The studies on *Wilkiea macrophylla* indicated a relatively constant pattern of succession on the leaf age sequence down a single stem. Whether the same species and sequences would be found on another species of shrub is likely to provide further insight into the ecology of foliicolous lichens.

Another shrub species growing in close proximity to W. *macrophylla* and which bears a diverse lichen flora is *Capparis arborea* (F.Muell) Maiden, in the family Capparaceae. *Capparis arborea* is a shrub or small tree which is common in the rainforests of south-eastern Queensland, where it may be a prominent feature of the usually sparse understorey. The habitat is quite dark—light intensity in the Mt Glorious forest approximates 2% of that external to the community (Björkman and Ludlow 1972), with photosynthesis in the shrubs being dependent to a significant extent on light flecks moving across the forest floor (Björkman *et al.* 1972).

The leaves of *Capparis arborea*, unlike those of *Wilkiea macrophylla*, are very variable in size on any one stem. Long sequences of leaves colonised by lichens can also be found on stems, and, since the formation of visible lichen thalli is a process which takes about 3 years (Rogers and Barnes 1986), this suggests long time sequences are represented along single axes. These long leaf sequences appear to make the shrub a suitable substratum for the study of succession of foliicolous lichens using the chronosequence approach recommended by

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Rogers *et al.* (1994). The assumption of the chronosequence approach is that leaves progressively distal from the apex represent an age sequence, and, therefore, studies of leaves successively distal from the apex can be construed as a study of succession. The relationship between a chronosequence and a real time sequence is complex, and has been discussed by Rogers *et al.* (1994). The variation in leaf size allows investigation of a second environmental attribute on lichen colonisation. Two-way analysis of variance of cover of different species on leaves of different size and age permits partitioning of variance between these two characters, their interactions and within cell variation.

Methods

A population of *Capparis arborea* was located in an undisturbed subtropical rainforest at Mt Glorious (27°19′S, 152°56′E, altitude 600 m) within 100 m of the location of the *Wilkiea macrophylla* shrubs studied by Rogers *et al.* (1994). In this population, twigs were sought on which the terminal leaves were devoid of lichens, but on which more distal leaves carried a developed lichen flora. Twenty-four such twigs were located, collected and returned to the laboratory where the leaves were removed, dried and mounted on cards in the sequence in which they were arranged on the shoot.

Each leaf was examined under a dissecting microscope and the cover of each identifiable lichen species and that of unidentifiable (sterile) material recorded. Cover was estimated by superimposing a transparent sheet with a 4 mm grid marked out on its surface and recording the number of points beneath which a given lichen was present. The number of points falling within each leaf was recorded and percentage cover calculated for each identifiable lichen species and for total lichen cover.

The sequence of colonisation was investigated by estimating the ratio of the proportion of stems with records of taxon A more proximal than taxon B to the proportion of those in which B occurred more proximal than A (Rogers *et al.* 1994). To allow for relative commonness of the species, a second sequence was calculated in which proportions were further weighted for the number of twigs upon which each species occurred. If only one of the two taxa occurred on a twig, it was taken as proximal, and a mutual occurrence at the relevant leaf position was treated as a 0.5 score for each taxon.

To allow comparison of the effect of leaf size and chronosequence on cover of lichens, leaves were sorted into classes on the basis of position in the chronosequence and of the number of cover points on the leaf. Classes were determined so that each cell of a two-way size-sequence matrix contained at least 10 entries. The cover of species on leaves was grouped into a leaf sequence for chronosequence positions 1–6, 7–12, 13–18 and 19–33. Leaf size was blocked into those which included 1–10 cover points, 11–20, 21–40 and > 40 cover points.

The relative impact of leaf position in a chronosequence and leaf size on cover of total lichen cover and of *Porina epiphylla* was examined by use of a two-way anova of log-transformed cover data followed by Tukey *post-hoc* tests to locate differences between classes (Wilkinson 1990). Cover of other species was too sparse to be examined using this technique, so frequency of occurrence of species was determined within nine classes defined in terms of position in chronosequence (leaf positions 1–6, 7–18 and 19 or greater) and leaf size (1–20, 21–60 and 61 or more cover points). Differences within the total nine-cell matrix, between the three size and three age classes were sought using χ^2 contingency analysis. Probabilities were adjusted to allow for multiple comparisons using the Bonferroni procedure (Wilkinson 1990). To avoid cells with very low expected values, only the more common species were examined this way including *Gyalectidium filicinum*, *Porina epiphylla*, *P. impressa*, *P. leptosperma*, *P. limbulata*, *P. rufula*, *Strigula elegans*, *S. subtilissima*, and *Mazosia melanophthalma*.

Results

A total of 24 shoots bearing 437 leaves were collected. Leaf size varied from a small leaf which included only four sampling points within its margins to a very large leaf with 204 points. The number of leaves in a sequence (counting the first leaf on a twig to bear lichens to the most distal leaf on the twig) ranged from 4 to 33.

Fifteen species of lichens were recognised on the leaves examined, nine of which were common *Gyalectidium filicinum* Müll. Arg. (32 leaves), *Mazosia melanophthalma* (Müll. Arg.) R.Sant. (67), *Porina epiphylla* (Fee) Fee (192), *Porina impressa* R.Sant. (30), *Porina leptosperma* Müll. Arg. (25), *Porina limbulata* (Krempelh.) Vainio (25), *Porina rufula*

(Krempelh.) Vainio (55), *Strigula elegans* (Fee) Müll. Arg. (110), and *Strigula subtilissima* (Fee) R.Sant. (117). There were six rare species, *Mazosia phyllosema* (Nyl.) Zahlbr. (2), *Opegrapha vegae* R.Sant. (4), *Sporopodium xantholeucum* (Müll. Arg.) Vainio (1) *Tricharia albostrigosa* R.Sant. (8), *Trichothelium alboatra* R.Sant. (1), and *Strigula schizospora* R.Sant. (1). No species were observed on the leaves examined which did not also occur on a grid point.

The sequence of colonisation of the seven more common species was not simple, and no sequence table could be prepared which showed a simple increase in ratios of species A: species B as first coloniser down the columns and right to left across the rows, but a close approximation was prepared (Table 1). Table 1 indicates a successional sequence of the seven more common species, *Strigula elegans, Porina epiphylla, Strigula subtilissima, Gyalectidium filicinum, Mazosia melanophthalma, Porina rufula* and *Porina impressa.* When weighted for commonness, the species order changed (Table 2) and indicated a successional sequence: *Gyalectidium filicinum, Strigula elegans, Strigula subtilissima, Mazosia melanophthalma, Porina impressa, Porina rufula* and *Porina epiphylla.*

Regression analysis showed leaf size and position in the chronosequence to be significantly related ($r^2 = 0.011$, $F = 5.062$ for 439 degrees of freedom, $P = 0.025$). Mean cover for all lichens and for *Porina epiphylla* is shown in Table 3.

Table 1. The ratio of leaves of *Capparis arborea* in rainforest at Mt Glorious, Queensland, first colonised by lichen species A: leaves first colonised by lichen species B

The sequence of species in the array has been organised to have minimum values on the diagonal and maximum values at the bottom left. Species are: SE, *Strigula elegans*; SS, *Strigula subtilissima*; PE, *Porina epiphylla*; GY, *Gyalectidium filicinum*; MM, *Mazosia melanophthalma*; PR, *Porina rufula;* PI, *Porina impressa*

	Taxon A					
Taxon B	SE	PE	SS	GY	MM	PR
PE	1.10					
SS	0.93	1.42				
GY	2.38	1.88	1.92			
MM	3.00	2.82	2.67	1.12		
PR	5.00	4.25	3.67	1.50	1.36	
PI	9.00	6.50	3.89	2.75	2.33	2.00

Table 2. The ratio of leaves of *Capparis arborea* in rainforest at Mt Glorious, Queensland, first colonised by lichen species A as a proportion of leaves with A: leaves first colonised by lichen species B as a proportion of leaves with B

Lichen species are identified as in Table 1

	Taxon A					
Taxon B	GY	SE	SS	MM	PI	PR
SE	1.44					
SS	1.90	1.00				
MM	2.34	1.83	1.53			
PI	2.58	2.45	1.00	1.04		
PR	2.58	2.50	1.72	1.12	0.92	
PE	3.20	1.92	2.53	1.02	1.02	1.22

Table 3. Total lichen cover and cover of *Porina epiphylla* on leaves of various size and age classes from *Capparis arborea* in rainforest at Mt Glorious, Queensland, Australia

The significance of differences between species occurrence on leaves of a given class are calculated using Tukey *post-hoc* tests (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$) S1—S4 indicates leaf size classes and A1–A4 leaf chronosequence classes as defined in the text

Species	Class	Mean cover	se	*n*	Different from
All lichen					
	S1	18.21	2.22	83	2*, 3***, 4***
	S2	23.64	1.73	132	1*, 2*, 4***
	S3	19.23	2.10	90	1***
	S4	15.43	1.72	147	1***, 2***
	A1	13.74	1.90	128	2***, 3***
	A2	20.70	1.91	113	1***
	A3	21.17	2.15	96	1***
	A4	20.93	1.85	115	
P. epiphylla					
	S1	5.01	1.56	83	2***, 3***, 4***
	S2	12.60	1.22	132	1***
	S3	7.30	1.48	90	1***
	S4	5.95	1.21	147	1***
	A1	5.26	1.34	128	2***, 3**, 4***
	A2	8.62	1.34	113	1***
	A3	7.26	1.51	96	1**
	A4	9.73	1.30	115	1***

Analysis of variance showed that pooled cover of all lichens showed statistically significant difference with respect to both leaf position in the chronosequence ($F = 4.041$, 3 df, $P < 0.01$) and leaf size ($F = 4.426$, 3 df, $P < 0.05$). The interaction effect between size and position in the chronosequence was also significant ($F = 1.988$, 3 df, $P < 0.05$). Tukey *post-hoc* tests showed that cover of lichens on leaf class one (the smallest size) was significantly different from that on leaf classes two and three. Cover on leaves of chronosequence class one was also shown to be significantly different from those on leaves of chronosequence classes two, three and four. Significant differences were located when paired comparisons were made between pairs of size classes and between pairs of chronosequence classes for all lichen and *Porina epiphylla* (Table 3). Four of the possible six comparisons between distribution of cover of all lichens and three of the six for *P. epiphylla* on leaves of different size were significant, and three of those between leaves of different chronosequence were also significant.

The overall contingency table relating lichen frequency to leaf size class and leaf position in the chronosequence for seven of the nine species examined was highly significant (*Mazosia melanophthalma*, $\chi^2 = 51.39$, 8 df, $P < 0.001$; *P. epiphylla* , $\chi^2 = 60.96$, 8 df, $P < 0.001$; *P. leptosperma*, $\chi^2 = 60.24$, 8 df, $P < 0.001$; *P. limbulata*, $\chi^2 = 18.03$, 8 df, $P < 0.05$; *P. rufula*, $\chi^2 = 77.82$, 8 df, $P < 0.001$; *Strigula elegans*, $\chi^2 = 42.70$. 8 df, $P < 0.001$; *Strigula subtilissima*, $\chi^2 = 51.25$, 8 df, $P < 0.001$). Leaf size was significantly associated with lichen frequency for six species and leaf position in the chronosequence was significantly associated with lichen frequency for four species (Table 4).

When grouped into finer classes than those used for analysis of variance, it is apparent that the relationships between leaf size and lichen cover and between leaf chronosequence position and lichen cover are quite complex (Figs 1, 2). Total cover does not vary greatly

Table 4 Significant associations between frequency with which lichens occurred on leaves of different size and chronosequence classes of *Capparis arborea* from rainforest at Mt Glorious, Queensland, Australia
Columns refer to overall significance in a table with nine cells and eight degrees of freedom representing a matrix of three leaf size and chronosequence classes, to significance of differences relating to three chronosequence classes (2 df), and significance relating to three size classes (2 df). Significance relates to probabilities Bonferroni corrected for repeated comparisons (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, NS = no significant association)

Species	Overall	chrono	size
Gyalectidium filicinum	NS	NS	NS
Mazosia melanophthalma	***	**	***
Porina epiphylla	***	**	***
Porina impressa	NS	NS	NS
Porina leptosperma	***	*	***
Porina limbulata	*	NS	**
Porina rufula	***	*	***
Strigula elegans	*	NS	NS
Strigula subtilissima	**	NS	**

with leaf size, whereas cover of *Porina rufula* appears to increase on larger leaves. Other species (e.g. *Strigula elegans*) show a complex pattern, appearing to show higher cover on moderately small leaves, this decreasing to middle size ranges, but increasing again on the larger leaf classes. Cover in relation to position in chronosequence is also complex. Past position 10 in the chronosequence total cover appears to be independent of leaf age. *Porina epiphylla* and *Strigula subtilissima* appear to increase in cover with leaf age, whereas *Porina impressa, and Porina rufula* appear to decrease in cover with leaf age. The species which bears most detailed examination is *Porina epiphylla*, by far the most common species. *Porina epiphylla* is a late successional species which shows its lowest cover on the smallest size class of leaves and its greatest cover on the second smallest size class of leaves (Table 3). It also shows the least cover on the youngest leaves. Frequency of occurrence is greatest on leaves which are both large and further down the chronosequence. Examination of the frequency distribution of species of *Strigula*, on the other hand, showed that neither species exhibited significant differences across the three leaf age classes used for frequency studies, but that *S. subtilissima* did increase in frequency with leaf size. *Porina epiphylla* was the predominant lichen species, providing the greatest amount of cover of all species in every leaf age class and every leaf size class except the smallest in which the hemiparasitic species *Strigula subtilissima* was predominant.

Discussion

The total of 15 lichen species found on the leaves of *Capparis arborea* is the same as that found on *Wilkiea macrophylla* in the same region (Rogers *et al.* 1994) and a little more than that on *Wilkiea macrophylla* in rainforests of the Border Ranges (13 species, Conran and Rogers 1983). The only species on *C. arborea* leaves not found on *W. macrophylla* at Mt Glorious were *Mazosia phyllosema* and *Trichothelium alboatra*. The sequence of colonisation on leaves of the two species of shrub at Mt Glorious, however, seems not to be similar, for when the seven most common species on each shrub (the same taxa on each shrub) were numbered in order of colonisation and a regression analysis performed relating order of colonisation on one shrub to that on the other, no significant relationship was detected.

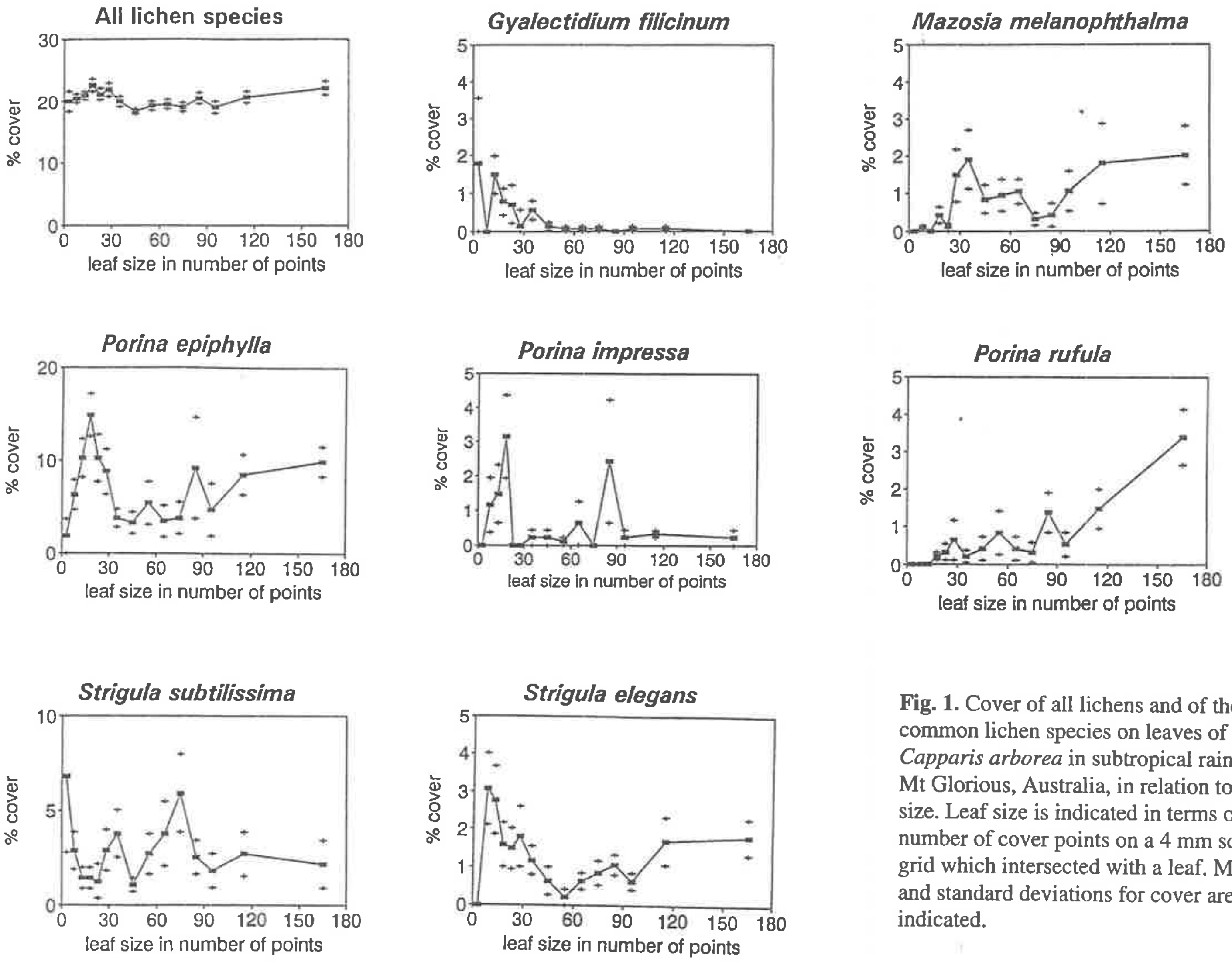

Fig. 1. Cover of all lichens and of the seven common lichen species on leaves of *Capparis arborea* in subtropical rainforest at Mt Glorious, Australia, in relation to leaf size. Leaf size is indicated in terms of the number of cover points on a 4 mm square grid which intersected with a leaf. Means and standard deviations for cover are indicated.

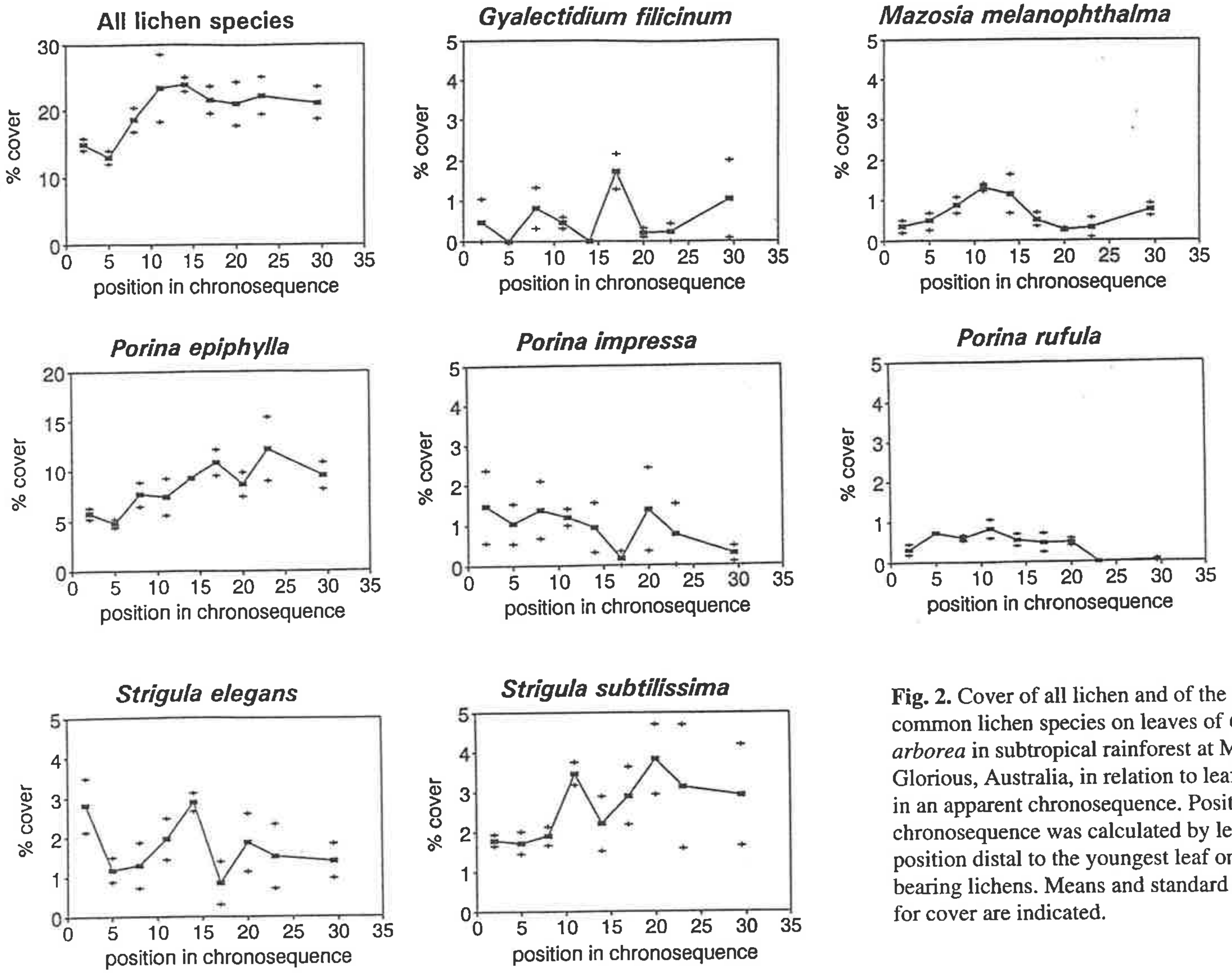

Fig. 2. Cover of all lichen and of the seven common lichen species on leaves of *Capparis arborea* in subtropical rainforest at Mt Glorious, Australia, in relation to leaf position in an apparent chronosequence. Position in the chronosequence was calculated by leaf position distal to the youngest leaf on a twig bearing lichens. Means and standard deviations for cover are indicated.

The difference between the sequence of lichen colonisation on *Capparis arborea* leaves displayed in Tables 1 and 2 is substantial, with two species moving dramatically between the two analyses. *Porina epiphylla* is in absolute terms the second most common species colonising previously uncolonised leaves, but it relatively rarely appears as the first species in the chronosequence when loading for commonness is included. *Gyalectidium filicinum*, on the other hand, is a relatively uncommon species, but one which occurs disproportionately often as the first lichen to appear on a chronosequence. In considering colonising sequences, therefore, care must be taken to differentiate between species which tend to occur early in a sequence and those which occur often.

The differences between the colonisation sequences on the two shrub species may be related in part to leaf size, leaves of *Wilkiea macrophylla* usually being very much larger than those of *Capparis arborea*. The leaves also differ in surface texture, those of *W. macrophylla* being smooth and shiny, those of *C. arborea* being coriaceous and dull. Leaves of *W. macrophylla* are also thicker and more rigid than those of *C. arborea*. Differences in both size and texture could influence lichen colonisation.

Leaf size is likely to affect a number of factors significant in lichen colonisation and growth. Wider leaves will have a deeper boundary layer of still air across their surface (Monteith and Unsworth 1990), and therefore lichens near the centre of a wide leaf will be less exposed to desiccating winds than those near the edge or near the centre of a narrow leaf. Boundary layer conditions are also likely to influence the settling of spores onto the leaf surface. Larger leaves also show greater temperature variations across their surface than do smaller leaves (Monteith and Unsworth 1990), a factor which could influence lichen colonisation and growth. Large leaves are less likely to be shaded or protected from incoming rain or canopy drip which provides both water and nutrient than are small leaves on the same twig, providing yet more differences in lichen habitat on leaves of different size.

Surface texture is likely to influence the availability of microsites for the lodgement of lichen spores and their subsequent establishment (Armstrong 1981; Pentecost 1981).

The importance of leaf size in the colonisation of *Capparis arborea* leaves by *Porina epiphylla* merits attention. The 50-fold variation in leaf size reported is enormous, especially given that only fully mature leaves were studied. Although significantly related by regression analysis, the weak relationship between leaf size and position in the chronosequence accounts for only about 1% of the total variance, indicating that both leaf size and leaf chronosequence position are important for lichen colonisation. All aspects of leaf size considered when examining leaf size as a factor differing between *Capparis arborea* and *Wilkiea macrophylla* should be included as factors influencing colonisation on leaves of different size of *C. arborea*.

Figures 1 and 2 indicate that *Porina epiphylla* has greater cover on moderately small and very large leaves as well as on old leaves. The presence of peaks for cover at two leaf sizes, however, suggests that at least two environmental attributes are likely to be involved as no single factor is likely to show such a distribution. Similar arguments could possibly be made from Fig. 1 with respect to *Mazosia melanophthalma* and *Porina impressa*, although the statistics are less convincing for these less common species. In the context of the significance of leaf size, it is of interest that *Strigula elegans* which colonised first on *C. arborea* and sixth on *W. macrophylla* and *Gyalectidium filicinum* (fourth and seventh respectively), were both species which tended to have a higher level of cover on very small leaves of *C. arborea* than on larger leaves. Conversely, *Mazosia melanophthalma* which colonised fifth on *C. arborea* but second on *W. macrophylla*, had a relatively low cover on small leaves. It appears, therefore, that species which show greater development on small leaves colonise those leaves earlier and are disadvantaged in their colonisation of the uniformly large leaves of *W. macrophylla*.

When considering the relative importance of leaf size and position of a leaf in a chronosequence it must be remembered that leaf size is a measured quantity and comparable from twig to twig, whereas position distal to the apex on different twigs may not represent the same time interval. The position in a chronosequence as it is applied in this study is, therefore, a less well defined attribute than leaf size.

Understanding frequency data is also complex. Higher frequencies on larger leaves is no surprise, for it is reasonable to expect increased probability of colonisation on larger surfaces, although not all taxa did so. The failure of either species of *Strigula* to show increased frequency with leaf age is, however, surprising, for both species are subcuticular, and have been assumed to colonise through breaks in the cuticle (Santesson 1952), which would be expected to increase with leaf age and increased probability of abrasion and herbivory. The appearance of *Strigula* species as early colonisers in either absolute or relative terms may be explained in part by the very rapid growth rate, and hence early visibility, of *Strigula* species a consequence of their hemi-parasitic nutrition (Rogers 1989).

The failure of *Gyalectidium filicinum*, *Porina impressa* and *Strigula elegans* to increase in frequency on older leaves may be explained if these species are short lived, maintaining their population by constant reinfection. The thalli of these three species are characteristically small (Santesson 1952), which is consistent with such an argument; no direct data on life expectancy, however, is available. Since total lichen cover reaches only about 20% and only about 25% of leaves bear any of the three species saturation colonisation is not a compelling argument to explain the limited populations.

The relationship between leaf size and leaf position in a chronosequence with cover and frequency of different lichens has been shown to be complex. However, the basis for the relationship cannot be resolved by a study such as this, but may be elucidated by ecophysiological studies. That there is also a significant interaction between size and position in the chronosequence for total lichen cover indicates a very complex relationship indeed is likely to exist amongst the controlling factors. It is clear that lichen colonisation of leaves is not necessarily the simple time-dependent process reported for *Wilkiea macrophylla* leaves by Rogers *et al.* (1994).

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Colonization, growth, and survival strategies of lichens on leaves in a subtropical rainforest

R. W. ROGERS
Botany Department, University of Queensland, St Lucia, Qld 4067, Australia

Abstract

Rainforest leaves are a relatively short-lived habitat which is well defined in both time and space, and which is occupied by a range of specialized lichens which might be expected to show survival strategies contrasting with those of other lichens. Changes in the lichen populations of individual leaves in subtropical rainforest at Mt Glorious, Queensland, Australia were observed for 1662 days. Over 1100 days elapsed before 50% of surviving leaves showed visible lichen thalli and the probability of colonization estimated from life tables did not exceed 0.42 ± 0.20 at any time. Porina epiphylla *had a relative growth rate of* 3.01×10^{-2} *mm² mm*$^{-2}$ *week*$^{-1}$*, a high value for a lichen. The relative growth rate of* Strigula subtilissima, *however, was* 6.86×10^{-2} *mm² mm*$^{-2}$ *week*$^{-1}$*, the highest rate known for any lichen. Small size and high relative growth rates indicate that lichens on leaves have the most extreme ruderal strategy yet demonstrated amongst the lichens.*

Introduction

Lichens on leaves (foliicolous lichens) usually grow on the cuticle of the upper surface of living leaves, but in a few cases grow between the cuticle and the epidermis. Most are crusts only a fraction of a millimetre thick, and rarely more than 15 mm diameter. Foliicolous lichens are both interesting in themselves and, because of their peculiarities, are likely to help understand the ecology of the other lichens.

Leaves present an unusual habitat, in that each has a well defined beginning when it appears from a growing bud, and an equally well defined end when it abscisses. Any sedentary organism which grows on a leaf must be capable of completing its life cycle in the time available between leaf appearance and leaf fall, using the limited resources available on the leaf surface. Each leaf, therefore, may be considered a natural habitat with well defined natural boundaries in both space and time. The leaf surface creates a niche which, in tropical rainforests, is exploited by a range of plants and fungi, including lichens.

A theoretical framework in which the ecology of lichens may be approached has been proposed by Grime (1979), in which he postulated that plants evolve within a framework determined by limiting resources (stress), damage to the organism (disturbance) and competition. Stress relates to the quality of the niche exploited by the organism, and may be considered as the inverse of productivity. Disturbance is a measure of the length of time for which a niche is available. Competition is the tendency of organisms to exploit the same resources in the environment. Each of these factors may vary in intensity, and also in frequency. These factors result in three primary survival strategies — stress tolerators, ruderals and competitors, respectively. These three strategies can be considered extremes between which triangular ordinations can be constructed showing the relative survival strategies of the chosen organisms. Grime (1979) argued that for herbaceous plants size and maximum relative growth rate (R_{max}) (Grime & Hunt 1975) is sufficient information to ordinate species within the triangle. Determination of the size of lichens presents no special problems, but determination of maximum relative growth rate is not practicable in lichens, for they cannot normally be grown under uniform conditions. Rogers (1988) argued that the minimum relative growth rate necessary to account for growth achieved in the field (R_{field}) was an appropriate substitute for R_{max}. Using this approach Rogers (1988) constructed a triangular strategy ordination of lichens from different habitats and with different growth forms and showed that there is a range of strategies evident in lichens. It was also shown that when compared with herbaceous flowering plants lichens are extreme stress tolerators.

Studies on the rate of colonization and growth of foliicolous lichens are few: Wellman (1972), in an account of algal and lichen pathogens of tropical horticultural plants, reported that lichen thalli were 'barely visible' on leaves 1 year old and de Wilde-Duyfjes (1967) found that thalli of *Strigula elegans* increased in diameter at a rate of about 1 mm per year.

Because of their very small size, foliicolous lichens cannot be considered competitors, but must be either stress-tolerators or ruderals. Nutrient stress is unlikely to be a significant factor, for Witkamp (1970) has shown that epiphylls accumulate nutrients from leaf leachate and subcuticular species are bathed in the cellular fluids of the leaf, and are so placed in a relatively high nutrient environment. Light stress, however, may be a significant factor in the evolution of foliicolous lichens, for they live in a low light environment within the rainforest. While it might be thought that leaves are evanescent structures and that foliicolous lichens, therefore, ought to be relatively ruderal, Rogers and Barnes (1986) showed that the length of life of a leaf in a rainforest (half-life 6.8 years for *Wilkiea macrophylla*) may be so long that foliicolous lichens could not be assumed to have evolved a ruderal strategy on that basis alone. Direct observation of the growth rates and thallus dimensions of foliicolous lichens and comparison with the sizes and growth rates of other lichens is necessary before the place of foliicolous lichens on the stress tolerator–ruderal continuum can be determined.

Methods

Rate of colonization

Lichens colonizing leaves of *W. macrophylla* (A. Cunn.) A.DC. bushes were observed in the complex notophyll vine forest ('Rainforest') at Mt Glorious, (27°19′S, 152°56′E, alt. 600 m), where the bushes are a major component of the understorey.

Thirty-nine twigs from seven bushes were labelled with stainless steel tags, and leaves identified by their position on the twig. Lichens on each leaf were identified to species level using a 10× lens: a flashlight was necessary to augment available daylight even on sunny days. New leaves produced were recorded at intervals between 30 and 113 days for 1662 days (4.55 years), the study being stopped when nearby roadworks changed the light regime in the area. At each recording time the lichen flora of all leaves was noted.

The rate of colonization was determined for *Gyalectidium* aff. *filicinum* Mull.Arg., *Porina epiphylla* (Fee) Fee, *Strigula subtilissima* (Fee) Mull.Arg. and for the first reported colonization by any lichen at all whether it could be attributed to a taxon or not. This was done by constructing tables analogous to standard 'life-tables' (Krebs 1978) in which the mid-point of the period at the end of which a leaf or lichen on a leaf was first recorded was treated as the 'birth' date of the leaf or lichen, and the mid-point of the period at the end of which a leaf had disappeared was treated as the death date of that leaf and any lichen on it. Only data from leaves initiated during the study were considered, and each cohort of leaves was followed separately, ensuring that ages of leaves and times taken before lichen colonization occurred were known. The proportion of surviving leaves colonized by lichens was also calculated.

Growth rates

After the last series of field observations, selected leaves were harvested and returned to the laboratory. On those for which the date of the first appearance of lichen thalli was known the size of the largest distinct colony of the two common species *P. epiphylla* and *S. subtilissima* was measured (to the nearest 0.1 mm) along their longest axis, and at right angles to that axis, under a dissecting microscope. Assuming the thalli to be elliptical the relationship between maximum area achieved and maximum possible age of thalli could be established.

Armstrong (1976) demonstrated that an exponential function most adequately described lichen growth, a conclusion which Topham (1977) believed to apply generally to lichens for up to 10 years, although older lichens entered a linear growth phase. Hill (1981) suggested a more complex relationship between growth and size, but that relationship was also essentially an exponential one, especially at small thallus sizes. In order to estimate the growth rate of foliicolous lichens, therefore, a least-squares regression was calculated for the relationship between the natural log of the thallus area and thallus age. When calculating this regression only the maximum sized thallus in any age class of leaves, and only those points which showed an increase in maximum size with age were considered. This meant that if the maximum thallus size found on any age class of leaves was smaller than that found on younger leaves, then the cohort with smaller thalli was excluded from further calculations. This ensures that the growth rate calculated will account for the growth actually observed.

Results

Determination of when lichens first appeared on a leaf was necessarily imprecise, but presence of thalli greater than 0.5 mm diameter would certainly have been noticed. No lichen growth, however, was apparent until over 500 days had elapsed, and over 1100 days elapsed before 50% of leaves showed lichen thalli visible with a hand lens (Fig. 1a). Examination of 'life table' data indicated that the cumulative probability of colonization of a leaf reached only 0.42 (±0.20) after 1662 days.

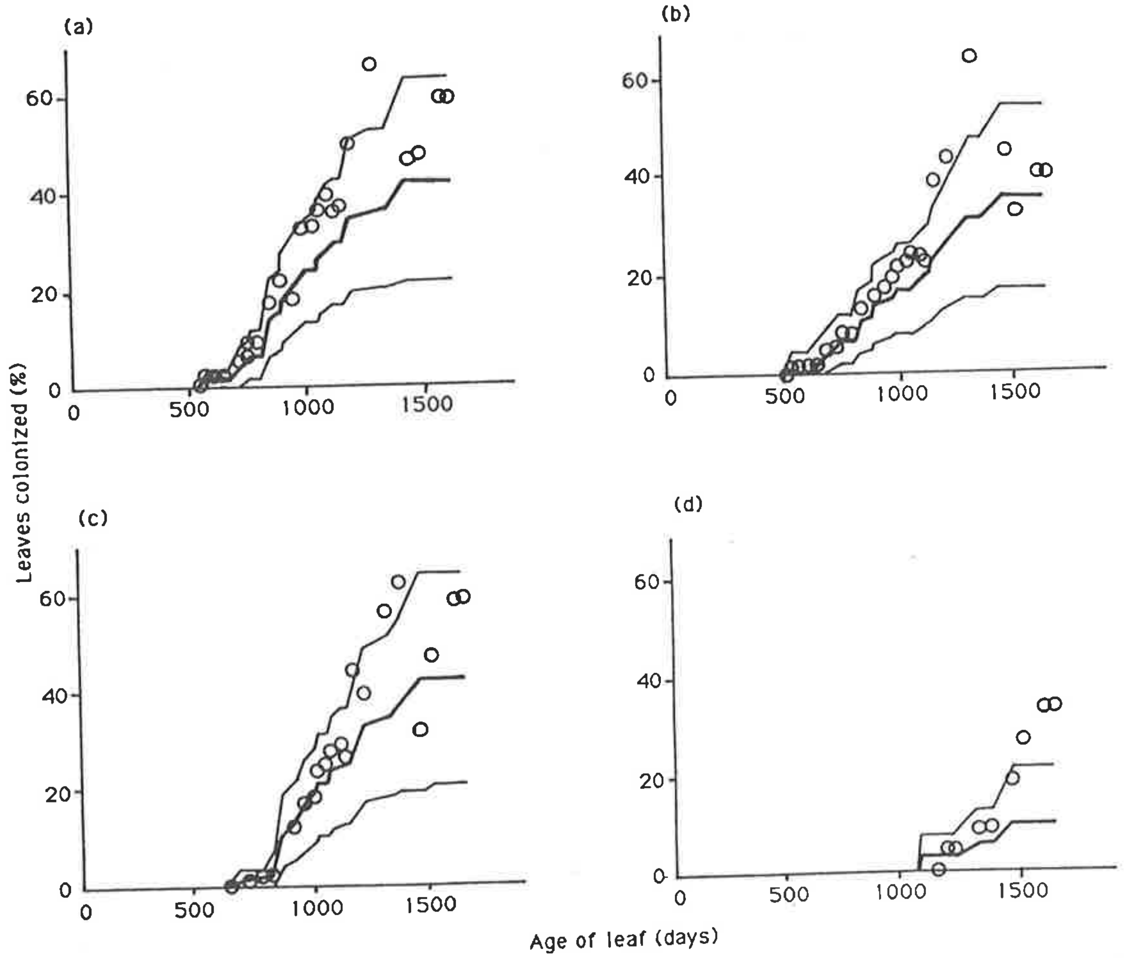

FIG. 1. The probability that a leaf of *W. macrophylla* of given age in a subtropical rainforest at Mt Glorious, Australia, will be colonized by: (a) any lichen; (b) *P. epiphylla*; (c) *G.* aff. *filicinum*; (d) *S. subtilissima*, as estimated from life tables, with 95% confidence intervals indicated. Circles indicate the proportion of leaves surviving actually colonized.

The probability of colonization of leaves of various ages by *P. epiphylla*, *G.* aff. *filicinum* and *S. subtilissima* is shown on Fig. 1, together with the proportion of surviving leaves colonized by each of these taxa.

Growth rates

Porina epiphylla thalli up to 15 mm diameter and with well developed perithecia grew on leaves which appeared during the study period. These thalli were clearly mature and well developed, reaching the size reported by Santesson (1952) as normal for the species. Twenty-one different leaf age classes were available for the measurement of maximum thallus size and the equation $y=0.601e^{0.0043x}$ (y=area of thallus in mm^2, x=time since the appearance of the first lichen on the leaf, e=the base of natural logarithms) described the relationship between age and thallus area ($r^2=0.93$, $P<0.01$). From this relationship a relative growth rate of 3.01×10^{-2} mm^2 mm^{-2} week^{-1} was calculated.

Strigula subtilissima mature fertile thalli were found on leaves which had appeared during the study period. The maximum thallus size in 12 different age classes was recorded, and the equation $y=8.01\ e^{0.0098x}\times10^{-3}$ described the relationship of thallus age and area ($r^2=0.99$, $P<0.01$). From this relationship a relative growth rate of 6.86×10^{-2} mm^2 mm^{-2} week^{-1} was calculated.

Discussion

Colonization of leaves

The time taken for lichens to appear on *W. macrophylla* leaves is amongst the shorter times reported in the literature for lichen colonization, and only a little slower than that reported by Wellman (1972) for lichens on leaves of crop plants. Colonization can occur on deciduous twigs in the first year (Degelius 1978) but more usually 2 or 3 years elapse before the first lichens appear on twigs (Bailey 1976; Degelius 1978; Hale 1981). It takes 1–4 years for lichens to become apparent on soil (Fink 1917), 2 or 3 years on dead organic matter in old fields (Robinson 1959), 2–4 years on bare rock (Fink 1917) and less than 5 years on glacial moraines (Orwin 1970). As the mean number of species of lichens on leaves continues to increase on the oldest classes of *W. macrophylla* leaves (Conran & Rogers 1983), the process of colonization must continue for much longer than the estimated leaf half-life of 6.8 years (Rogers & Barnes 1986). While the claim by de Wilde-Duyfjes (1967) that *S. elegans* (Fee) Mull.Arg. colonized leaves only 2 months old cannot be rejected out of hand, it was based not on direct observation, but on the assumption that the leaves concerned lived for only 12–14 months. This assumption is not tenable given the data of Bentley (1979) and Rogers and Barnes (1986) concerning the length of life of leaves on rainforest shrubs, nor is it consistent with the observations of Wellman (1972).

Probabilities of colonization

The use of life tables to estimate cumulative probabilities of colonization assumes that the probability of colonization remains constant. An estimate based on the proportion of surviving leaves colonized does not make this assumption, but is subject to large fluctuations. The results of the two methods are, however, generally concordant (Fig. 1), and the proportion of surviving leaves that have been colonized usually falls within the 95% confidence levels for probability of colonization. It is, however, noticeable that late in the study the proportion of surviving leaves colonized is consistently higher than the predicted probability of colonization from life tables. This may simply be the consequence of inherent errors in the small number of leaves followed for longer periods, or it may represent a change in probability of colonization of new leaves during the term of the study.

Growth rates

The relative growth rate of *S. subtilissima* is the highest yet reported for any lichen exceeding those reported by Rogers (1988) and by Snelgar and Green (1982). *Porina epiphylla* has a lower relative growth rate than *S. subtilissima*, but it is still amongst the higher values known. Using the rather sketchy data of de Wilde-Duyfjes (1967) it was possible to calculate the relative growth rate of *S. elegans*, another subcuticular foliicolous lichen, by assuming that a thallus 1 mm diameter grew to 2 mm diameter in 100 days. The calculated relative growth rate for *S. elegans* of 6.64×10^{-2} mm^2 mm^{-2} week^{-1} is very close to the figure of 6.86×10^{-2} mm^2 mm^{-2} week^{-1} for *S. subtilissima*. These values are an order of magnitude larger than the next highest rate, that of *Cladina alpestris*, which has a relative growth rate of 4.5×10^{-3}g g^{-1} week^{-1} (Rogers 1988).

Apart from the three foliicolous lichens discussed above, the other lichen species with high relative growth rates all have large thalli, and are from cool climates (Rogers 1988): *Cladina alpestris*, *Stereocaulon oregana* and *Cetraria nivalis* (data of Karenlampi 1971) are all fruticose species from Finland, and *Lobaria oregana* (data of Rhoades 1977) is from cool mountain forests in Canada. *Sticta caperata* and *Pseudocyphellaria homophylla* have relative growth rates of 2.02×10^{-2} mm^2 mm^{-2} week^{-1} and 2.58×10^{-2} mm^2 mm^{-2} week^{-1}, respectively, if calculations are based on the thalli with an initial diameter of 25 mm, about the smallest thalli measured by Snelgar and Green (1982). These two species are from mountain *Nothofagus* forests of New Zealand. The tropical and subtropical species examined (*Dirinaria applanata*, *Dirinaria confluens*, *Hyperphyscia adglutinata*, *Parmotrema austrosinense* and *Pyxine subcinerea*) all show much lower relative growth rates (Rogers 1988).

The very high relative growth rate of *Strigula* spp. may be related to the photobiont of the genus, the green alga *Cephaleuros*, and its peculiar growth habit. *Cephaleuros* is an obligate subcuticular epiphyte of leaves, stems, and fruits (Chapman & Good 1983) and is a well known pathogen of crops in tropical areas (Wellman 1972). *Cephaleuros* is capable of heterotrophic growth using a range of carbohydrate sources, and can use a number of amino acids as a nitrogen source. An organic carbon source increases its growth rate in the light (Joubert *et al.* 1975). Since it is subcuticular, the intercellular fluids of the leaf must supply its water and mineral needs. *Cephaleuros*, therefore, may be considered a parasite which obtains at least its water and minerals, and possibly assimilated materials as well, from the host plant.

Leaves of *W. macrophylla* show a marked response to growth of a *S. subtilissima* thallus. In transverse sections of a leaf cut through a *S. subtilissima* thallus a thick cork-like layer is apparent within the leaf, above which the pallisade mesophyll cells of the leaf have proliferated and become disorganized. There is, however, no evidence that fungal hyphae penetrate the epidermal cells, nor that they pass between the epidermal cells deeper into the leaf.

Although the fungal component of a subcuticular lichen does not enter the leaf tissues it presumably lives under particularly favourable circumstances for, like its photobiont, it is exposed directly to the intercellular fluids of the leaf. A number of fungal parasites are able to gain their nutrition exclusively from the intercellular fluids of leaves (Manners & Gay 1983), although fungi which form lichens with green algae normally absorb polyols not the sugars which predominate in the apoplastic space of leaves (Smith *et al.* 1969). Thus, while the lichen fungus must directly parasitize plant tissues for water and minerals, it may absorb amino acids and carbohydrates as well.

A subcuticular lichen thallus, therefore, apparently has a continuous favourable water and nutrient supply, as well as a possible heterotrophic carbon source. Such conditions could account for the relatively high growth rate observed in *Strigula* species.

Strategies

Grime (1979) adopted size (spread and height) and relative growth rate as attributes well suited for the placing of plants in a triangular strategy ordination, as both were effective and relatively easily obtained. Rogers (1988) adapted this approach for lichens. If the morphological index for lichens used by Rogers (1988) is applied (Morphological Index (M) = T + D/2 where T = 1 for thalli less than 0.5 mm thick, which is true for the lichens studied in this case, and D = 1 for lichen thalli less than 2 cm diameter, which is also true for the lichens studied in this case) the foliicolous lichens studied here can be incorporated into a triangular ordination along with the other lichens (Fig. 2). In Fig. 2 the two *Strigula* species fall outside the CSR triangle, but the original axes of Rogers (1988) have been retained to emphasize the unique mode of

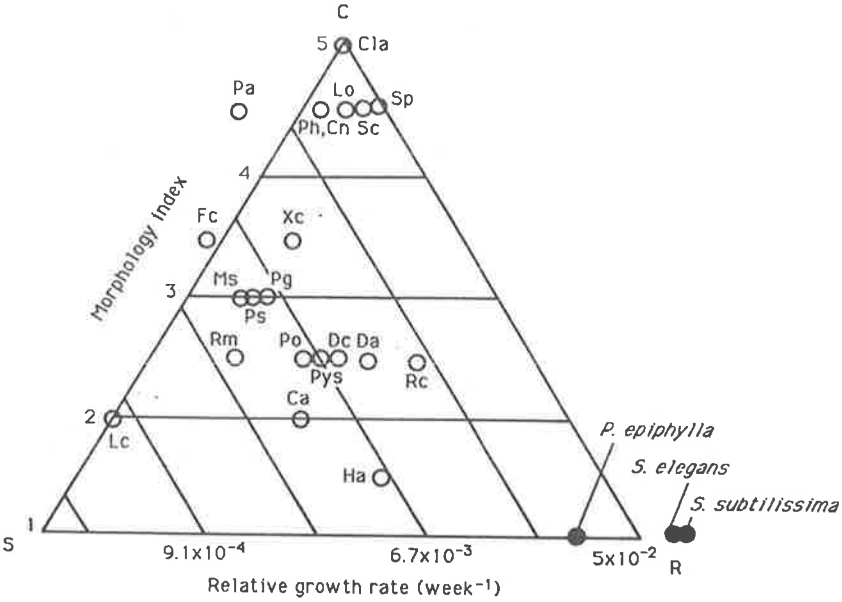

FIG. 2. CSR ordination of lichens using data from Rogers (1988) and Snelgar and Green (open circles) with the addition of the foliicolous lichens *P. epiphylla*, *S. subtilissima* and *S. elegans* (solid circles). The subcuticular partial leaf parasites *S. subtilissima* and *S. elegans* have been left lying outside the triangle because of their biological differences from the other lichens. Ca, *Caloplaca aurantia* (Pers.) Hellb.; Cla, *Cladina alpestris* (L) Nyl.; Cn, *Cetraria nivalis* (L) Ach.; Da, *Dirinaria applanata* (Fee) Awasthi; Dc, *D. confluens* (Fr.) Awasthi; Fc, *Flavoparmelia caperata* (L) Hale; Ha, *Hyperphyscia adglutinata* (Floerke) Mayrhofer & Poelt; Lc, *Lecanora caesiorubella* Ach.; Lo, *Lobaria oregana* (Tuck.) Mull. Arg.; Ms, *Melanelia sulcata* (Tayl.) Esslinger; Pa, *Parmotrema austrosinense* (Zahlbr.) Hale; Pg, *Parmelia glabratula* ssp. *fuliginosa* (Fr. ex Duby) Laundon; Ph, *Pseudocyphellaria homeophylla* (Nyl.) Dodge; Po, *Phaeophyscia orbicularis* (Neck.) Moberg; Ps, *Parmelia saxatilis* (L) Ach.; Pys, *Pyxine subcinerea* Stirton; Rm, *Ramalina maciformis* (Del.) Bory; Rt, *Rhizocarpon tinei* (Tornab.) Runemark; Sc, *Sticta caperata* Bory in Nyl. Sp, *Stereocaulon paschale* (L) Fr; Xc, *Xanthoparmelia conspersa* (Ach.) Hale. Morphology index = $(T+D)/2$, when D = thallus thickness or height: <0.5 mm = 1; 0.5–1 mm = 2; 1–2.5 mm = 3; 2.5–10 mm = 4; >10 mm = 5. When D = thallus diameter: <2 cm = 1; 2–5 cm = 2; 5–10 cm = 3; 10–25 cm = 4; >25 cm = 5.

nutrition of these two subcuticular lichens, for which the ability of the host to provide water, mineral nutrients, and perhaps assimilates, may be as important as, or more important than, attributes of the lichen itself.

Incorporation of relative growth rates derived from both weight and size increments on the one set of axes is facilitated by both having only a time dimension. Since weight and area are linearly related for a number of foliose lichens (Rogers 1988), it seems likely that area and dry weight of crustose lichens are similarly linked. Extrapolation to fruticose thalli is less secure, but in all cases the growth rates of fruticose lichens were based on dry weight studies. It is, therefore, possible to consider all the relative growth rates plotted on Fig. 2 as based on dry weight estimates.

The very small size of the foliicolous lichens places them on the base of the triangle well away from the competitive pole. Stress tolerant species have low relative growth rates, and ruderal species high relative growth rates, therefore the high growth rates of *P. epiphylla*, *S. subtilissima* and *S. elegans* show that amongst the lichens they are extreme ruderals, i.e. they have evolved in an environment in which disturbance (*sensu* Grime 1979, in which disturbance is defined as partial or total destruction of the biomass) is the major selecting factor. In this context, however, it must be remembered that the relative growth rates of lichens is several orders of magnitude smaller than those recorded for the herbaceous flowering plants studied by Grime (1979) (Rogers 1988). The disturbance which seems most likely to be the selecting factor is that associated with leaf fall, which invariably results in death of the lichen. A lichen in such a habitat is in a position analogous to a desert ephemeral, in that it must complete its life cycle before a disturbance (in the one case drought, in the other leaf fall) results in its destruction, preventing reproduction from occurring.

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LICHEN SUCCESSION ON *WILKIEA MACROPHYLLA* LEAVES

R. W. ROGERS*, A. BARNES‡ and J. G. CONRAN§

Abstract: Changes in foliicolous lichen populations of the shrub *Wilkiea macrophylla* in rainforest at Mt Glorious (south-east Queensland) were observed in the field for 3 years. Leaves successively distal from the twig apices were treated as a chronosequence for lichen successional studies. Five species of lichen each colonized more than 50% of the leaves, and leaves successively distal from the apex showed increasing mean species number. Lichen cover rose until the seventh most distal leaf from the first colonized leaf along a twig, reaching 52%. More distal (older) leaves had apparently lower cover. Different lichen species show different instantaneous colonization rates that vary with time. The sequence of lichen colonization and subsequent community composition is best described by a 'Tolerance' model of succession if a single leaf is selected as the unit or with a 'Chronic Disturbance' model if a leaf population is considered.

Introduction

There have been few studies concerning the ecology of foliicolous lichens although the taxonomic peculiarity of the group has been long established (Santesson 1952). It is apparent from Santesson's reports that the foliicolous lichens normally show a broad tolerance of substrata, and that many are not restricted to leaves. Amongst the few ecological studies, Schell & Winkler (1981) examined the percentage cover of lichens on several sequences of leaves along twigs of *Eugenia* from Brazil, and Conran & Rogers (1983) estimated the frequency of lichen species on successively older leaves of *Wilkiea macrophylla* (A. Cunn.) DC (Monimiaceae) in Queensland. These studies assumed that leaves down a stem are a chronosequence, that is, an age sequence that can be studied as if a succession, a concept not uncommonly applied in ecology (e.g. Walker *et al.* 1984). Chronosequence theory, however, assumes that spatial separation has little significance, and that the environment has not changed appreciably during the time period under consideration. Age is not the only difference between leaves successively distal from the apex: lower leaves are subject to water flow from those above them, which may increase their nutrient supply, and they are also shaded by them. The only reported study of lichen colonization of leaves in real time is from Rogers & Barnes (1986) who examined lichen colonization of leaves of *W. macrophylla* with a respect to leaf half-life.

In order to improve understanding of successional processes in foliicolous lichens, and to determine the appropriate techniques for undertaking such

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*Botany Department, University of Queensland, St Lucia, Queensland 4072, Australia.
‡Tropical Health Program, University of Queensland, St Lucia, Queensland 4072, Australia.
§Botany Department, University of Adelaide, Adelaide, South Australia 5000, Australia.

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studies, lichens on the leaves of *W. macrophylla* bushes in the complex nothophyll vine forest (' rainforest ') at Mt Glorious, (27°19′S, 152°56′E, 600 m alt) were observed. At Mt Glorious *W. macrophylla* bushes are a major component of the understorey, and the leaves are obviously colonized by a diversity of lichens. Variations in the light environment within a similar forest at Gambubal in south-east Queensland (27°48′S, 152°55′E) have been documented by Turnbull & Yates (1993), who found a photon flux density consistently below 5 μmol m^{-2} s^{-1} in the understorey, compared with almost 2000 μmol m^{-2} s^{-1} in a canopy gap. Bjorkman and Ludlow (1972) found that the light intensity in a similar forest on the nearby Lamington plateau (28°13′S, 158°3′E) was only about 0·5% of that above the forest canopy. *Wilkiea macrophylla* bushes are especially suitable for this study, as they have small numbers of pairs of distichously opposite leaves, widely spaced along woody stems.

We were able to observe the succession of lichens on leaves in real time, and also to apply chronosequence theory to extend the study beyond the time available for direct observation. Such an approach is necessary as Rogers & Barnes (1986) estimated a mean half-life of 6·8 years for *Wilkiea macrophylla* leaves at this site. A further difficulty is the non-linearity of the age sequence down a stem: stems may resume growth after a break of several years, and may produce a series of leaves of effectively the same age in a single burst of growth.

Consideration of the early stages of the colonization of leaves by lichens is made difficult by the absence of any information on the process of establishment of lichens on leaves, and by the very limited information available about lichen establishment from propagules on any surfaces. Given that developed vegetative reproductive structures are rare in foliicolous lichens, however, it must be assumed that reproduction is by spore germination and subsequent contact with an appropriate alga.

Materials and Methods

Real-time studies of succession in the field

The lichen flora on every leaf of seven *W. macrophylla* bushes was recorded at Mt Glorious. The twigs were labelled with stainless steel tags, and leaves identified by their position on the twig. Lichens on each leaf were identified to species level using a × 10 lens working with a flashlight because of low light levels in the forest. New leaves produced were recorded at intervals of between 30 and 113 days for 3 years. At each recording time the lichen flora of all leaves was studied.

The frequency with which each lichen occurred on leaves and the proportion of leaves bearing either no lichens at all or only indeterminate thalli was calculated using records from all leaves present at the initiation of the study and leaves that developed prior to the completion of the study period.

Real-time data were examined in several ways. In a few cases the rate of apparent colonization was estimated for individual taxa that had reached a determinable state by constructing tables analogous to standard life-tables using data from leaves initiated after the commencement of the study and thus with known age. This approach could not, however, be used for most taxa as identifiable thalli rarely developed within 3 years of leaf initiation. The rank order of colonization rates for these slower-developing taxa was inferred from their sequence of colonization by examining lichen taxa (as defined below) in pairs and calculating, as a proportion of all occurrences, the frequency with which one colonized before the other. These investigations were not amenable to probabilistic analysis because leaves were of varying and unknown age, leading to unequal opportunities for colonization, and because leaves on the same twig were not independent of one another.

The seven bushes studied had a total of 39 twigs and 188 leaves. As it was not possible to identify all lichens to species in the field, the following seven categories were used:

1. *Gyalectidium* sp., probably *G. filicinum* Müll. Arg.;
2. *Mazosia melanophthalma* (Müll. Arg.) R. Sant.;
3. *Porina epiphylla* (Fée) Fée;
4. *Porina impressa* R. Sant.;
5. *Strigula* species including *S. elegans* (Fée) Müll. Arg., *S. subtilissima* (Fée) R. Sant. and *S. schizospora* R. Sant., which could not be separated reliably in the field and have therefore been retained as an aggregate.
6. *Tricharia albostrigosa* R. Sant.
7. Indeterminate sterile thalli.

Rare species seen but not studied in the field included *Porina leptosperma* Müll. Arg., *P. rufula* (Krempelh.) Vainio, *Lopadium fuscum* Müll. Arg., and *Sporopodium xantholeucum* (Müll. Arg.) Zahlbr.

Laboratory studies of an apparent chronosequence

To establish the pattern of lichen colonization on leaves along a twig, assuming a chronosequence, 25 twigs having terminal leaves without lichens were taken from the vicinity of the bushes observed in the field. In the laboratory the 360 leaves on the twigs were examined under a dissecting microscope and the species present on each leaf recorded. Examination of leaves under the dissecting microscope allowed better discrimination of species and detection of additional taxa including *Mazosia phyllosema* (Nyl.) Zahlbr., *Opegrapha vegae* R. Sant., *P. limbulata* (Krempelh.) Vainio, *Strigula elegans* (Fée) Müll. Arg. *S. schizospora* R. Sant., *S. subtilissima* (Fée) R. Sant., *Trichothelium alboatrum* Vainio and a species of *Calenia*. Percentage cover for each taxon was estimated by superimposing a grid over the leaf. To standardize comparisons of leaves on different twigs ascending numbers were assigned to leaves increasingly distal from the apex, numbering commencing at the youngest colonized leaf. The frequency of occurrence and percentage cover for each lichen species was calculated for each leaf position along stems.

The sequence of colonization was investigated by estimating the ratio of the proportion of stems with records of taxon A more proximal than taxon B to the proportion of those in which B occurred more proximal than A. If only one of the two taxa occurred on a twig it was taken as a proximal occurrence, and mutual occurrence at the relevant leaf position was treated as a 0·5 score for each taxon.

Leaves in position 7 or further down the stem were grouped into a single class to ensure that at least 25 leaves were included in each leaf position class for the frequency calculations. This grouping, however, makes the standard error estimates approximations because of the loss of independence within samples.

Results

Real-time successional studies in the field

Lichens were restricted to the morphological upper surface of the leaf, the morphological lower surface not being colonized even if the leaf was inverted by accident of growth.

Life-tables showing the probability of colonization by the two more common lichen taxa (indeterminate sterile thallus and *Gyalectidium*) were compiled and the probability of colonization as a function of leaf age estimated (Figs 1 & 2). The ratio of the number of leaves first colonized by each species in relation to all other species during the field observations is presented in Table 1.

Chronosequence studies

The mean species richness of successively older leaves is shown in Fig. 3. Frequency, mean cover of the more common species, and mean total lichen

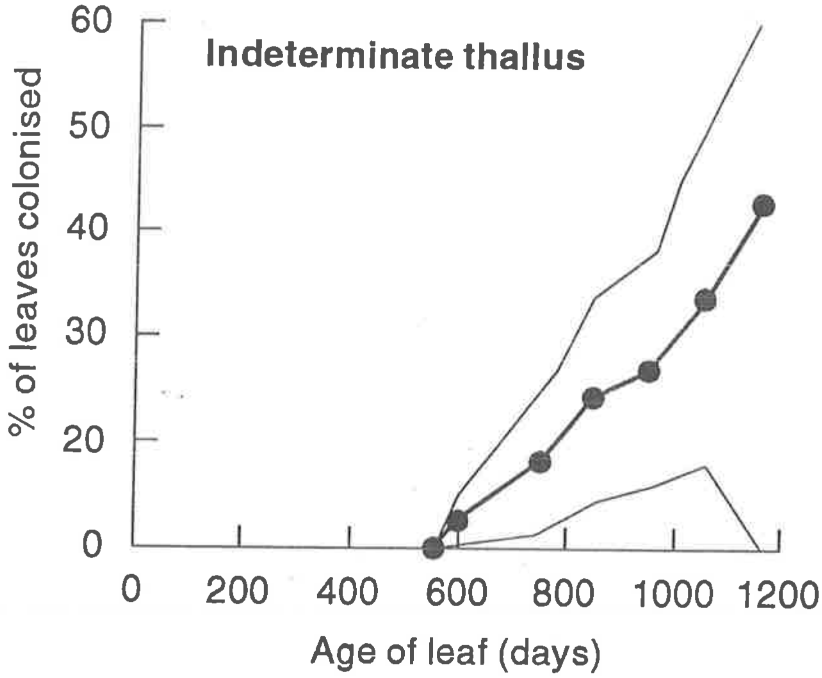

FIG. 1. Probability of colonization by indeterminate lichen thalli of leaves of *Wilkiea macrophylla* of known age observed in real-time. Fine lines indicate 95% confidence intervals.

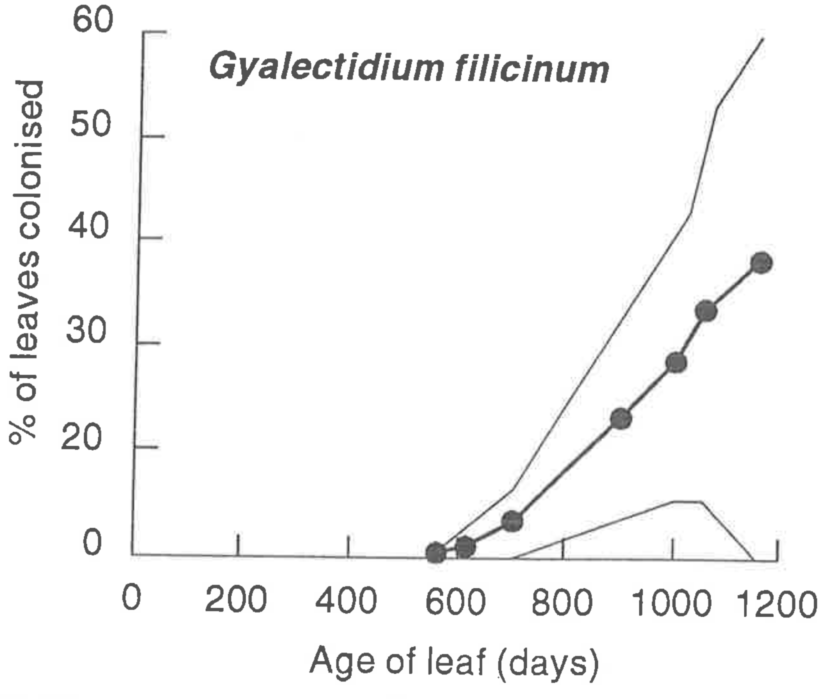

FIG. 2. Probability of colonization by *Gyalectidium* sp. of leaves of *Wilkiea macrophylla* of known age observed in real-time. Fine lines indicate 95% confidence intervals.

TABLE 1. *The ratio of the number of leaves first colonized by taxon A to the number of leaves first colonized by taxon B, calculated from real-time observations*

	Taxon A						
Taxon B	IT*	GY	PE	SI	PI	MM	TA
GY	3·27						
PE	2·91	2·13					
SI	4·13	4·04	2·48				
PI	4·61	4·46	9·14	1·61			
MM	8·19	11·73	26·67	7·69	6·14		
TA	21·33	43·33	8·78	6·40	3·31		
NA	37	32	23	4	1	1	1

*IT, indeterminate thallus; GY, *Gyalectidium* sp.; PE, *Porina epiphylla*; SI, *Strigula* spp.; PI, *P. impressa*; MM, *Mazosia melanophthalma*; TA, *Tricharia albostrigosa*; NA, total number of leaves colonized by species A during the period of observation.

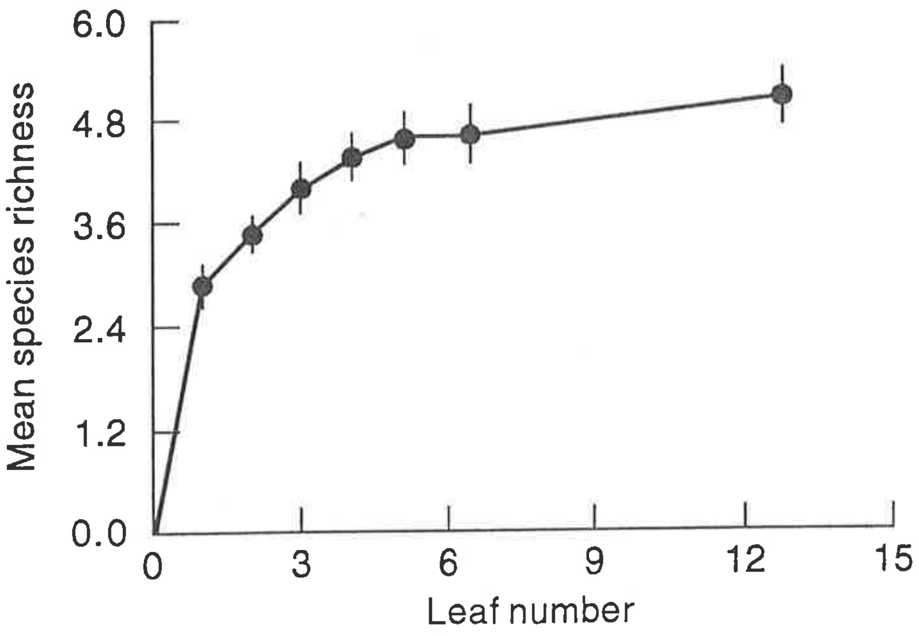

FIG. 3. Mean species richness (mean number of species per leaf) of leaves of *Wilkiea macrophylla* as observed in a chronosequence study, and therefore of putatively increasing age. Leaf numbers represent successively distal leaves from the apex of the shoot, more distal leaves being pooled into a single class to ensure that at least 25 individuals were present in every class. Bars indicate standard errors of the mean.

cover are shown in Figs 4 and 5. Species frequency increased distally with five species present on more than 50% of the older leaves (Fig. 4).

Lichen cover varied greatly from leaf to leaf, and taxon to taxon. On one leaf a lichen cover of 100% was recorded, and the highest cover reported for a single

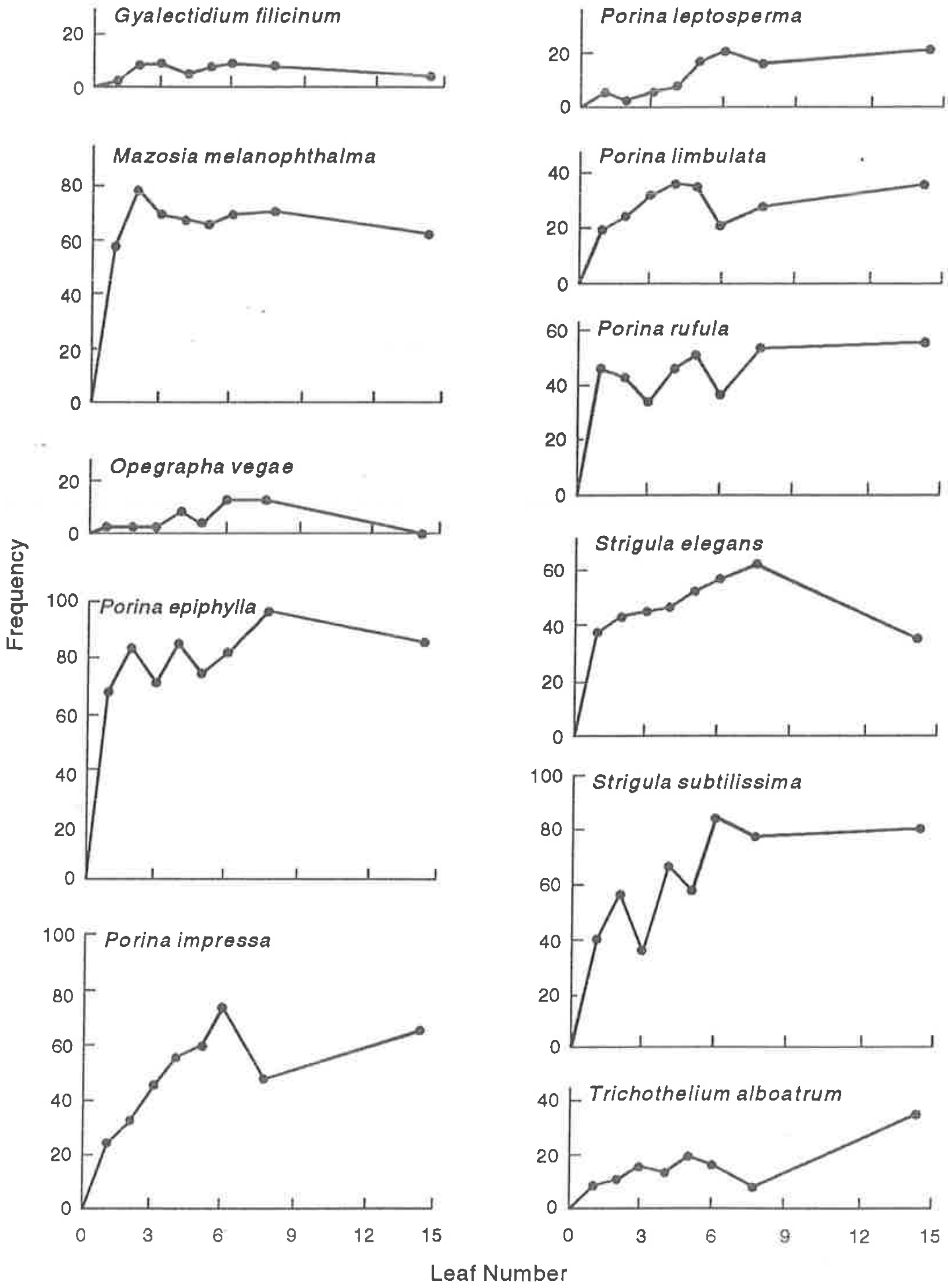

FIG. 4. Frequency of occurrence of lichen species on leaves of *Wilkiea macrophylla* as observed in a chronosequence study, and therefore of putatively increasing age. All leaves ten or more locations distal from the youngest leaf bearing lichens were pooled to ensure that at least 25 leaves were present in each class.

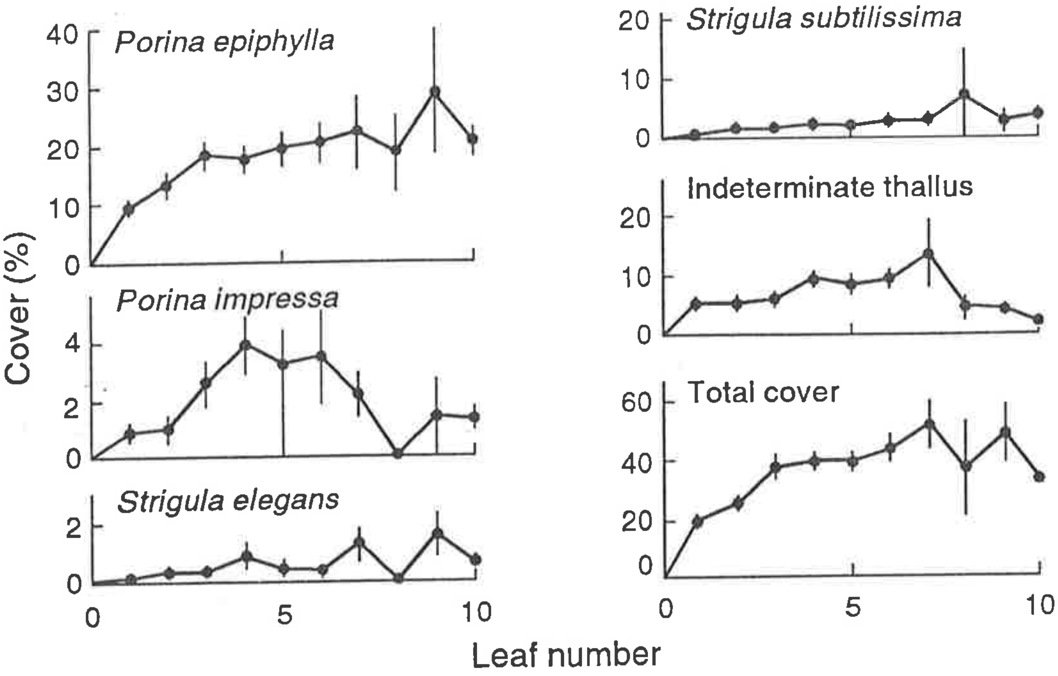

FIG. 5. Mean cover of selected species of lichens and of total lichen cover on leaves of *Wilkiea macrophylla* as observed in a chronosequence study, and therefore of putatively increasing age. All leaves ten or more locations distal from the youngest leaf bearing lichens were pooled to ensure that at least 25 leaves were present in every class. Bars indicate standard errors of the mean.

taxon on any one leaf was 78% for *Porina epiphylla*, with cover of 49% recorded for indeterminate thalli, 48% for *Mazosia melanophthalma*, 42% for *Strigula subtilissima*, 36% for *P. impressa*, and 20% for *P. limbulata*. All other species had a maximum cover of less than 10%. The mean total lichen cover reached a maximum of 52% at the seventh leaf position, where *P. epiphylla* had a mean cover of 22%. Indeterminate thalli also had their maximum mean cover at leaf 7, with 14% cover. Mean lichen cover decreased to 33% on the most distal class of leaves.

Information on the sequence of colonization is presented in Table 2. For each pair of taxa the ratio of the number of twigs proximally colonized by one taxon to the number proximally colonized by the other are presented. This table is so organized that the maximum number of cells have a value greater than one, and that the values tend to increase from top to bottom and right to left. As a consequence, the order of the taxa indicates their average ranking with respect to rates of colonization, the fastest colonizers appearing to the top and left of the table.

Discussion

Colonization of leaves

The detection of the very earliest stages of lichen establishment is not possible in the field, for this would require the examination of surfaces with a compound microscope or scanning electron microscope to detect spore germination and subsequent lichenization of a photobiont. However, the time

TABLE 2. *The ratio of the proportion of twigs for which A appeared on a twig nearer the apex than B : proportion of twigs for which B occurs nearer the apex in the chronosequence study*

	Taxon A								
Taxon B	PE*	IT	MM	SS	PR	PI	PL	SE	GY
IT	1·8								
MM	1·4	1·4							
SS	2·8	2·1	1·2						
PR	1·0	2·6	1·6	1·2					
PI	3·6	2·6	3·5	1·3	2·4				
PL	2·6	2·9	4·0	0·6	1·3	1·3			
SE	2·3	4·0	1·4	1·1	0·7	2·1	2·6		
GY	11·5	5·3	15·7	13·7	13·7	5·3	16·0		
N	25	25	24	25	21	16	24	8	
L	201	168	104	92	60	79	31	32	8

*PE, *Porina epiphylla*; IT, indeterminate thallus; MM, *Mazosia melanophthalma*; PR, *P. rufula*; SE, *Strigula elegans*; SS, *S. subtilissima*; PI, *P. impressa*; PL, *P. limbulata*; GY, *Gyalectidium* sp; N, total number of twigs upon which species A was detected;, L, total number of leaves upon which species A was detected.

taken for lichens to become apparent on these leaves is similar to that reported in the literature for other substrata—about 2 years for deciduous twigs (Bailey 1976; Hale 1981), 2 or 3 years on dead organic matter in an old field (Robinson 1959), and less than 5 years on glacial moraines (Orwin 1970). As species richness increases onto the oldest leaves (Fig. 3), the process of colonization must continue for much longer than the estimated leaf half-life of 6·8 years. There is, therefore, no evidence at this stage to suggest that the colonization processes of foliicolous lichens are any faster than those of lichens on many other surfaces. The speed of colonization is the same as that known for more-or-less permanent surfaces and probably explains why foliicolous lichens are not found on a wider range of leaves, as few plants have leaves that survive for longer than 2 years (Rogers & Clifford 1993).

Lichen frequency

The pattern of increasing lichen frequency on leaves of increasing age in this study is similar to the findings of Conran & Rogers (1983), although they found that *Sporopodium xantholeucum*, *S. phyllocharis* var. *flavescens* and *Tricharia albostrigosa* decreased in frequency on older leaves. In this study, *S. phyllocharis* var. *flavescens* was not found at all and the other two species were rare. There was, however, an apparent reduction in frequency of *Opegrapha vegae* and *Strigula elegans* on older leaves at the Mt Glorious site, suggesting that undamaged leaves (which cannot be colonized by *S. elegans*) survive longer than damaged ones.

Lichen cover

The increase in lichen cover with leaf age was expected to be a consequence of lichen colonization and thallus growth. On leaves in the oldest leaf class, cover by indeterminate thalli or *P. impressa* is less than on the next youngest class (leaf class 7). The reduction in cover of indeterminate material is probably due to thalli maturing, thereby enabling identification. However, *P. impressa* shows a substantial reduction in cover that cannot be accounted for in such a manner. It is the only identified species consistently present to show a reduction in cover on older leaves, implying that it has a different life strategy (*sensu* Grime 1979) from the others.

Sequence of colonization

Direct observation of a colonization sequence was not feasible, for more than one species was usually present on a leaf when it was first examined. This discussion is therefore based on the sequences implied in Tables 1 and 2. If taxa colonize independently, are equally observable, and are influenced by the same factors in their rates of colonization, Tables 1 and 2 would be expected to show consistent trends of higher values down and to the left of the tables. The trends in Table 1 are like this, with some variation associated with *M. melanophthalma*. Table 2, however, is much more complex with frequent exceptions to the expected pattern.

Differences are apparent between sequences of colonization determined from the time-lapse study and the chronosequence study. In particular, *Gyalectidium* was second in the sequence based on real-time studies, but last on chronosequence studies, and *M. melanophthalma* was last in the real-time study but third in the chronosequence study: these differences may have a number of explanations. Although the forest appears uniform, there are apparently differences between the two study sites as lichen habitats. For example, *Gyalectidium* is common in the real-time study site, but not at the chronosequence site. Secondly, some differences may be artefacts of the methodologies. It is likely that thalli indeterminate in the field were identifiable in the laboratory, reducing the occurrences of indeterminate thalli, and resulting in the recognition of *P. epiphylla* as the earliest colonizer in the chronosequence study. In the field, young thalli of *M. melanophthalma* were easily confused for *Gyalectidium*, which may in part explain why *M. melanophthalma* appeared late in the real-time study, but early in the chronosequence study.

A model for lichen colonization of leaves

Not all lichens show the same rates of colonization as others, but how the rate of colonization varies with time is not clear. A simple model for lichen colonization that allows for differing colonization rates between taxa and for rates to be influenced by leaf age was, therefore investigated.

Consider a single leaf of age t days, and assume that colonization by each taxon is independent of whether a leaf is colonized by others. If it is assumed that the instantaneous colonization rate of one taxon relative to another remains constant as leaf age increases then the probability of colonization by lichen species A in the time interval t to $t+\Delta t$ may be written as $L_A f(t)$ where L_A is a constant and $f(t)$ is a function of leaf age. Making the same assumption, it can be shown that the expected values of the ratios displayed in Table 1 are given by L_A/L_B and that L_A/L_B is also the approximate expected value of the ratio of the

Table 3. *The ratio of leaves colonized by species A: leaves colonized by species B, based on field observations of succession*

	Taxon A					
Taxon B	IT*	GY	PE	SI	PI	MM
GY	0·97					
PE	1·40	1·44				
SI	1·29	1·32	0·92			
PI	2·25	2·32	1·61	1·75		
M	4·05	4·17	2·88	3·23	1·80	
TA	10·97	11·29	7·82	8·53	4·87	2·71

*Taxa are ordered and identified as in Table 1.

Table 4. *The ratio of leaves colonized by species A: leaves colonised by species B, based on chronosequence study*

	Taxon A							
Taxon B	PE*	IT	MM	SS	PR	PI	PL	SE
IT	1·2							
MM	1·9	1·7						
SS	2·3	2·0	1·2					
PR	3·3	2·9	1·7	1·4				
PI	4·7	4·0	1·3	1·1	0·7			
PL	2·4	2·1	2·4	2·0	1·4	1·9		
SE	5·8	5·0	3·0	2·5	1·8	2·4	1·5	
GY	31·8	20·5	12·4	10·3	7·3	5·1	5·1	4·1

*Taxa are ordered and identified as in Table 2.

total number of leaves colonized by A to those colonized by B (see Appendix). The observed values of these latter ratios for all pairs of lichens in the real-time study are shown in Table 3, and for the chronosequence study in Table 4.

For the model to provide an acceptable description of the colonization processes figures in Tables 1 and 3 should correspond, as should those in Tables 2 and 4, but there are major discrepancies between them. For both the real-time and chronosequence studies the second method of estimating the ratio L_A/L_B tends to give smaller estimates of instantaneous colonization rates for the more common taxa relative to the rarer ones. A number of plausible reasons may be advanced for the failure of the model to describe the situation:

(1) Lichen species could have quite different age-dependent instantaneous colonization distributions [i.e. their $f(t)$ values are different]. This might occur because the nature of the cuticle changes with age, making

colonization by subcuticular species easier and simultaneously removing the surface that allowed some epicuticular species to establish.

(2) Not all leaves are equally colonizable by all species. An undamaged leaf, for instance, cannot be colonized by *S. elegans*.

(3) When a leaf is colonized by one species its chances of being colonized by another are modified. If a large portion of the surface of a leaf is covered by one lichen the probability of colonization by others is reduced. *Porina epiphylla*, therefore, ought to exclude other species to a substantial extent. On the other hand, *Gyalectidium*, which apparently has evanescent thalli, should be progressively excluded from the leaf by other species.

Selection of method for studies of succession

Both direct real-time observation and the study of a chronosequence have merits and demerits for establishing successions of lichens on leaves. Chronosequence studies need a large number of twigs collected from slow-growing bushes, which could have a serious impact on the bushes concerned (Rogers & Barnes 1986), and also suffer from the weakness of the assumptions on which they are based. Direct observation, however, suffers because of the difficulties in making accurate determinations under field conditions, and is very time-consuming. Because of its accuracy and efficiency the chronosequence approach is the more appropriate method for establishing sequences of succession provided that a large number of twigs are available, and an absolute time scale is not required.

Nature of the succession

In the locations examined almost any species can be first to reach an identifiable stage, but some have higher instantaneous colonization rates than others, and these rates vary with time. Noble & Slatyer (1981) examined four basic models for plant succession—the ‘Classical’ (Clementsian) model in which one species facilitates colonization by the next, an ‘Initial Floristic Composition’ model in which the eventual species composition is determined by the species that first colonize an area, a ‘Tolerance’ model in which species are successful whether or not others have preceded them and a ‘Chronic Disturbance’ model, in which any species can be first in a succession, and be replaced by any other.

There is no quantitive evidence of a classical (Clementsian) succession in which one lichen species facilitates the entry of another into the community, although there is a probabilistically determinable sequence of colonization apparently resulting from different (and varying) instantaneous colonization rates for different taxa. It must be observed, however, that the rare species *O. vegae* is an obligate lichen parasite, and therefore does require ‘facilitation’ in that a host must first be present. There is no evidence that initial floristic composition determines the ultimate floristic composition of the lichen flora of a leaf, although the data are too sparse to adequately test this hypothesis in terms of a quantitative comparison of initial species densities of colonization

The left hand side of this equation would therefore provide an estimate of L_A/L_B but it cannot be calculated from the available information in these studies. However, an approximation for the left hand side is provided by

$$(\Sigma \text{ all leaves } P_A)/(\Sigma \text{ all leaves } P_B) \tag{6}$$

which can be estimated by N_A/N_B, where N_A and N_B are the number of leaves observed to be colonized by A and B, respectively. The value of N_A/N_B for all pairs of taxa recorded in the field study are given in Table 3 and for the laboratory study in Table 4.

Unless L_A and L_B are of similar magnitude, the approximations employed above are not always accurate. Computer simulation studies showed that over the plausible range of leaf ages and instantaneous colonization rates biases would rarely be greater than 25%. The direction of bias was, however, predictable and always overestimated the instantaneous colonization rates of rarer taxa relative to common ones.

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and ultimate cover developed on the leaf at maturity. If a single leaf is considered in isolation, it is apparent that the ‘Tolerance’ model adequately describes the situation that has been studied, for the lichen community apparently grows and develops without a fixed colonization sequence, and any species is able to grow to maturity without the presence of others.

Since the ‘Tolerance’ model is a simpler explanation for the observed successional patterns on a single leaf than are the other possibilities, the ‘Tolerance’ model must stand as the most likely explanation. It can, on the other hand, be argued that the population of leaves in one place is the appropriate basis for considering succession in foliicolous lichens rather than the single leaf. In this case the ‘Chronic Disturbance’ model of succession is appropriate in that while individual leaves are not subject to disturbance during their life, there is an irregular but frequent addition of new surfaces suitable for colonization by lichens, and a regular loss of colonized leaves from the environment.

The successional model considered most appropriate will, therefore, depend on whether the unit considered is the individual leaf or the population of leaves in a location.

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Appendix

The probability of colonization by species A during the time interval t to $t+\Delta t$ is

$$\Delta P_A(t)=L_A f(t)\Delta t \tag{1}$$

Consider a leaf that is not infected by either A or B at age t. Then

$$\lambda_{AB}=\frac{\Delta P_A(t)=L_A}{\Delta P_B(t)=L_B} \tag{2}$$

where λ_{AB} is the odds favouring colonization by A before B in $t-(t+\Delta t)$. Because L_A and L_B are constants, L_A/L_B is independent of leaf age. L_A/L_B is therefore the odds favouring colonization by A before B for a leaf of any age and is also the expected value of the ratio of the number of leaves colonized by A before B to the number colonized in the reverse order.

A second but approximate expression for an estimate of L_A/L_B is derived below.

By integrating equation (1) above, the probability of a leaf being colonized by species A under this model is

$$P_A=1-e^{-}L_{A^{\tau}}\int_{o} f(t)dt \tag{3}$$

where T is the length of time the leaf is available for colonization or study, and e is the base of exponential logarithms. A similar function may be written for species B. Eliminating the time function in equation (3) written for both species A and B leads to

$$\frac{\log(1-P_A)}{L_A}=\frac{\log(1-P_B)}{L_B} \tag{4}$$

This expression may be summed over all leaves in a sample irrespective of their ages. Since L_A and L_B are constants, after rearranging this becomes

$$\frac{\Sigma_{\text{all leaves}}(\log 1-P_A)}{\Sigma_{\text{all leaves}}(\log 1-P_B)} \tag{5}$$

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ECOLOGICAL STRATEGIES OF LICHENS

R. W. ROGERS*

Abstract: Survival strategies of 34 species of lichens from a range of substrata, climates and growth forms were examined using the triangular ordination procedure of Grime. Triangular ordination is apparently an appropriate technique to apply to lichens, all available data falling within a triangle except for two foliicolous species which are probably partial leaf parasites. Statistically significant relationships between survival strategy and growth form, mode of asexual reproduction, substratum preference, family affiliation, and diversity of secondary chemical biosynthetic pathways have been demonstrated.

Introduction

Strategy studies have proved a valuable approach to the ecology of the flowering plants (Grime 1979, 1984, 1986), and clearly have a broad application amongst a range of organisms (Grime 1988*a*, Shepherd 1981, Southwood 1977). A strategy may be defined as a ' grouping of similar or analogous genetic characteristics which recur widely among species or populations and cause them to exhibit similarities in ecology ' (Grime 1979). Studies of strategy, therefore, are to do with the detection of generalizations: careful and detailed study will undoubtedly detect exceptions to the general rule, thus highlighting organisms which are likely to be of special interest.

A number of studies have now addressed ecological strategies in lichens (Rogers & Barnes 1986, Rogers 1988, 1989, Topham 1977) all applying the triangular ordination model of Grime (1977). This model applies to the established phase (in contrast to the reproductive phase) of the life history of plants growing in communities in equilibrium with their environment. Grime (1988*b*) states that ' the triangular model produces two main testable predictions:

> (1) that competition for resources (C), stress (S), and disturbance (D) as defined by Grime (1979), are so thoroughly interdependent that shifts in the intensities of one lead inescapably to adjustments in the intensities of the others; and,
>
> (2) that the potentiality of the green plant is so constrained that species and genotypes attuned to particular C-S-D equilibria by natural selection will possess predictable functionally integrated sets of traits. '

The triangular model has been criticised by Loehle (1988) who concluded that ' the triangular representation scheme distorts data, results in loss of information and generates overly restrictive assumptions about strategic or environmental trade-offs '. Grime (1988*b*) argues that the express purpose of the model is to suggest that strategic trade-offs do indeed occur, and provides a means to test that it is so.

*Botany Department, The University of Queensland, St. Lucia, Queensland 4067, Australia.

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The relationships between ecological strategy and morphological and life-history attributes of flowering plants have been examined by Grime (1979, 1986). It is reasonable to expect that ecologically significant attributes of lichens will also correlate with those used to construct a strategic ordination.

Mode of reproduction is an attribute which Grime (1979, 1986) found to be related to strategy in herbaceous plants, and which Topham (1977) believed significant as an indicator of strategy in lichens. Morphology index involves both thallus spread and thallus thickness or height. Since it is possible for a lichen thallus to spread widely or remain small, its actual growth form, which is likely to be ecologically significant, is not necessarily linked to the morphology index. Growth form was considered to be ecologically significant and another possible indicator of ecological strategy. Secondary chemicals may be a defensive response to predation or an aggressive allelopathic response (Lawrey 1986). In the absence of information on the total cost of production of such compounds, it is arguable that the diversity of biosynthetic pathways maintained for the production of such compounds is an index of the total investment, and might, therefore, be related to strategy. It also has been suggested that strategy is related to substratum type (Rogers & Barnes 1986), with short-term substrata only open to colonisation by ruderal species.

This paper analyses the ecological strategies of the established phase in a range of lichens, using published data. Strategic ordination of species is undertaken using the approaches of both Grime and Loehle, so that the results might be compared and the implications examined. The relationship between strategy *sensu* Grime (1977) and the morphological, chemical, taxonomic, and ecology attributes of lichens is also examined.

Materials and Methods

To execute a Grime triangular ordination information is needed on relative growth rate of young individuals, and mature thallus size (Rogers 1988). The literature was searched for studies on the growth rates of lichens from which relative growth rates of young thalli could be determined. Relative growth rate (increment in plant matter per unit of existing matter in unit time) is a parameter with only a time dimension, and can be calculated from any set of sequential growth measurements. In the case of lichen thalli data are almost always presented in terms of radial growth, which can be converted to increments of area. For foliose lichens this is closely correlated with dry weight increment (Rogers 1988) and can therefore be included on the same axes as estimates based on dry weight increments. All species for which relative growth rates could be estimated were included, the highest relative growth rate being used if more than one measurement was available for a species. No data were excluded arbitrarily. Information on size of mature thalli was obtained from appropriate floras and revisional studies.

The data were tabulated and species located in a triangular ordination using relative growth rate on one axis, and a morphology index (Table 1) modified from Rogers (1988) on another. In order to provide a more uniform spread of taxa throughout the triangle, the morphology index was modified to provide more grades among the very large and very small thalli than in Rogers (1988). The same data were also prepared in a simple rectangular (two dimensional) ordination after the style recommended by Loehle (1988) to allow comparison between the two methods.

Information concerning vegetative reproduction (presence of isidia, soredia or with no such specialised structures) was collated from floras and revisions. Growth form (fruticose, foliose, placodioid, or crustose) was also noted from the literature, as was substratum preference (terricolous, saxicolous, corticolous, foliicolous). This additional information was plotted onto triangular ordinations. For species which had a characteristic in common, mean values of relative growth rate, morphological index, and index of ruderality were calculated from the ordinations, and tests for significant differences were carried out (Anovar or T-test). The secondary chemicals present in the species were determined from revisional studies or the reviews of Culberson (1969), Culberson & Culberson (1970) and Culberson *et al.* (1977). Biogenetically similar chemicals were then grouped after Culberson and Culberson (1970). The relationship between number of secondary chemical biosynthetic groups present and the ordination axes was examined using regression analysis.

Results

Thirty-four records were located in which relative growth rates were either given or could be calculated (see Rogers 1988). These data, together with estimated morphology index, diversity of secondary chemicals, preferred substratum, growth form and mode of vegetative reproduction are presented in Table 1. The species were plotted onto a triangular ordination on the basis of relative growth rate and morphology index (Fig. 1), and in a two factor (rectangular) ordination (Fig. 2).

Mean values of the three indices for each of the relevant attributes are shown in Table 2.

Growth form

Growth form showed a clear relationship to primary strategy (Fig. 3), with fruticose lichens concentrated towards the competitive pole of the triangle, foliose lichens scattered from the centre of the triangle towards the competitive pole, placodioid lichens below the centre of the triangle, and the crustose species scattered from the stress tolerant pole to the ruderal pole.

There are statistically significant differences between the mean values for at least one index between all growth forms except the crustose and placodioid groups. Of the 18 possible interactions between the four growth forms eight are significant (five fruticose, four foliose, three placodioid, four crustose). One significant difference relates to relative growth rate, three to morphology index, and four to ruderality index.

Fruticose species have a higher mean maximum relative growth rate than foliose species (t = 3·18, 20 degrees of freedom (df)), but there are no other significant differences between mean relative growth rates. Fruticose species also show a statistically higher mean morphology index than either placodioid species (t = 4·09, 8 df) and crustose species (t = 4·11, 22 df). Fruticose species show a significantly lower mean index of ruderality than do placodioid (t = 4·11, 8 df) or crustose (t = 2·30, 14 df) species, as do foliose species (t = 3·32, 16 df and t = 3·21, 22 df respectively). There are no other significant differences.

Vegetative reproduction

Vegetative reproductive structures appear to be related to strategy (Fig. 4). Although species occurring closest to the competitive pole have no specialised means of asexual reproduction, all of the isidiate species considered occur near the competitive pole. Sorediate species occur near the stress-tolerant pole, and species with neither soredia nor isidia at a distance from the stress-tolerant pole.

There are statistically significant differences between mean values for either the morphology index or relative growth rate for each of the three classes of vegetative reproduction. From the nine possible interactions, three significant

TABLE 1. *Estimated maximum relative growth rate (RGR) morphology index (MI) and derived ruderality index (RI) of some lichens*

Species	Ref	RGR	MI	RI
Strigula subtilissima (Fée) Müll. Arg. [Ss]	10	0·069	0·0	100
Strigula elegans (Fée) Müll. Arg. [Se]	10	0·064	0·0	98
Cladina alpestris (L.) Nyl. [Cl]	5	0·045	4·5	12
Stereocaulon paschale (L.) Fr. [Sp]	5	0·042	4·0	2
Cladina rangiferina (L.) Nyl. [Cr]	5	0·038	4·0	15
Cladina mitis (Sandst.) Hale & W. Culb. [Cm]	5	0·036	4·0	18
Cetraria nivalis (L.) Ach. [Cn]	5	0·032	3·5	26
Lobaria oregana (Tuck.) Müll. Arg. [Lo]	11	0·032	4·5	8
Porina epiphylla (Fée) Fée [Pe]	10	0·030	0·5	76
Pseudocyphellaria homeophylla (Nyl.) Dodge [Ph]	7	0·026	4·5	5
Sticta caperata Bory in Nyl. [Sc]	7	0·022	4·5	6
Rhizocarpon tinei (Tornab.) Runem. [Rt]	6	0·015	1·5	48
Lecanora muralis (Schreb.) Rabenh. [Lm]	8	0·015	2·0	41
Diploicia canescens (Dicks.) DeNot. [Di]	8	0·013	2·0	38
Parmotrema austrosinense (Zahlbr.) Hale [Pa]	9	0·010	3·5	6
Dirinaria applanata (Fée) Awasthi [Da]	9	0·0093	2·5	26
Xanthoparmelia conspersa (Ach.) Hale [Xc]	1	0·0092	3·0	15
Dirinaria confluens (Fr.) Awasthi [Dc]	9	0·0077	2·5	22
Rhizocarpon candidum Dodge [Rc]	6	0·0077	1·0	48
Xanthoria elegans (Link) Th. Fr. [Xe]	12	0·0073	1·0	40
Phaeophyscia orbicularis (Neck.) Moberg [Po]	1	0·0061	2·0	24
Pyxine subcinerea Stirton [Py]	9	0·0061	2·0	25
Parmelia glabratula ssp. *fuliginosa* (Fr. ex Duby) Laundon [Pg]	1	0·0054	3·0	5
Parmelia sulcata Taylor [Ms]	2	0·0045	3·0	5
Parmelia saxatilis (L.) Ach. [Ps]	1	0·0044	3·0	3
Flavoparmelia caperata (L.) Hale [Fc]	2	0·0044	3·0	0
Pseudephebe minuscula (Nyl. ex Arnold) Brodo & Hawksw. [Pm]	13	0·0041	2·5	10
Caloplaca aurantia (Pers.) Hellb. [Ca]	3	0·0040	1·5	26
Ramalina maciformis (Del.) Bory [Rm]	4	0·0028	2·5	5
Lecidea tumida Massal. [Lt]	1	0·0022	2·0	7
Hyperphyscia adglutinata (Floerke) Mayrhofer & Poelt [Ha]	9	0·0015	1·0	42
Rhizocarpon alpicola (Schaer.) Rabenh. [Ra]	14	0·0012	1·5	18
Lecanora caesiorubella Ach. [Lc]	2	0·00080	0·5	15
Rhizocarpon obscurata (Ach.) Massal. [Ro]	1	0·00053	0·5	6

Morphology Index = (T + D)/2. T = thallus thickness: <0·5 mm = 0, >0·5–1·0 mm = 1, >1·0–5·0 = 2, >5·0–10·0 = 3, >10·0–25 mm = 4, >25 mm = 5. D = thallus diameter: <10 mm = 0, >10–25 cm = 1, >25–50 mm = 2, >50–100 mm = 3, >100–250 mm = 4, >250 mm = 5.
Ref = references: 1–Armstrong (1973), 2–Brodo (1965), 3–Farrar (1974), 4–Lange *et al.* (1970*a*), 5–Karenlampi (1971), 6–Burrows & Orwin (1971), 7–Snelgar & Green (1982), 8–Hill (1981), 9–Rogers (1988), 10–Rogers (1989), 11–Rhoades (1977), 12–Carrara & Andrews (1973), 13–Miller (1973), 14–Denton & Karlen (1973).
Symbols for species used in Fig. 1 are shown in square brackets.

differences were detected, all of which involved the presence of soredia, one presence of isidia, and one the absence of both soredia and isidia. Two significant differences related to the morphology index, and one to relative growth rate.

Species with isidia have a higher morphology index than species with soredia (t = 2·09, 13 df), as do species with neither soredia nor isidia (t = 1·77, 29 df).

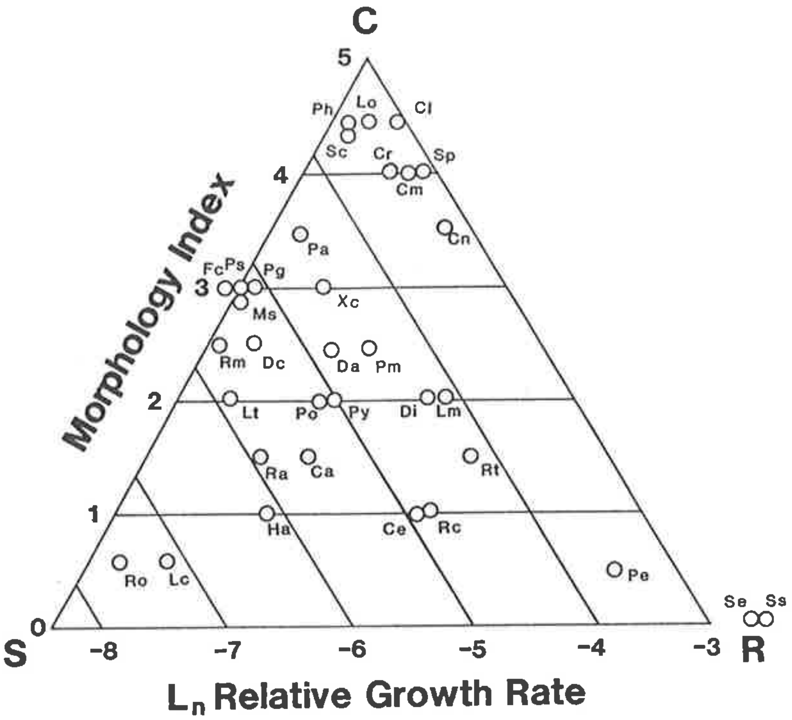

FIG. 1. Triangular ordination of lichens from various habitats using maximum relative growth rate and morphological index as axes. Data and symbols identifying species are from Table 1.

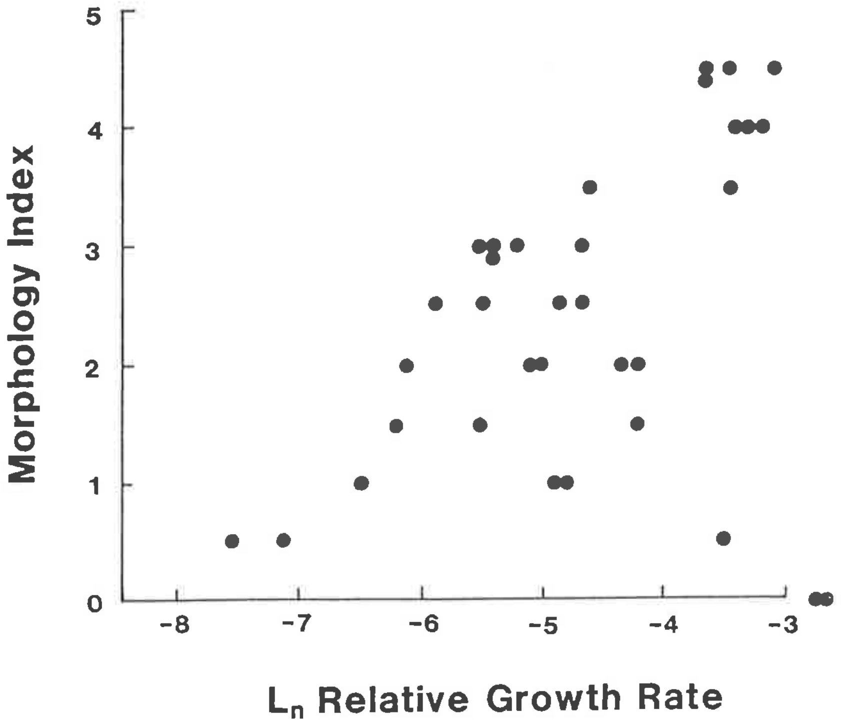

FIG. 2. Rectangular ordination of lichens using the same axes and data as in Fig. 1.

TABLE 2. *Mean and standard deviation for relative growth rate (RGR), morphology index (MI), and ruderality index (RI) for selected attributes of lichens included in Fig. 1*

Attribute	RGR	MI	RI
Growth Form			
Fruticose	0·0286 (0·0003)	3·57 (0·62)	13·14 (121·7)
Foliose	0·0108 (0·0001)	2·73 (1·60)	12·57 (65·3)
Placodioid	0·0088 (1·57)	1·57 (0·163)	35·67 (70·3)
Crustose	0·0212 (0·0008)	0·833 (0·500)	46·22 (142·4)
Vegetative Reproduction			
Isidia	0·0063 (0·0001)	3·000 (0·0001)	7·67 (41·3)
Soredia	0·0054 (0·0001)	1·67 (1·15)	17·1 (212·9)
Neither	0·260 (0·0004)	2·59 (2·5)	30·5 (919·9)
Substratum			
Rock	0·0061 (0·0001)	1·94 (0·623)	21·4 (282·7)
Bark/Wood	0·0114 (0·0001)	2·54 (3·38)	13·76 (128·5)
Soil	0·0386 (0·0001)	4·00 (0·125)	14·60 (76·8)
Leaves	0·0543 (0·0005)	0·167 (0·0833)	91·33 (177·3)
Family			
Cladoniaceae	0·040 (0·0001)	4·17 (0·083)	15·00 (9·00)
Lobariaceae	0·0267 (0·0001)	4·50 (0·0001)	6·33 (2·33)
Parmeliaceae	0·0093 (0·0001)	2·688 (1·281)	9·15 (62·53)
Physciaceae	0·0073 (0·0001)	2·000 (0·300)	23·5 (105·0)
Rhizocarpaceae	0·0031 (0·0001)	1·000 (0·250)	24·0 (468·0)

Numbers in brackets = variance of the mean

Species with neither isidia nor soredia also show a higher mean maximum relative growth rate than do those with soredia. No other differences between mean growth rates, mean morphology indices or mean ruderality indices could be demonstrated.

Substratum preference

Substratum preference appeared to be related to ecological strategy (Fig. 5). Terricolous species were concentrated near the competitive pole and foliicolous species at the ruderal pole. Saxicolous and corticolous species, however, were apparently scattered between the competitive and stress-tolerant poles.

There are statistically significant differences between the mean values of at least one index for each of the four substratum classes. Of the 18 possible interactions, 12 show significant differences in mean values for indices for the substratum classes (six saxicolous, six corticolous, four terricolous, eight foliicolous). Five differences relate to relative growth rate, four to morphology index, and three to index of ruderality.

Mean relative growth rates of all groups differed one from the other, except for terricolous and foliicolous species. Saxicolous species showed the slowest mean relative growth rate, being exceeded by corticolous species (t = 1·81, 24 df), terricolous species (t = 13·42, 17 df), and foliicolous species (t = 8·61,

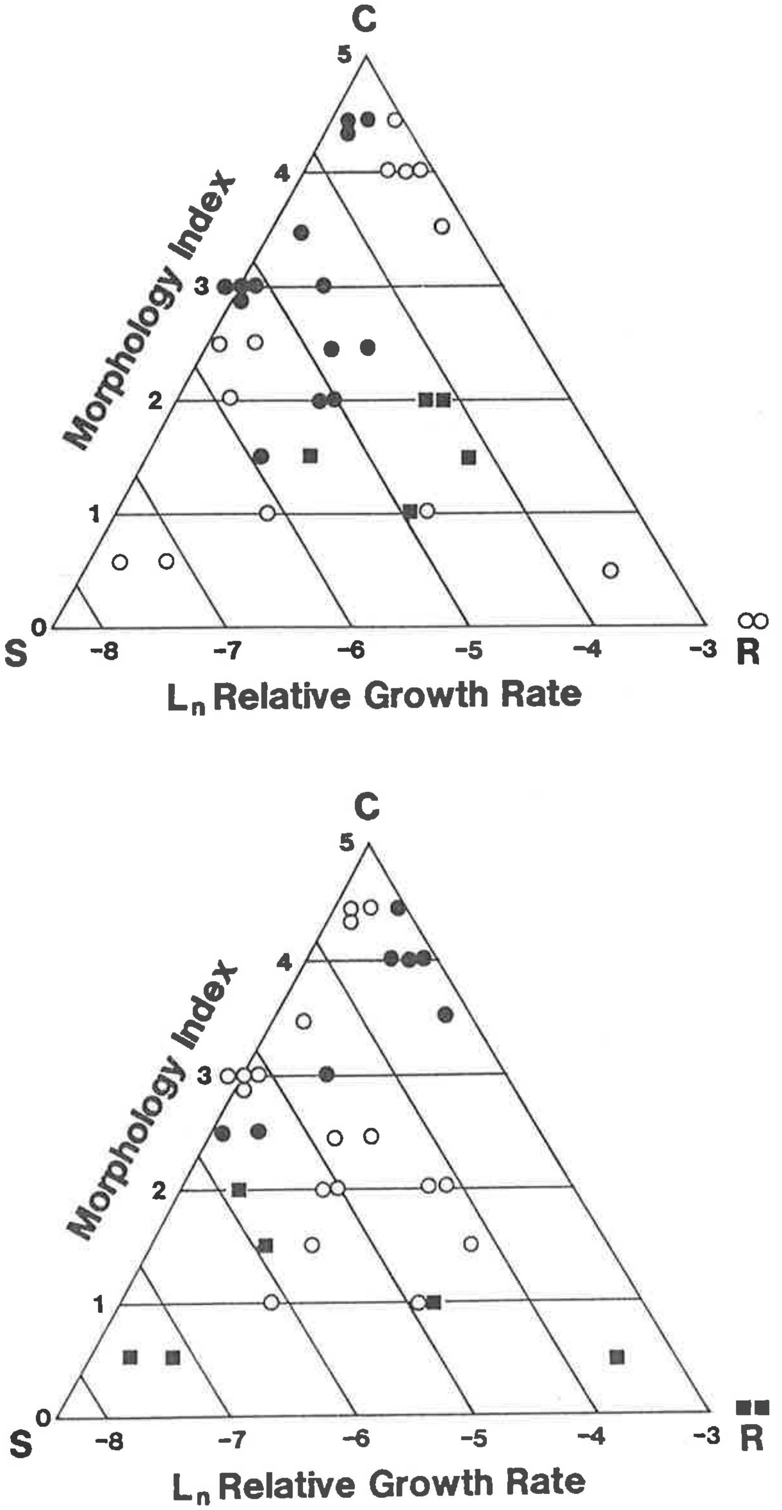

FIG. 3. The relationship between growth form and ecological strategy of lichens: Top, ● foliose, ■ placodioid species; Bottom, ● fruticose, ■ crustose species. Unfilled spots indicate species not showing the growth forms considered in that triangle.

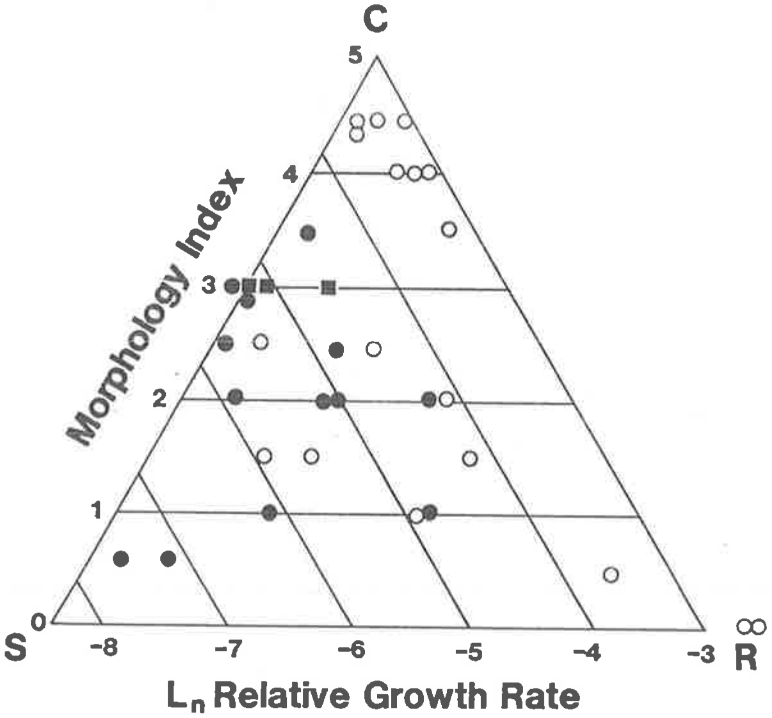

FIG. 4. The relationship between mode of vegetative reproduction and ecological strategy of lichens: ● sorediate species; ■ isidiate species; ○ no specialized structure for vegetative reproduction.

15 df). Corticolous species had lower relative growth rates than terricolous species ($t=5{\cdot}68$, 15 df) and foliicolous species ($t=5{\cdot}34$, 13 df). Saxicolous species had a higher mean morphology index than foliicolous species ($t=3{\cdot}76$, 15 df), as did corticolous species ($t=2{\cdot}58$, 13 df) and terricolous species ($t=15{\cdot}7$, 6 df). Terricolous species also showed a statistically higher morphology index than did saxicolous species. No other mean morphology indices showed significant differences. The mean index of ruderality for foliicolous species was significantly higher than that for saxicolous species ($t=6{\cdot}7$, 15 df), corticolous species ($t=10{\cdot}30$, 13 df) and terricolous species ($t=10{\cdot}00$, 6 df).

Secondary chemicals

The number of biogenetically related groups of chemicals in thalli was statistically related to strategy, although a regression relating relative growth rate to chemical complexity was not significant. There is a statistically significant ($F=8{\cdot}95$, $P<5\%$) regression showing a weak positive relationship between chemistry and morphology index ($r^2=0{\cdot}219$). There is also a statistically significant regression ($F=5{\cdot}39$, $P<5\%$) showing a weak negative relationship ($r^2=0{\cdot}144$) between index of ruderality and chemical complexity.

Family affiliation

Family classification was strongly associated with strategy (Fig. 6). The Cladoniaceae and Lobariaceae appear to be strongly competitive, the

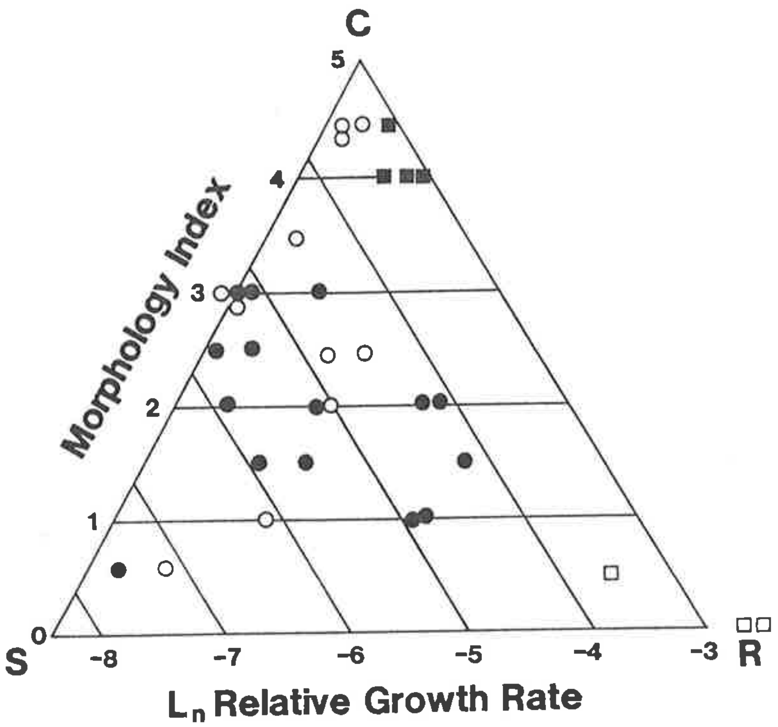

FIG. 5. The relationship between substratum occupied and ecological strategy in lichens. Substrata: ■ soil; □ leaves; ● wood or bark; ○ rock.

Parmeliaceae rather less so, and the Physciaceae occupy the centre of the ordination. The Rhizocarpaceae are more stress-tolerant than the other families examined.

There are statistically significant differences involving the mean value for at least one of the ordinal characters between every combination of families. Of the 30 possible comparisons, 17 show significant differences (seven Cladoniaceae, nine Lobariaceae, five Parmeliaceae, seven Physciaceae, six Rhizocarpaceae). Of these differences seven involved relative growth rate, six morphology index and two ruderality index.

The species in the Cladoniaceae showed significantly higher mean relative growth indices than did those in the Lobariaceae ($t=3{\cdot}26$, 4 df), Parmeliaceae ($t=5{\cdot}19$, 9 df), Physciaceae ($t=11{\cdot}61$, 7 df) and Rhizocarpaceae ($t=10{\cdot}26$, 4 df). The Lobariaceae showed a higher mean relative growth rate than species in the Parmeliaceae ($t=2{\cdot}96$, 9 df), the Physciaceae ($t=6{\cdot}52$, 7 df) and the Rhizocarpaceae ($t=6{\cdot}36$, 4 df). No other mean relative growth rates showed significant differences. The morphology index of the Cladoniaceae was significantly higher than that of the Physciaceae ($t=6{\cdot}28$, 7 df) and the Rhizocarpaceae ($t=9{\cdot}5$, 4 df). That of the Lobariaceae was higher than the Parmeliaceae ($t=2{\cdot}68$, 9 df), the Physciaceae ($t=7{\cdot}64$, 7 df), and the Rhizocarpaceae ($t=12{\cdot}12$, 4 df). The Parmeliaceae and Physciaceae both showed a higher mean morphology index than the Rhizocarpaceae ($t=2{\cdot}43$, 9 df and $t=2{\cdot}64$, 7 df respectively). Mean index of ruderality for the

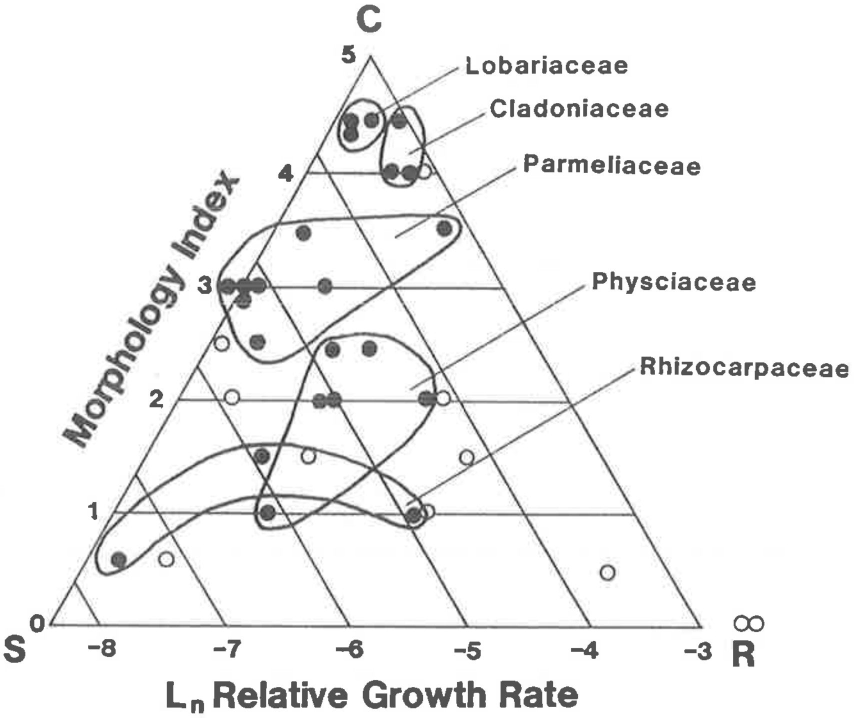

FIG. 6. The relationship between family affiliation and ecological strategy of lichens. Filled spots within an enclosed area belong to the indicated family.

Cladoniaceae was higher than that for the Lobariaceae (t=4·46, 4 df), that of the Lobariaceae higher than that for the Physciaceae (t=2·78, 7 df) and that of the Parmeliaceae higher than that of the Physciaceae (t=2·96, 12 df).

Discussion

Thirty-four species is a very small proportion of the total known lichens, and the distribution of the sample through growth forms, climatic zones and substrata is far from random. For example, no information is available concerning species growing between the tropics, and all the terricolous species studied are large thalli from Finland. The data base, however, has proved large enough to show statistically significant differences, and therefore is large enough to allow hypotheses to be advanced, thus providing a framework for further study.

Triangular and rectilinear ordinations

When plotted as a Grime triangular ordination the species fitted within the triangle with a few exceptions that were quite close to the margins (Fig. 1). *Flavoparmelia caperata* falls just outside the triangle on the CS axis, and the species of *Strigula* fall well outside the triangle at the ruderal corner. *Strigula* is a special case involving subcuticular growth on leaves, with the alga *Cephaleuros* as photobiont, an alga which is apparently capable of living as a partial leaf parasite (Rogers 1989). One effect of the changed scaling for the morphology index is that *Parmotrema austrosinense* which formerly fell a little outside the triangle is now within it.

The rectilinear ordination (Fig. 2) is striking in that all of the species (except for *Strigula*) fit within a triangle, just as would be expected if the hypotheses of Grime (detailed in the Introduction) are indeed correct. There is no evidence of large slow-growing thalli. The large arctic-alpine species such as *Rhizocarpon alpinum, R. candidum,* and *Pseudephebe minuscula* have quite moderate growth rates, and *R. obscuratum*, which has a very low growth rate, remains small. Although trade-offs involved in adaptation to one particular life strategy rather than another are probably very complex, relative growth rate and morphological index seem to be sufficient to provide the framework within which broad ecological strategies can be detected.

There appears to be neither an immediate loss nor gain of information in the use of either the triangular or rectangular plot. The triangular plot, however, does have within it an implicit theoretical consideration, that there is a third axis which can be inferred by examination of the first two. A factor which enables a measurement of ruderality has not been proposed for lichens: ruderality can, however, be estimated from the triangular plot if Grime's hypothesis is correct. It is perhaps significant in this respect that the foliicolous lichens, which occupy relatively short-lived habitats, are those which appear in the ruderal corner. Rogers (1988) has also shown that, during succession on a palm trunk, the nature of the community changes from one which consists of small species with moderate growth rates to species of larger size and higher growth rates, a shift from ruderal to competitive strategies with time. If Grime's hypothesis is correct, additional information can be derived from the triangular model and a third index can be interpolated from the two that have been measured. An independent index of ruderality, however, is necessary to finally determine this.

Attributes and the strategic ordination

Statistical analysis of the mean ordinal values of lichens with different morphological and reproductive attributes demonstrates that factors other than those used in the ordination are related to the axes, although not necessarily in a simple manner.

Fruticose species are statistically more competitive than foliose lichens, an observation which is consistent with the finding of Rogers (1988) that aggression as measured by overtopping of one thallus by another is closely related to thickness of thallus for foliose and crustose lichens.

Reproduction is an important factor in many strategic analyses, and is the basis upon which r-K selection is based (Stearns 1977). If it is assumed that the species of *Cladina* are capable of reproduction by fragmentation, then species with progressively larger vegetative propagules tend to be more competitive, and those with smaller propagules (soredia or spores) tend to be stress-tolerant or ruderal, as suggested by Topham (1977). Grime (1979) argued that competitive species are equivalent to K-selected species and that ruderal species are equivalent to r-selected species, which is consistent with these results, as r-selected species tend to produce large numbers of small propagules, and K-selected species tend to produce small numbers of larger propagules (Stearns 1977). Stearns (1977) also argues that K-selected species have a relatively small investment in reproduction. In the case of the *Cladina* species, the total input into reproduction is very small indeed, as the apothecium has been developed into a photosynthetic organ, and fragments of normal thallus rather than a special organ are apparently used as reproductive structures. The relatively small number of isidiate species examined severely limits the possibility of detecting significant differences between those species and others.

The relationship between substratum and strategy is one which might be expected. Slow-growing species simply cannot survive on evanescent substrata such as leaves. The data block is deficient, however, in studies on short-lived substrata. Studies on tropical and cool temperate foliicolous lichens would help in this context. Since lichens colonise deciduous twigs rapidly, and these can be aged easily (Degelius 1978), they may be an appropriate substratum for study.

The number of families with more than two species involved in the study is limited. It does, however, indicate that different strategies are as characteristic of lichen families as they are of higher plant families (Grime 1984).

The use of larger numbers of biosynthetic pathways for the production of secondary substances is positively related to the morphology index, negatively related to the ruderality index, and independent of the relative growth. This indicates that ruderal species tend not to invest as heavily in defence mechanisms as competitors and that stress tolerators show an intermediate investment. Ruderals, being fugitives, are not expected to invest as extensively in chemical defensive mechanisms as stress tolerators, for the loss of any tissue is likely to be significant to the slow-growing stress tolerators (Grime 1979). Neither would ruderals be expected to invest in chemical offensive (allelopathic) mechanisms as do competitors, which have the displacement or exclusion of other species as an essential part of their strategy.

Conclusions

The data presented here are an independent test of Grime's hypotheses. Excepting the genus *Strigula*, shown to be a special case, the first of the hypotheses cannot be negated. The use of the triangular ordination appears to be ecologically sound and it is likely that the biology of any lichen which does not fall within the Grime triangle delimited in Fig. 1 is exceptional and worth further investigation.

The following hypotheses relating lichen biology to ecological strategy can be made:

(1) Growth form and strategy are linked in such a way that fruticose species tend to be competitors, foliose species competitive to stress-tolerant-competitive species, placodioid species competitive stress-tolerant ruderals, and crustose species stress-tolerant to ruderal in strategy.

(2) Mode of asexual reproduction is linked to strategy in such a way that sorediate species tend to be stress-tolerant, isidiate species competitive, and species with no specialised mode of vegetative reproduction are either ruderal or competitors.

(3) Substratum preference is related to strategy in such a way that species on evanescent substrata will be ruderal, those on rocks and wood stress-tolerant to competitive, and those on soil competitive.

(4) Families tend to show a uniform strategy, with some showing narrower phyletic limitations than others.

(5) Diversity in secondary chemistry and the total quantity of secondary products produced will reflect strategy, with competitors tending to produce larger numbers and larger quantities of allelopathic compounds, and stress-tolerators producing larger numbers and larger quantities of anti-predator compounds.

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THE CORTICOLOUS SPECIES OF *HAEMATOMMA* IN AUSTRALIA

R. W. ROGERS*

Abstract: Eight corticolous species of *Haematomma* are recognized in Australia, including four new species (*H. eremaeum*, *H. pruinosum*, *H. sorediatum* and *H. stevensiae* spp. nov.) and one new combination (*H. infuscum*). The characters found useful in differentiation of the species included apothecium form, apothecial pigmentation, spore septation, and thallus chemistry. Taxonomic and distributional data are provided for all species. Two taxa are reduced to synonymy for the first time, and a key is provided.

Introduction

The genus *Haematomma* contains crustose ascohymenial lichens with a lecanorine apothecium and acicular spores with three to over 20 transverse septa. The apothecial disc is commonly coloured red-brown to red-orange‡, and it is from this that the genus derives its name although not all species in the genus are so coloured. The pigments involved in the colouration of the epithecium are apparently diverse, as is the chemistry of the thallus. There has been no monographic treatment of this genus, which is widely distributed in both Hemispheres.

Materials and Methods

This revision is based on collections in various herbaria, and on field collections. Collections for the revision made by Ms G. N. Stevens and myself are housed in the herbarium of the Botany Department, University of Queensland (BRIU). Dr J. A. Elix made his personal collections available, and these are cited as J.A.E. Material was also made available from various herbaria in Australia (MEL, PERTH, NSW, CBG). In addition, type specimens of taxa thought likely to be relevant after a literature search were requested from many institutions.

Specimens were examined microscopically to determine spore size and number of septa. Most specimens were examined by t.l.c. (using the standard techniques of Culberson 1972) to determine chemical constituents. Tests with K were carried out on sectioned apothecia of selected samples.

Anatomy and Morphology

Thallus

The thallus of Australian collections shows relatively little variation of diagnostic value. One species produces small, rather sparse orbicular soralia, but no isidiate species have been seen. The thallus may comprise scattered squamules on a thin

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* Botany Department, University of Queensland, St Lucia 4067, Australia.

‡ All colour references are to Kornerup & Wanscher (1967).

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grey or greyish-white prothallus, as in *Haematomma subfuscum*, or may develop into a thin to thick continuous or areolate layer. No species shows any development of marginal lobes. Most thalli in contact with another are separated by a black, hypothalline line. The rope-like prothallial strands noted by Hillmann (1940) are very rare, and appear not be taxonomically important. In some specimens the thallus, while continuous, is so thin that it reveals the texture of the bark beneath it, whereas in others it forms a thick layer obliterating the surface texture of the substrate. Variation in thallus colour, from chalky white to greyish-green or greyish-yellow, does not, as might be anticipated, reflect chemical variation, but appears to be environmentaly determined.

Apothecia

There are two basic apothecial forms found in the Australian corticolous *Haematomma* species. Most taxa (*H. sorediatum*, *H. eremaeum*, *H. stevensiae* and *H. infuscum*) have an apothecium which appears to commence development in a small thalline wart which slowly enlarges and opens to reveal the coloured disc within. These taxa show a mature sessile lecanorine apothecium with a markedly constricted base. A second apothecial type involves the apparent formation of the hymenium just below the surface of an areole and its initial appearance as a fully immersed usually somewhat irregular and apparently emarginate disc (*H. similis* and *H. collatum*). This form may stay immersed or, by growth of the hypothecium, hymenium and margin come to stand above the rest of the thallus displaying a rather ragged and irregular adnate lecanorine exciple. These adnate apothecia may, with age, appear to be sessile and constricted at the base as the disc broadens and the rather friable margin erodes around the base. The difference in origin of the two types is, however, quite easily seen (Fig. 1).

Ascospores

These are very variable (see Fig. 2) in size (from 30 µm long in *Haematomma similis* to over 70 µm long in *H. puniceum*) and in septation (usually five in *H. similis*, and often 13 in *H. puniceum*), some quite large spores having only relatively few septa (e.g. *H. collatum*). The spores are asymmetric, one end always thicker than the other, although both or only the narrower end may be pointed. In the ascus the spores are always helically coiled, and therefore need to be forcibly ejected from the ascus for measurement and examination. No Australian material was found to show the longitudinal septa reported for *H. wattii* (Stirton) Zahlbr., and on which Hillmann (1940) erected the section *Stirtonia*. Variation in spore size and septation appears taxonomically useful although there is considerable variation within taxa.

Apothecial pigments

At least three acetone-soluble pigments occur in the Australian material. The occurrence of these pigments is correlated with morphological characteristics, and because of the differing K reactions of the epithecium, provides a useful diagnostic character. Variation in apothecium colour seems unrelated to the pigments extracted in acetone. Pigment B, found in *Haematomma puniceum* and *H. sorediatum*, is

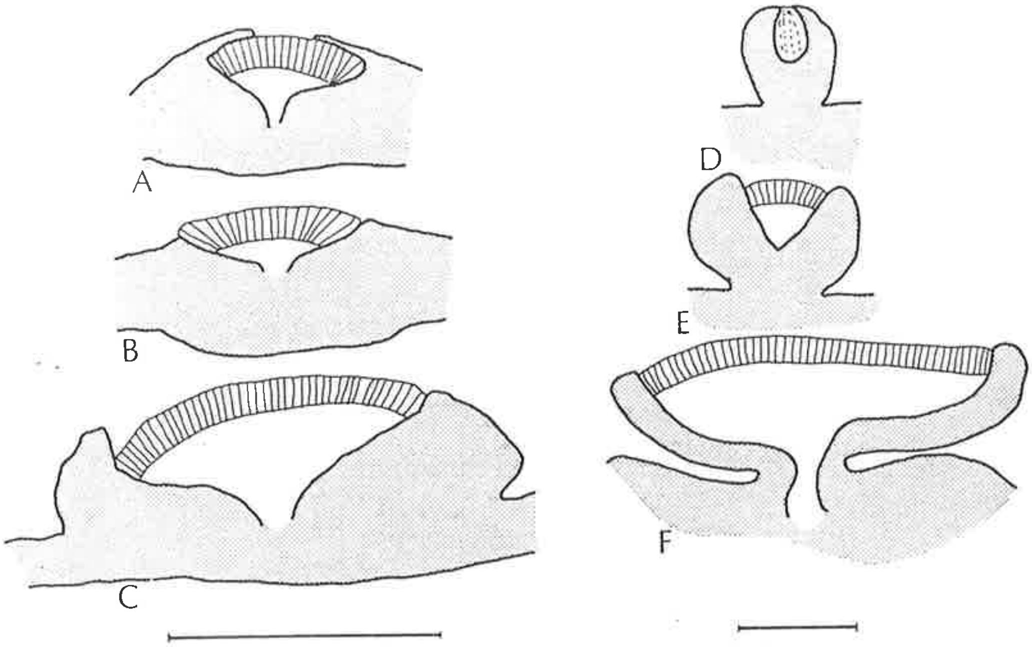

FIG. 1. Stages in the development of the apothecium in *Haematomma*. A–C, Development of the immersed to adnate form of apothecium illustrated from *H. similis*; D–F, stages in the development of the sessile form illustrated from *H. stevensiae*. Scale = 50 μm.

notably soluble in K, and streams of evanescent purple-grey solution resulting from the addition of K can be seen flowing from apothecial sections mounted in it. Apothecia with pigment A (*H. collatum, H. eremaeum, H. infuscum, H. similis*) and pigment C (*H. eremaeum*), or with no acetone-soluble pigments (*H. stevensiae*) show a lasting magenta or grey-magenta coloration in the epithecium with K, but no discoloration of the solution itself occurs.

Chemistry

The complexity of the chemistry of *Haematomma* species has been noted by Culberson (1964) and by Huneck & Follmann (1972). Asahina (1964) examined chemical variation in the *H. puniceum* complex, and discovered a number of variants which he described. Examination of the Australian corticolous collections shows two basic chemical variants. One group of taxa shows development of orcinol paradepsides (perlatolic acid with divaricatic acid or rarely imbricaric acid as accessory substances) and the other a dibenzofuran derivative (placodiolic acid). All Australian specimens examined also contained atranorin. Presence of chemically closely related derivates was not considered a sufficient basis in itself for the erection or maintenance of species. Simple colour tests do not suffice to separate the chemical variants, so t.l.c. studies or microcrystal tests may be necessary for some determinations.

The use of solvent 'C' of Culbersen (1972) was found to provide adequate separation of the products in the Australian *Haematomma* species. To aid determination of the pigments, however, the R_F classes into which the pigments fall for all three of the standard solvents is provided in Table 1.

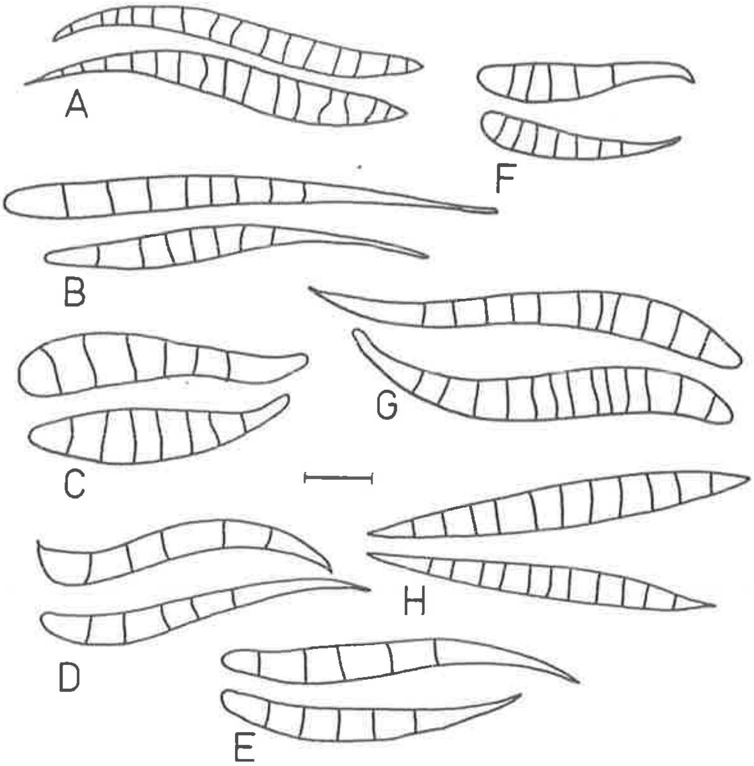

FIG. 2. Ascospores of Australian *Haematomma* species. A, *H. puniceum* (H-ACH 1258—holotype); B, *H. collatum* (PRE 49—holotype); C, *H. eremaeum* (PERTH—holotype); D, *H. infuscum* (BM—lectotype); E, *H. pruinosum* (PERTH 001050—holotype); F, *H. similis* (FI— holotype); G, *H. sorediatum* (MEL 9169—holotype); H, *H. stevensiae* (MEL 1031269—holotype). Scale = 5 μm.

TABLE 1. *Chromatographic characteristics of the acetone-soluble pigments*

	R_F Classes				
Pigment	Solvent A	Solvent B	Solvent C	UV	Colour with sulphuric acid
A	5	6	6	—	Gold
B	5	5	5	+ Gold	Pink
C	5	4	4	—	Pink

Species delimitation

The genus *Haematomma* is well represented in the corticolous lichen flora of tropical and subtropical regions. It appears to show a great many of the possible combinations of spore septation, spore size, thallus chemistry, apothecial form, and apothecial pigments which could theoretically be made from the few basic differences that exist. If we allow only two basic spore septation types (three to seven or eight to 15 septa) three chemical variants (atranorin only, atranorin +

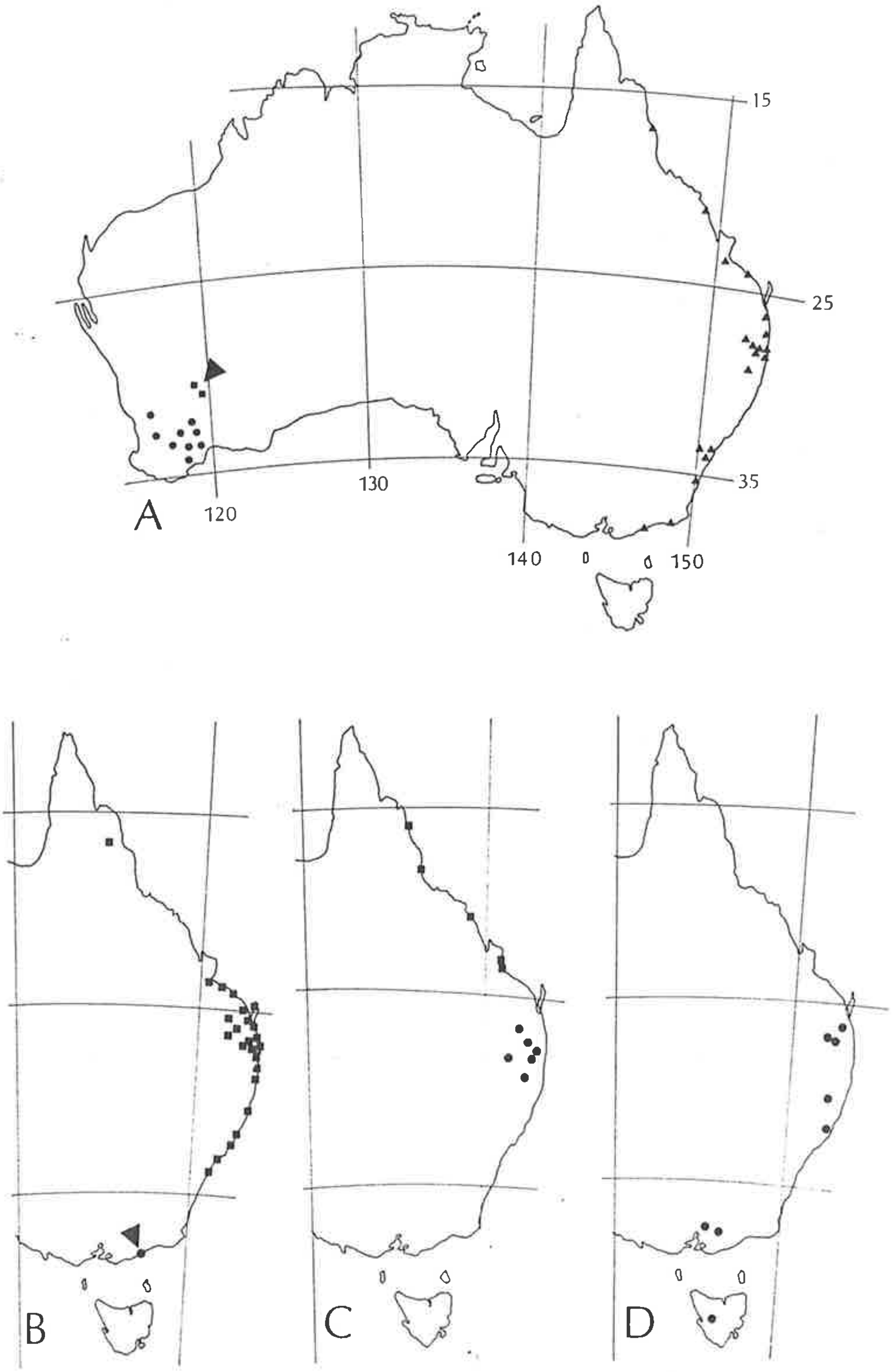

FIG. 3. Distribution of the corticolous species of *Haematomma* in Australia. A, ●, *H. eremaeum*; ■, *H. pruinosum*; ▲, *H. puniceum*; B, ■, *H. similis*; ●, *H. sorediatum*; C, ■, *H. stevensiae*; ●, *H. collatum*; D, ●, *H. infuscum*.

orcinol paradepsides, atranorin + dibenzofurans), two apothecial forms (adnate, sessile), and two thallus variations (± soredia) then, in theory we could expect to find 24 species. This number increases rapidly as such characters as apothecial pruina or more detailed thallus chemistry are considered. This suggests three basic choices—to treat the whole tropical–subtropical corticolous *Haematomma* flora as a species complex, to extract perhaps four taxa (the combinations based on apothecial form and the two basic chemical schemes) or to regard each combination of characters as a species. For the present I have chosen to regard each of the possible combinations found as a discrete species. The apparent ecological reality of the taxa so defined (Fig. 3) clearly supports this decision: for example *H. accolens* differs from *H. eremaeum* only in pigmentation, but the ecological contrast is remarkable—*H. accolens* from the cool wet environment of Assam, *H. eremaeum* from semi-arid Australia.

Ecology

It is apparent from the distribution maps that in eastern Australia *Haematomma* is essentially a genus of the humid coastal strip. It is only in western Australia that the genus is found at any great distance from the sea or in dry areas.

Species of *Haematomma* are apparently not common anywhere within their range, but as the thalli are often small they may be frequently overlooked. However, in an examination of 458 lichen-bearing trees in the Brisbane City area and its surrounds, only 14 were found to support *Haematomma similis*, the only species of the genus present in this area.

The species of *Haematomma* are selective in the substrates they will colonize. Most species are found on smooth-barked trees with a soft, somewhat fleshy bark which is live very close to the outer surface. In the Brisbane region, for example, *H. similis* was found on various species (Table 2). *H. eremaeum* is the only species which appears to be common on rough barks. It is notable that only one of all the collections cited is on the bark of *Eucalyptus*, probably the most common tree genus in coastal Australia, and a genus with many species which do support lichens.

TABLE 2. *Frequency of* Haematomma similis *on bark of various trees in the vicinity of Brisbane*

Tree	Bark type	*n*	Number with *H. similis*	Percentage
Cupaniopsis anacardioides	smooth	13	2	15
Casuarina spp.	rough	55	1	2
Alphitonia excelsa	smooth	39	6	15
Acacia spp.	rough	37	1	3
Avicennia marina	smooth	35	3	9
Eucalyptus spp.	rough	168	1	1

n = number of trees examined

Key to the corticolous species of Haematomma in Australia

1. Apothecia immersed or sessile and broadly adnate at the base . . 2
Apothecia sessile, markedly constricted at the base 3

2(1) Spores 5–7 septate . . . . **H. similis** (p. 126)
Spores 11–13 septate . . . . **H. collatum** (p. 121)

3(1) Thallus sorediate . . . . **H. sorediatum** (p. 128)
Thallus esorediate 4

4(3) Epithecium K+ magenta to grey magenta, coloration K insoluble . 5
Epithecium K+ purple-grey, coloration K soluble and rapidly fading . . . **H. puniceum** (p. 125)

5(4) Apothecia densely pruinose . . . . **H. pruinosum** (p. 125)
Apothecia without pruina 6

6(5) Contains placodiolic acid; from western Australia . . . **H. eremaeum** (p. 124)
Without placodiolic acid; from eastern Australia 7

7(6) Contains divaricatic and perlatolic acid; spores usually more than 50 µm long; mostly coastal tropics . . . **H. stevensiae** (p. 128)
With neither divaricatic nor perlatolic acid; spores usually less than 50 µm long; mostly montane. . . . . . **H. infuscum** (p. 124)

The Species

1. Haematomma collatum (Stirton) Dodge

Beih. Nova Hedwigia **38:** 41 (1971).—*Lecanora punicea* * *collata* Stirton, *Trans. Glasgow Soc. Fld Nats* **5:** 216 (1877); type: South Africa, Boschberg Mts, on bark on branches of trees in woods, 1875, *MacOwen* (PRE49—holotype).

(Figs 2B, 4A)

Thallus white to grey, chinky to granular, without soredia, corticate.

Apothecia immersed when young, becoming adnate, but only constricted at the base by erosion with age, not normally confluent; thalline margin either not apparent or very uneven in thickness; disc brownish-red to reddish-brown, epruinose. Asci eight-spored. Ascospores helical, asymmetric; 11–15 transversely septate, 45–70 × 4–5·5 µm.

Chemistry: atranorin, perlatolic acid, ± divaricatic acid, acetone-soluble apothecial pigment A. (Epithecium pigments K+ magenta to grey-magenta insoluble.)

This species differs from *H. similis* in its larger, more septate spores, and its tendency to have adnate rather than immersed apothecia. *H. punicea* var. *rufidulum* (Fée) Zahlbr. differs mainly in the absence of secondary lichen substances.

In Australia this species is apparently endemic to a small humid region in south-eastern Queensland.

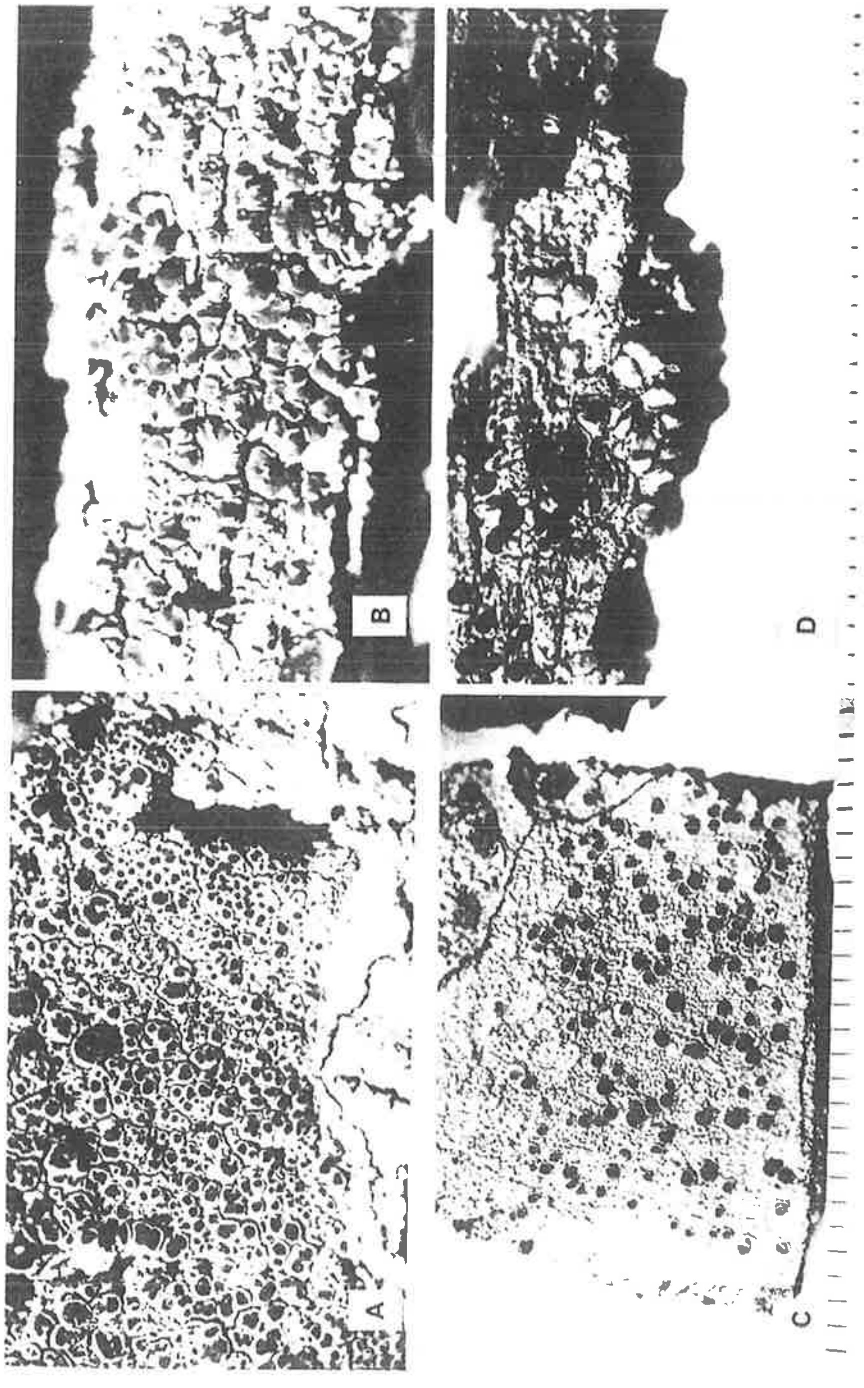

Fig. 4. Thalli of Australian *Haematomma* species. A, *H. collatum* (BRIU, *Rogers* 2157); B, *H. eremaeum* (PERTH—holotype); C, *H. infuscum* (BRIU, *Rogers* 2078); D, *H. pruinosum* (PERTH—holotype).

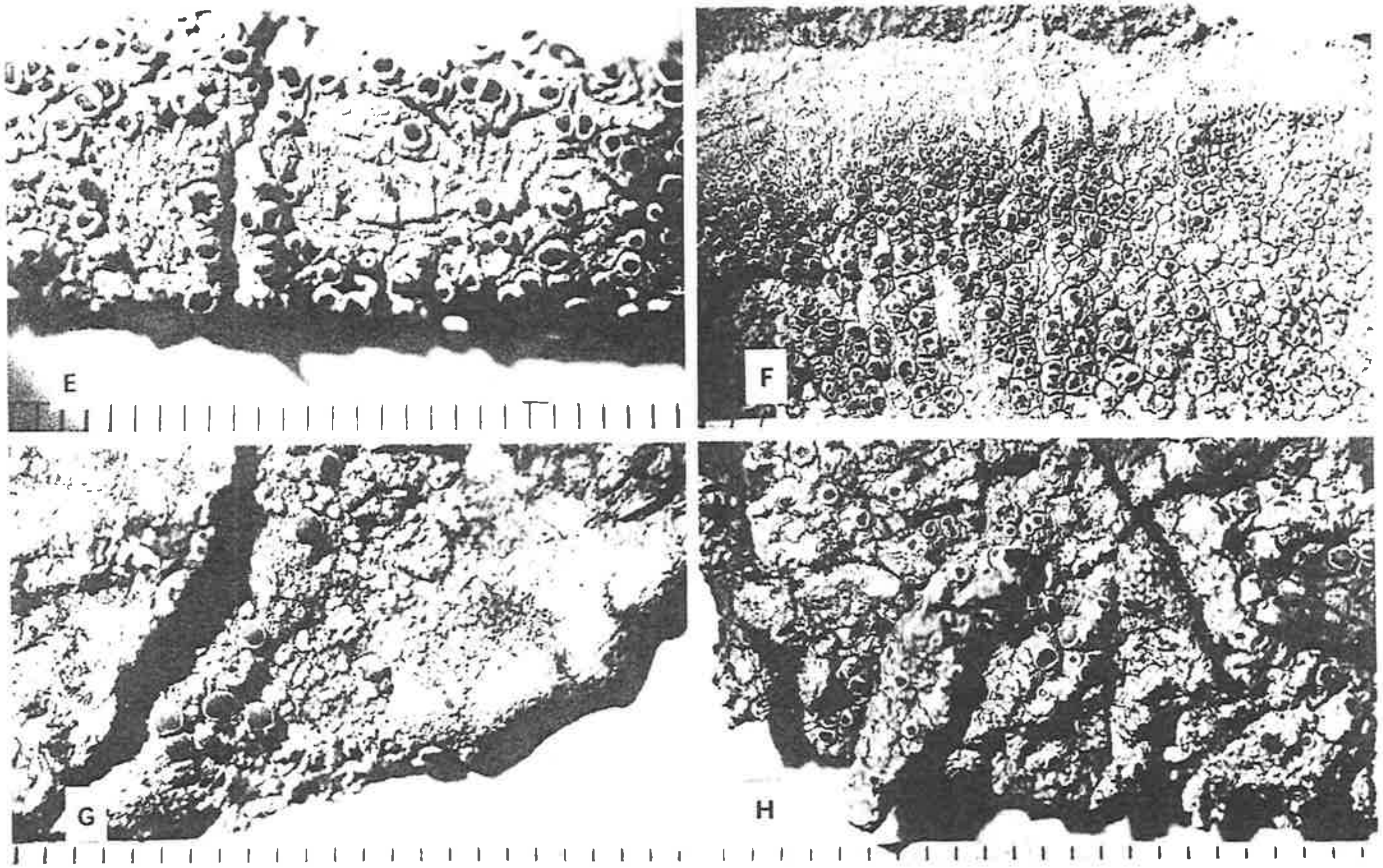

FIG. 4 (continued) E, *H. puniceum* (BRIU, *Rogers* 720); F, *H. similis* (BRIU, *Rogers* 4340); G, *H. sorediatum* (MEL—holotype); H, *H. Stevensiae* (MEL—holotype). Scale marks = 1 mm.

Additional specimens examined: **Queensland:** Narayen C.S.I.R.O. Research Station near Mundubbera, on twigs in softwood scrub, 18 February 1980, *Rogers* 2201; Esk, *F. R. M. Wilson* (NSW L4008); Toowoomba, *Hartmann* (MEL 9166, 9168) (G); Moggill State Forest, on *Alphitonia excelsa*, 17 August 1980, *Stevens;* Woolstone, *F. R. M. Wilson*, (NSW L3988); Brisbane, 1891, *Bailey* (G); Between Beechmont and Binna Burra, 7 km from Binna Burra, on bark of rainforest margin *Alphitonia excelsa*, 17 June 1979, *Rogers* 2156, on bark of *Acacia*, 17 June 1979, *Rogers* 2158, on bark of rainforest tree 17 June 1979, *Rogers* 2157.

2. Haematomma eremaeum R. W. Rogers sp. nov.

Thallus griseus vel caeruleo-griseus, aliquando granulosus et rimosus, esorediatus, cum cortice debiliter evoluto. Apothecia sessilia, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens, integrum vel aliquando crenatum vel distortum; discus griseo-ruber vel rubro-brunneus, epruinosus. Asci 8-spori. Ascosporae helicae in asco, asymetricae, 5–11 septatae, 35–45 × 3–4·5 µm. Atranorium, acidum placodiolicum, et acetono-solva pigmenta A et C continens. (Pigmentum epithecii K+ magentum vel griseo-magentum, esolvum.)

Typus: Australia, Western Australia, 2 miles north-west of Ongerup, Western Australia, e ramulis emortuis *Melaleucae hamulosae*, 11.x.1972, *K. Newbey* L/8 (PERTH—holotypus).

(Figs 2C, 4B)

Thallus, grey to yellowish-grey; somewhat granular or areolate; without soredia; cortex poorly developed.

Apothecia sessile, constricted at the base, to 1 mm diam; thalline margin prominent, entire or somewhat irregular; disc greyish-red to reddish-brown epruinose. Asci eight-spored. Ascospores helically coiled, asymmetric, five to 11 septate, 35–55 × 5–7·5 µm.

Chemistry: atranorin, placodiolic acid, acetone soluble apothecial pigments A and C. (Epithecium K+ magenta to grey-magenta, the coloration insoluble.)

This species is endemic to a dry, mostly inland region of southern Western Australia.

H. eremaeum differs from *H. puniceum* in having fewer septa (five to 11 instead of 11–15) in the spores, different apothecial pigments (A and C instead of B), and in its ecological preferences (occurring in semi-arid areas with winter rainfall patterns, whereas *H. puniceum* occurs in areas with a high summer rainfall).

Additional specimens examined: **Western Australia:** 49 km north of Lake Barlee Homestead, 26 September 1970, *P. G. Wilson 8877* (PERTH); Wongan Hills, 15 June 1974, *K. F. Kenneally* (PERTH); *loc. cit.*, 20 May 1980, *K. F. Kenneally* 7211 (PERTH); Kondinin Forestry Reserve, 8 October 1967, *G. C. Bratt & R. Weeks* 67/373; 18 miles east of Kulin on dead *Acacia*, 11 December 1971, *R. D. Royce* (PERTH); 10 km south-east of Kulin, 15 June 1977, *R. Hnatiuk* 770509, 770524, 770536 (PERTH); Tutanning Reserve, Pingelly, 20 July 1966, *J. P. Kruiscamp* 5 (PERTH, MEL 1020387); Boddington, on *Acacia acuminata*, August 1945, *A. M. Baird* (MEL 8828); West margin of Lake King, 29 August 1970, *R. A. Saffrey* (PERTH); West River, at South Coast Highway, 21 April 1980, *D. Richardson* (PERTH); Wedgicarrup, west of Wagin, 10 September 1947, *N. T. Burbidge* (MEL 1023723); 10 miles north of Borden, 8 October 1965, *R. T. M. Pescott* A17 (MEL 1023722).

3. Haematomma infuscum (Stirton ex Bailey) R. W. Rogers comb. nov.

Lecanora punicea var. *infusca* Stirton ex Bailey, *Qd Agric. J.* 5: 38(1899); type: Australia, Queensland, Jimbour, *F. M. Bailey* ['F. M. Bailey (out of number 10)'] (BM—lectotype, selected here).—*Haematomma punicea* var. *infusca* (Stirton ex Bailey) Zahlbr., *Cat. Lich. Univ.* 5: 770(1928).

(Figs 2D, 4C)

Thallus crustose; white to grey; indeterminate, granular or a thin grey prothallus with scattered thin leprose granules; without soredia; cortex poorly developed.

Apothecia sessile, constricted at the base, to 1 mm diam; thalline margin well developed, entire or somewhat crenate; disc orange-red to red, epruinose. Asci eight-spored. Ascospores helically coiled one about the other in the ascus, asymmetric, five to 15 septate, 35–55 × 3·5–5 µm.

Chemistry: atranorin, no acetone soluble apothecial pigments. (Epithecium pigment K+ magenta, the coloration insoluble in K.)

This is a species of cool damp forests which has apparently been little collected, but is widely distributed from the Bunya Mountains of southern Queensland to Tasmania.

Additional specimens examined: **Queensland:** State Forest *c.* 6 km west of Imbil, on *Alphitonia excelsa,* 5 May 1979, *Rogers* 2078.—**New South Wales:** Dorrigo National Park on eastern side of Dorrigo Mountain, 24 miles west of Bellengen, 29 October 1965 *Filson* 7650 (MEL 1023719); forest just east of Yarrawitch, Port Macquarie to Walcha road, 9 May 1965, *Filson* 7210 (MEL 1023717).—**Victoria:** Boobyalla Saddle, western slopes of Mount Boobyalla, 6 km north of Warburton, 21 March 1965, *Filson* 7022 (MEL 1023712).—**Tasmania:** Mt Arthur, on *Drimys aromatica, F. R. M. Wilson* (NSW L4003).

4. Haematomma pruinosum R. W. Rogers sp. nov.

Thallus albidus vel griseus, farinosus, non granulosus, esorediatus, cum cortice debiliter evoluto. Apothecia sessilia, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens, integrum vel aliquando distortum; discus pallide roseus, dense pruinosus. Asci 8-spori. Ascosporae helicae in asco, asymentricae, 3–6 septatae, 50–65 × 4·5–7 µm. Atranorium, acidum placodiolicum, et acetono-solva pigmenta A et C continens. (Pigmentum epithecii K+ magentum vel griseo-magentum, esolvum.)

Typus: Australia, Western Australia, Mount Manning, 10.iv.1980, *A. U. Milewski* (PERTH 001050—holotypus).

(Figs 2E, 4D)

Thallus white to grey, powdery, not granular, without soredia; cortex poorly developed.

Apothecia sessile, constricted at the base, to 1 mm diam, thalline margin prominent, entire or somewhat irregular; disc pale pink, densely pruinose. Asci eight-spored. Ascospores helically asymmetric, transversely three to six septate, 45–65 × 4·5–7 µm.

Chemistry: atranorin, placodiolic acid, acetone soluble pigment A. (Epithecium K+ magenta to grey-magenta, the coloration insoluble.)

This species differs from *H. eremaeum* in having densely pruinose apothecia and in having spores with fewer (three to six instead of five to 11) septa.

Additional specimen examined: **Western Australia:** Mt Elvire, 12 April 1980, *Milewski* (PERTH 001074).

5. Haematomma puniceum (Ach.) Massal.

Atti Ist. veneto Sci., ser. 3, 5: 253(1860).—*Parmelia punicea* Ach., *Meth. Lich.*: 167(1803); type: America, ‘ in Cinchona Specibus ’, comm. J. E. Smith (H-ACH 1258—holotype).

(Figs 2A, 4D)

Thallus crustose; white to grey, granular to more or less areolate sometimes reduced to scattered granules on a thin prothallus; without soredia; with or without a cortex.

Apothecia sessile on the thallus, constricted at the base, innate only very early in development, to 1 mm diam; thalline margin prominent, entire or somewhat crenate or distorted; disc orange-red to red, epruinose. Asci eight-spored. Ascospores helical, asymmetric, nine to 15 septate transversely, 50–70 × 3–4·5 µm.

Chemistry: atranorin placodiolic acid, acetone-soluble apothecial pigment B. (Epithecium pigment K+ purple grey, soluble.)

The name *Haematomma puniceum* has been widely misapplied. The holotype is esorediate (O. Vitikainen, *in litt.*). European authors have commonly used the name for a sorediate species (Poelt & Vězda 1977). Examination of an apothecial section from the holotype showed that the spores are transversely 15 septate, and 5·5 × 60 µm. Fée (1837) considered the species had four to six septate spores, Nylander (1867) placed material with seven septate spores in the species, and Culberson (1964) believed *H. puniceum* had five to seven septate spores.

The holotype is too small to examine chemically. The material studied chemically by Asahina (1964) is of a different species with 4–6 septate spores ('*Lecanora punicea*', ex herb. Agrel, UPS).

The Australian material listed below cannot be differentiated from *H. puniceum* by any available character.

The type of *H. africanum* Steiner differs from the holotype of *H. puniceum* in having dark brown apothecial discs and 17–22 septate spores. In addition, it differs from the Australian material in having an extra acetone-soluble pigment.

In Australia this species is restricted to a narrow, humid coastal strip in the east, occurring in mangrove communities in the northern part of its range and in humid forests in the central and southern parts.

Additional specimens examined: **Queensland:** Cairns, Trinity Inlet, 16 December 1976, *Tarte* 2546, on *Rhizophora*, 30 August 1976, *Stevens* 1360, 2142, 2984a, 2984b; Keppel Sands, on bark of *Rhizophora*, 10 June 1975, *Rogers* 884; Muellersville near Rockhampton, 1881, *Thozet* (G); Gladstone, on twig of *Rhizophora*, 9 June 1975, *Rogers* 720a, b, c on bark of *Ceriops* between town and power station, 10 June 1975, *Rogers*; Mouth of the Noosa River, *Stevens* 2981; Toowoomba, 1882, *Hartmann* (G); Three Mile Scrub, Brisbane [=Ashgrove], *F. R. M. Wilson* (NSW L3997); Cunningham's Gap, 1883, *Hartmann* (G); on the Mount Mitchell side of the New England Highway, Cunningham's Gap National Park, 1 November 1965, *Filson* 7776 (MEL 1023714); On the way to the Coomera River, Macpherson Range, 21 May 1952, *P. F. Morris* (MEL 1023716); 7 km from Binna Burra, on the Beechmont Road, 12 June 1979; *Rogers* 2161; Binna Burra horse paddock, on *Alphitonia* at the rainforest margin, 17 June 1979, *Rogers* 2155.—**New South Wales:** 4·5 km north of Chillingham, May 1979, *Stevens* 2966, 2967; Dorrigo to Megan Road, 7 miles north of Dorrigo, 29 October 1967, *Filson* 7667 (MEL 1023718); Mt. Wilson, September 1904, *J. Gregson* (NSW L4006); Mosman, August 1894, *F. R. M. Wilson* (G); Bulli June 1904, *Cheel* (NSW L4007); 13 km north of Nowra along Highway 79, on twigs of *Acacia* sp., *Elix* 1848 (J.A.E.). **Victoria:** Mt Drummer, 18 km east of Cann River township, on *Acacia* 21 November 1978, *J. A. Elix* 5222 (J.A.E); Lakes Entrance, 6 November 1901, *R. A. Bastow* (MEL 9170); Lake War War, *F. R. M. Wilson* (NSW L3995); Cunninghame, March 1888, *F. R. M. Wilson* (NSW L3994); Cunninghame, in a gully near the lake, March 1888, *F. R. M. Wilson* (NSW L4000), *F. R. M. Wilson* (NSW L3989, L3990, L3991).

6. Haematomma similis Bagl.

Nuovo G. Bot. ital. 7: 248(1875); type: Ethiopia, Abita, Keren, on wood, *c.* 4,500 ft, 1870, *O. Beccari* [plante de Paese dei Bogos no. 79] (FI—holotype).

Haematomma puniceum var. *subinnatum* Malme, *Ark. Bot.* **29A**(6): 33(1937); type: Uruguay, Colonia Risso, 1895, *Ba* (S—lectotype, selected here).

Haematomma puniceum var. *subarthonioideum* Zahlbr., *Ann. Crypt. Exot.* **5:** 250 (1932); type British East Africa, Bura, *B. Schroder* 284 (W—lectotype, selected here).—*Haematomma subarthonioideum* (Zahlbr.) Hillmann, *Reprium nov. Spec. Regni veg.* **49:** 36(1940).

' *Haematomma subtile*, Bagl. ' appears to be an invalid name used by Dodge (1971: 42) in error for *H. similis.*

(Figs 2F, 4F)

Thallus white to greenish-grey, smooth or areolate, without soredia, corticate.

Apothecia immersed or rarely becoming adnate, never constricted at the base, sometimes confluent or very irregular; disc red (usually vivid red), epruinose; asci eight-spored; spores helically coiled, asymmetric, five to seven transversely septate, 30–45 × 3–5 µm.

Chemistry: atranorin, perlatolic acid, divaricatic acid (or rarely atranorin and imbricaric acid), acetone soluble apothecial pigment A. (Epithecium pigment K+ grey-magenta, insoluble.)

The type of *H. similis* is a small thallus, 8 mm diam, with three to seven septate spores, 25–40 µm long, and contains atranorin and imbricaric acid. Imbricaric acid appears only as a sporadic variant in Australian material, but this difference in chemistry is thought insufficient to warrant separation.

The type of *H. puniceum* var. *subinnatum* differs from the type of *H. similis* only in that it contains no imbricaric acid; it has only atranorin and pigment A. The type of *H. puniceum* var. *subarthoniodeum* Zahlbr. is chemically identical to the type of *H. similis,* and is also morphologically very similar.

In Australia this species occurs almost exclusively in a strip within a few kilometres of the coast north from Sydney.

Additional specimens examined: **Queensland:** Kuranda, on trunk of forest tree, 27 July 1976, *Elix* 2636, (J.A.E.); Port Alma on bark of *Ceriops*, 10 June 1975, *Rogers* 786; The Hummock, 9 km east north-east of Bundaberg, 30 May 1977, *I. R. Telford* 5380B (CBG 7702635); Frazer Island—Wathumba Creek, on bark of *Ceriops*, 14 May 1975, *Stevens* 611; Mary River Heads, on bark of *Avicennia*, 17 May 1975, *Stevens* 596; Noosa River, Noosa, on *Avicennia* at edge of a glade, 28 December 1975, *Stevens* 2365; Aramanga Waterfall, 20 km from Gayndah, May 1979, *Stevens* 2977; 12 km west of Oakey at Brookvale Park, 26 February 1980, *B. Ballingall* 367A, (CBG 8004597); Bribie Island (Pumicestone Passage) on *Callitris* at the water's edge, 1979, *Stevens* 2980; 2 km south of Amity Point, Stradbroke Island, on bark of *Avicennia marina*, 16 May 1973, *Rogers* 2006; Serpentine Creek, Cribb Island, on bark of *Ceriops*, 19 September 1975, *Stevens* 1072; Nudgee Beach on *Cupaniopsis anacardioides*, 8 August 1975, *Rogers & Scarlett* 4382; Mud Island, Moreton Bay, *Stevens* 2982; Sugar Mill Road, Eagle Farm, on *Casuarina*, 19 December 1975, *Rogers & Scarlett* 7379, on *Alphitonia excelsa*, 19 December 1975, *Rogers & Scarlett* 7365; Scrub Rd and Mountain Rd, Belmont, on *Acacia*, 11 November 1975, *Rogers & Scarlett* 5751; 3 mile Scrub [= Ashgrove] Brisbane, *F. R. M. Wilson* (NSW L4010); Hannan St, Grovely, on *Alphitonia excelsa*, 15 December 1975, *Rogers & Scarlett* 7014; Ugly Gully in Moggill State Forest, on rainforest tree, 3 February 1975, *Rogers & Beasley* 3226; Whyte Island near gasometer, on *Avicennia*, 20 July 1978, *Stevens 2592; Botanic Gardens, F. R. M. Wilson* (NSW L4009); Monterey Avenue, Thornlands, on *Alphitonia excelsa*, 31 October 1975, *Rogers & Scarlett* 5518; Tingalpa Creek on *Avicennia*, 12 March 1975, *Rogers & Beasley* 5131; Goodna, *F. R. M. Wilson* (NSW L3996); Little Rocky Point, Jacobs Well, on coastal fringe *Brugiera*, *Stevens* 1373, *1415.*—**New South Wales:** Hastings Point, Cudgera Creek on *Avicennia*, 20 August 1977, *Stevens* 1972; Whalebone Wharf, Port Macquarie on *Avicennia* twigs, 22 August 1977, *Stevens* 1991, 2978; Tuggerah Lakes, September 1904, *J. Gregson* (NSW L4004); Manly on fig tree, 1 August 1897, *F. R. M. Wilson* (NSW L4012); Manly, August 1897, *F. R. M. Wilson* (NSW L4005).

A full list of specimens examined is lodged in the National Herbarium of Victoria (MEL) and in the Library of the British Lichen Society.

7. Haematomma sorediatum R. W. Rogers sp. nov.

Thallus albidus vel griseus, rimosus vel granulosus, sorediatus, corticatus. Apothecia sessilia, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens, integrum vel distortum; discus aurantiaco-ruber, epruinosus. Asci 8-spori. Ascosporae helicae in asco, asymetricae, 8–14 septatae, 50–70 × 4–7 µm. Atranorium, acidum placodiolicum, et acetono-solva pigmenta A et B continens. (Pigmentum epithecii K+ purpureo-griseum, solvum.)

Typus: Australia, Victoria, Lakes Entrance, ad corticem *Notolea ovata*, iii. 1889 *F. R. M. Wilson* (MEL 9169—holotypus).

(Figs 2G, 4G)

Thallus white to grey; chinky or granular; sorediate, corticate.

Apothecia sessile, constricted at the base, to 1 mm diam, thalline margin well developed, or somewhat irregular; disc orange-red, epruinose. Asci eight-spored. Ascospores helically asymmetric, transversely eight to 14 septate, 50–70 × 4–7 µm.

Chemistry: atranorin, placodiolic acid, acetone soluble apothecial pigments A and B. (Epithecium pigment K+ purple-grey, soluble.)

This species is apparently an endemic of the Lakes Entrance area of south-eastern Victoria. No collections have been made this century.

H. sorediatum differs from *H. leparioides* (Vainio) Vainio in that *H. sorediatum* contains placodiolic acid and atranorin, whereas *H. leparioides* contains only atranorin.

Additional specimens examined: **Victoria:** Lake Tyers, on bark of *Pomaderis apetala*, March 1888, *F. R. M. Wilson* (NSW L3999); Lake Tyers, on bark, March 1888, *F. R. M. Wilson* (NSW L3993).

8. Haematomma stevensiae R. W. Rogers sp. nov.

Thallus albidus vel cinereo-griseus vel griseo-viridis, rimosus vel granulosus, granulis aliquando valde bullatis, esorediatus, corticatus. Apothecia sessilia vel subpedicellata, usque ad 2·5 mm diametro; excipulum thallinum prominens, integrum; discus aurantiaco-ruber (vel raro ruber). Asci 8-spori. Ascosporae rectae vel helicae in asco, asymetricae, 5–15 septatae, 50–65 × 2·5–4 µm. Atranorium, acidum perlatolicum, et acidum divaricatum continens, acetono-solva pigmenta desunt. (Pigmentum epithecii K+ magentum vel griseo-magentum, esolvum.)

Typus: Australia, Queensland, Sunset Beach (proxime Mackay) Eimeo Beack Creek ad corticem *Rhizophora*, 14.viii.1976, *G. N. Stevens* 2970 (MEL 1031269—holotypus).

(Figs 2H, 4H)

Thallus crustose; white to yellow-grey or grey-green; indeterminate; areolate to granular, the granules sometimes becoming strongly bullate; without soredia; corticate.

Apothecia sessile to almost sub-pedicillate, to 2·5 mm diam; thalline margin well developed, entire, disc orange-red (or rarely red), epruinose. Asci eight-spored. Ascospores straight or helical, asymmetric, five to 15 septate, 50–65 × 4–5·5 µm.

Chemistry: atranorin, perlatolic acid, divaricatic acid, no acetone soluble apothecial pigments. (Epithecium pigments K+ magenta to grey-magenta, insoluble.)

This species is known only from mangroves in tropical Queensland, where it is apparently common. The species is named in honour of Nell Stevens, who has made a major contribution to the knowledge of lichens of mangrove communities in Australia.

Additional specimens examined: **Queensland:** Trinity Bay (MEL 9167); The Haven, Hinchinbrook Island on bark of *Aegiceras, Stevens;* Side Catwalk, Hinchinbrook Island on *Rhizophora*, 1979, *Stevens;* Eimeo Beach Creek (Sunset Beach), on tall *Excoecaria* on land fringe of grove, 16 July 1976, *Stevens* 2968, on bark of old *Rhizophora* on land fringe, 14 August 1976, *Stevens* 2969; Corio Bay, on *Excoecaria agallocha*, 18 June 1974, *D. Tarte;* Keppel Sands, on bark of *Excoecaria*, 10 June 1975, *Rogers* 774, 778.

I wish to thank Dr J. A. Elix for the loan of specimens and assistance with chemistry and Ms C. Scarlett and Ms G. N. Stevens for collecting specimens for the study. Mr O. Vitikainen kindly made notes concerning the holotype of *H. puniceum* for me, and sent me a section of an apothecium for examination. I am also grateful to the following institutional herbaria for the loan of material: BM, CBG, FI, G, H, MEL, NSW, PERTH, PRE, S, TUR, UPS, VER, and W. The Latin diagnoses were prepared by Dr & Mrs D. L. Hawksworth. This work was assisted by a grant from the Australian Biological Resources Study.

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19. **Rogers, R.W.** (1985). Additional notes on *Haematomma* in Australia. *Lichenologist* **17**, 307-9.

ADDITIONAL NOTES ON *HAEMATOMMA* IN AUSTRALIA

Eight corticolous species of the genus *Haematomma* have previously been reported in Australia (Rogers 1982). It has become apparent that to date no saxicolous *Haematomma* have been found in Australia: some saxicolous material, which had been provisionally identified as *Haematomma* in various collections is referrable to *Protoblastenia.*

Material examined since my original publication has resulted in a significant change in the known range of *H. sorediatum* and the discovery of new species in rain forest near Brisbane.

Haematomma sorediatum R. W. Rogers

Described from material collected in 1889 by F. R. M. Wilson near Lakes Entrance in Victoria, this species was known only from that area and had not been collected this century. It was feared that it might be extinct, since the Lakes Entrance area has been the subject of severe wildfires several times this century. However, a recent collection can now be cited: Marie Island N. P., 1·5 km north-west of summit of Mt Maria, uppermost Counsel Creek, 42°36′S, 148°05′E, alt. *c.* 300 m in rather humid creek with *Eucalyptus viminalis*, *Acacia melanoxylon* and *Pomaderris* understorey, on trunk of *Pomaderris apetala*, 11 March 1981, *L. Tibell* 11358 (UPS). Maria Island is an inshore island off the south-eastern coast of Tasmania. The specimen is small with small apothecia closely resembling the type. It is likely that this inconspicuous species will be found in other areas of *Eucalyptus* forest with a *Pomaderris apetala* understorey.

Haematomma bubalinum R. W. Rogers sp. nov.

Thallus albidus vel griseus, rimosus vel granulosus, corticatus. Apothecia sessilis, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens integrum; discus apparanter bubalinus, sed rubroaurantiacus et dense luteo-pruninosus. Asci 8-spori. Ascosporae helico in asco, asymmetricae, 9–15 septatae, 50–70 × 3–4·5 µm. Atranorin, acidum placodiolicum continens; pigmentum epithecii K-.

Holotypus: Australia, Queensland, Mt Mee State Forest (27°17′S, 152°45′E), on the bark of *Alphitonia excelsa* by side of track in rainforest, 9 June 1981, *R. W. Rogers* 2298 (MEL).

Thallus white to grey, chinky to granular, corticate. Apothecia sessile, constricted at the base, up to 1 mm diam, thalline exciple prominent, entire, disc plane, apparently buff, but reddish-orange with a dense covering of yellow pruina, Asci eight-spored. Ascospores helically asymetric, 9–15 septate, 50–70 × 3–4·5 µm.

Chemistry: Atranorin, placodiolic acid, no acetone-soluble pigments. Epithecium K –.

Additional specimen examined: **Queensland:** Mt Mee, State Forest, on bark of *Alphitonia excelsa*, by side of track in rainforest, 10 July 1981, *R. W. Rogers* 2261 (BRIU).

This species resembles *H. puniceum* (Ach.) Massal. in gross morphology, thallus chemistry and spores. It is, however, quite distinct as it has a dense layer of bright yellow pruina overlying the disc, lacks acetone-soluble pigments in the apothecium, and shows no K reaction in the epithecium. The species looks superficially very like *Lecanora chlarotera* s. lat. as the somewhat red disc shows through the yellow pruina, although there is no red coloration visible in mature apothecia except under magnification. It is currently known from only two collections from the same location, both on *Alphitonia excelsa* at the margin of rain forest. The forest in which the collections were made has since been destroyed and replanted with *Araucaria*. A search in other similar regions has so far failed to find more material.

I wish to thank Dr L. Tibell for sending me the Tasmanian collection of *H. sorediatum*.

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R. W. Rogers*

*Botany Department, University of Queensland, St Lucia, Queensland 4067, Australia.

TYPIFICATION OF *USNEA COMPRESSA* TAYLOR

In the protologue of *Usnea compressa* Taylor, Taylor (1847) stated 'Thallo pendulo, lineari, compresso, cinereo, dichotomo, elongate articulato, ramis basi angustatis, acuminatis, patentibus; gemmis granulatis; apotheciis terminalibus, planiusculis, concoloribus, pruinosis, margine ciliatis, extus laevibus'. Additional details include '. . . thallus 4–5 inches long, ultimate branches short, at right angles to stem, joints attenuated at each end, rough with numerous granular buds. The flattened and jointed stems distinguish this from *Usnea florida* Ach'.

The syntype material preserved at the Farlow Herbarium (FH-TAYL) consists of three specimens: (1) from Nepal, *Wallich* (Fig. 1), (2) from Mysore, *Wight* (Fig. 2), and (3) from Norfolk Island, *A. Thomson* (Fig. 3). The three specimens are mounted on separate sheets. There are no annotations by Motyka on any of them.

We have examined the three specimens and find them different from each other. The specimens from Nepal and Norfolk are fertile (with apothecia) and lack isidia, while the specimen from Mysore is sterile, isidiate and corresponds to *Usnea bismolliuscula* Zahlbr. in morphology and chemistry. As it is sterile, the specimen from Mysore is eliminated from consideration as a candidate for lectotypification as the protologue indicates a thallus with apothecia.

Although Motyka did not examine any of the three specimens at FH, in the discussion under *Usnea crassula* Mot. he reports 'In herb. Müll. Arg. adest specimen *U. compressae*, ad ipso auctore speciei [i.e. Taylor] determinantum, quod ad hanc speciem pertinet. Haec non est tamen vera *U. compressa*, nam primaria *U. compressa* e Nepaul Indiae Orientalis provenit et sit possibile species ex affinitate *U. thomsonii*; mihi est ignota' (Motyka, 1936–38: 591). The specimen in the herbarium of Müller (G) seen and cited by Motyka is a duplicate of the one from Norfolk Island. Whether this duplicate seen by Motyka and the one at FH are identical has not been confirmed by us, but Motyka referred that specimen to *U. crassula* Mot., which has a K− medulla while the specimen at FH has norstictic acid (K+ red) in its medulla. The specimens at FH from Nepal and Norfolk Island need to be discussed *vis-à-vis* the protologue of the taxon for lectotypification. Both the specimens have articulate branches, granular papillae, terminal pruinose apothecia with ciliate margins and a smooth receptacle, but there is a difference in the branching habit. The Nepal specimen reflects a lax dichotomous branching at intervals, the inter articulate region flattened by compression (probably due to pressure at the time of collection) and the presence of white pseudocyphellae; while in the Norfolk Island specimen, 8–10 major branches arise compactly from near the base, are almost equal in length, slightly compressed but not

20. **Rogers, R.W. & Bartlett, J.K.** (1986). The lichen genus *Haematomma* in New Zealand. *Lichenologist* **18**, 247-55.

Lichenologist **18**(3): 247–255 (1986)

THE LICHEN GENUS *HAEMATOMMA* IN NEW ZEALAND

R. W. ROGERS* and J. K. BARTLETT‡

Abstract: Five species of the lichen genus *Haematomma* Massal. *s.l.* (Ascomycotina, Lecanoraceae *s.l.*) are reported for New Zealand. Two new species *H. alpinum* and *H. saxicola* are described, and *H. sorediatum* is reported from New Zealand for the first time. Two other species, *H. babingtonii*, and *H. hilare*, are also reported. All five species appear to belong to the *H. puniceum* group. Pseudoplacodiolic acid is reported in the genus *Haematomma* for the first time.

Introduction

The genus *Haematomma* Massal. (Lecanoraceae *s.l.*) has been used to accommodate a range of species having lecanorine apothecia and spores with three or more transverse septa. Many of the species have red-coloured apothecial discs, although the pigments may differ in different species. It is clear that the genus is quite heterogeneous, and should be divided into several genera. Hafellner (1984) has erected the family Haematommaceae based on the genus *Haematomma* Massal., lectotypified on *H. vulgare* Massal. (i.e. *H. ochroleucum* (Necker) Laundon). It is clear that the species in the *H. puniceum* group are quite unrelated to *H. ochroleucum*: apothecial ontogeny is different, as is the ascus apical apparatus. *Haematomma* as known in Australia and New Zealand is probably referrable to the family Scoliciosporaceae Hafellner. Clarification of taxonomic relationships within the broad genus *Haematomma* will necessarily be a prolonged process as interrelationships are worked out within the Lecideaceae *s.l.* and the Lecanoraceae *s.l.* No modification of the genus is therefore proposed here, but it is used in the sense of Zahlbruckner (1927–8).

The lichen genus *Haematomma* has been reviewed recently for New Zealand by Galloway (1985), and for Australia by Rogers (1982, 1985). Galloway recognized three species for New Zealand: *H. babingtonii* and *H. hilare*, both of which are endemic to New Zealand, and *H. subpuniceum* which was described from South America. None of the nine species reported by Rogers were found by Galloway to occur in New Zealand. Zahlbruckner (1941) described *H. hilare* and reported *H. babingtonii, H. puniceum* and *H. puniceum* var. *rufopallens* from New Zealand: however, examination of most of the collections he cited revealed only *H. hilare* and *H. babingtonii*.

Following the collection of material of *H. sorediatum* from the North Island it was decided to undertake a revision of all available collections. Material was therefore borrowed from CHR, AK, CANUC and BM. The private collection of J. K. Bartlett (abbreviated here as JKB) was also available.

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*Botany Department, University of Queensland, St. Lucia, Queensland 4067, Australia.
‡6 Grove Lane Pakuranga, Auckland, New Zealand.

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All material was subject to examination by thin-layer chromatography (t.l.c.) using the standard methods of Culberson (1972). After initial sorting of collections by this method a selection of specimens was examined microscopically and the K reaction of the epithecium observed (Rogers 1982). Colour terminology is based on Kornerup & Wanscher (1967).

Anatomy and Morphology

Thallus: Quite variable in most species, ranging from thick to thin; usually somewhat granular, especially in *H. saxicola* and *H. babingtonii*. Only one species, *H. sorediatum* shows the development of soredia. The thallus of *H. hilare* is usually very thin, often almost invisible.

Apothecia: Sessile in all species reported for New Zealand. The margin is clearly lecanorine in all species, sometimes becoming quite thick. Pruina are developed very strongly on the discs of *H. babingtonii*, although the amount may decrease with age. Absence of pruina is a useful character for the separation of *H. alpinum* from *H. babingtonii*.

Ascospores: Elongate structures with 2–5 transverse septa in *H. alpinum, H. babingtonii* and *H. saxicola*, or up to 11–15 transverse septa in *H. sorediatum* and *H. hilare*. Spores of all species are illustrated in Fig. 1.

Chemistry: Both apothecial and thalline chemistry is of interest in this genus. The apothecia of *H. hilare* and *H. saxicola* contain a substance which

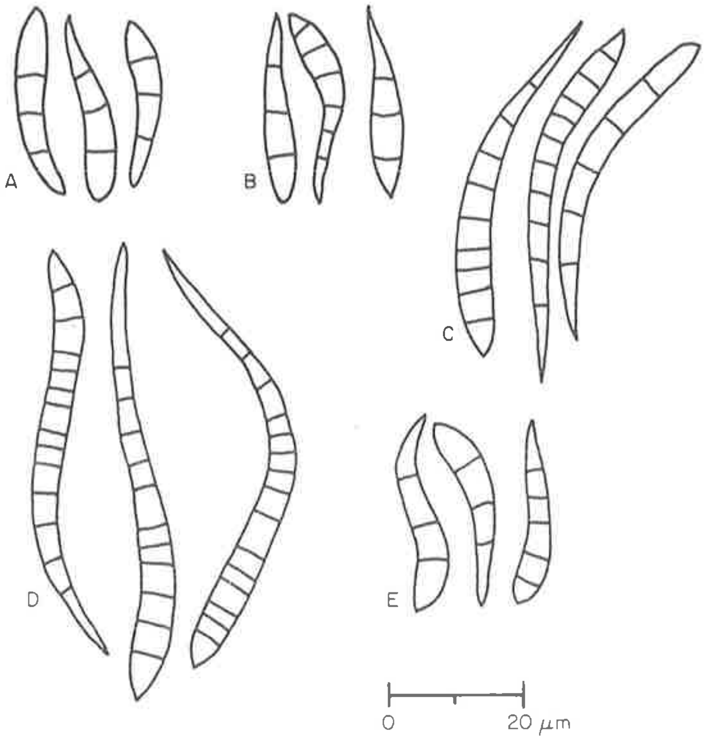

FIG. 1. Spores of the species of *Haematomma* known from New Zealand, drawn from the type specimen in each case: A, *H. alpinum;* B, *H. babingtonii*, C, *H. hilare*; D, *H. sorediatum*; E, *H. saxicola.*

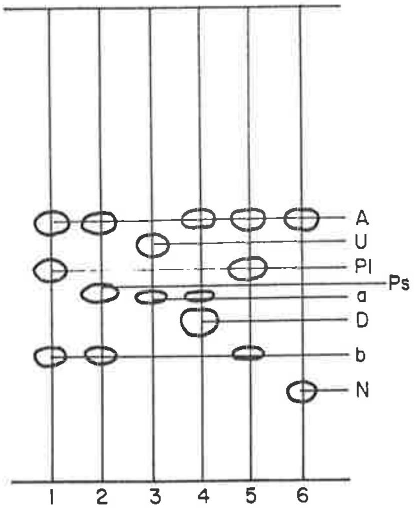

FIG. 2. Diagram illustrating thin-layer chromatographic characteristics of the species of *Haematomma* in New Zealand. 1, *H. alpinum*; 2, *H. babingtonii*; 3, *H. hilare*; 4, *H. saxicola*; 5, *H. sorediatum*; 6, control. A, Atranorin; U, unknown in *H. hilare*; Pl, placodiolic acid; Ps, pseudoplacodiolic acid; D, divaricatic acid; a, acetone soluble pigment; b, acetone soluble pigment; N, norstictic acid.

results in the epithecium producing a long-lasting magenta coloration that remains in or near the epithecium when a section is irrigated with K. The epithecia of the other species all turn purple-grey when irrigated with K, the colour flowing out of the section and fading rapidly, in or near the epithecium. An apothecial pigment which is UV+ gold on a t.l.c. plate has been found in all species from New Zealand, except *H. hilare*. All species except *H. hilare* show the presence of atranorin in the thallus. Pseudoplacodiolic acid is present in *H. babingtonii* and *H. hilare*, whereas *H. sorediatum* and *H. alpinum* contain placodiolic acid. Divaricatic acid occurs in *H. saxicola*. Characteristic t.l.c. patterns for the five species are shown in Fig. 2.

Biogeography: Four of the five species (*H. alpinum*, *H. babingtonii*, *H. hilare* and *H. saxicola*) are apparently restricted to New Zealand. *H. sorediatum* is otherwise known only from a few collections from Tasmania and Victoria (Rogers 1985). Within New Zealand the three relatively common species appear to have relatively distinct distributions. *H. sorediatum* occurs north of 38° and at a single location in the far north of the South Island. *H. babingtonii* occurs south of *H. sorediatum* in the North Island and is widespread in the South Island, where it is common at low altitudes. *H. alpinum*, on the other hand is restricted to the South Island, and is found only at high altitudes. This distribution pattern closely correlates with temperature variations. It appears that the species are never sympatric.

Key to the species of Haematomma in New Zealand

1	Section through apothecium fleetingly K+ purple-grey . . .	2
	Section through apothecium K+ magenta	4

2(1) Thallus sorediate . . . . **H. sorediatum** (p. 254)
Thallus esorediate 3

3(2) Disc densely pruinose . . . . **H. babingtonii** (p. 251)
Disc epruinose . . . . **H. alpinum** (p. 250)

4(1) Thallus saxicolous . . . . **H. saxicola** (p. 254)
Thallus corticolous . . . . **H. hilare** (p. 253)

The Species

Haematomma alpinum R. W. Rogers sp. nov.

Thallus albidus vel cinereo-griseus, rimosus vel granulosus, esorediatus, corticatus. Apothecia sessilia, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens, integrum vel distortum; discus aurantiaco-ruber vel ruber. Asci 8-spori. Ascosporae helicae in asco, asymmetricae 3–4 transeptae 30–40 × 2·3–4·0 µm. Atranorin, acidum placodiolicum continens. Pigmentum epithecii K+ magenteum esolvum.

Typus: New Zealand, Dry Creek Ridge, Mt Torlesse, on *Hymenanthera alpina*, *c.* 3000–4000 ft, *M. Sutherland* (WELT L215—holotypus).

(Figs 1A, 3, 5A)

Thallus crustose; white to yellow-grey, indeterminate, areolate to granular, esorediate, corticate. *Apothecia* sessile, constricted at the base, up to 2·5 mm diam; thalline margin well developed, entire or somewhat distorted, disc

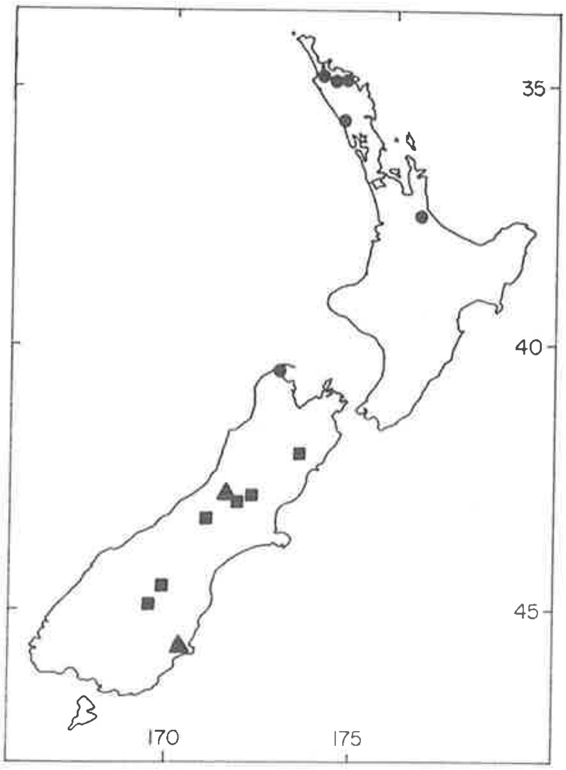

FIG. 3. Distribution of *H. sorediatum* (●), *H. alpinum* (■), and *H. hilare* (▲) in New Zealand.

reddish-brown, epruinose. Asci 8-spored. *Ascospores* helically coiled in the ascus, asymmetric, 3–4 transseptate, 30–40 × 2·5–4·0 µm.

Chemistry: atranorin, placodiolic acid, epithecium fleeting K+ purple-grey, acetone soluble apothecial pigment UV+ gold on t.l.c. plate.

This species is known mostly from twigs of *Hymenanthera* at altitudes of 1000–1300 m in the central spine of the South Island, hence the name *alpinum*. Thalli are usually small and on twigs. Superficially like *H. babingtonii, H. alpinum* differs in the absence of pruina from the apothecial disc even when young, and in containing placodiolic acid, whereas *H. babingtonii* has the apothecium almost always heavily pruinose, and contains pseudoplacodiolic acid.

Additional specimens examined: **South Island:** Molesworth, on dead branch of *Discaria,* 18 xi 1945, *H. H. Allen* (CHR 162110); Castle Hill, on *Hymenanthera, H. H. Allen* (CHR 398327); Dry Creek Ridge, Mt Torlesse, on *Hymenanthera alpina, M. Sutherland* (WELT L215B); Mt Peel, Canterbury, Easter 1965, *Graeme Martin* (CHR 398321); Hawkden Ra. 4500 ft, 2 xii 1978 *John Child* (CHR 397035); Old Man, 3700 ft, *P.C.* (CHR 384405).

Haematomma babingtonii Massal.

Mosk. Obs. Isp. Prir. **36:** 260 (1863); type:—ad truncos arborum N. Zelandia, *W. Colenso* (VER—holotype).

H. puniceum sensu Zahlbruckner (1941), *non* (Sw.) Massal.
H. puniceum var. *rufopallens sensu* Zahlbruckner (1941), *non* (Nyl.) Vainio.

(Figs 1B, 4, 5B)

Thallus crustose, white to yellow-grey, indeterminate, areolate to granular, esorediate, corticate. *Apothecia* sessile, constricted at the base, up to 2·5 mm diam; thalline margin well-developed, entire or somewhat distorted, disc pinkish-white to brownish-red, strongly white pruinose especially on young apothecia. Asci 8-spored. *Ascospores* helically coiled in the ascus, asymmetric, 3–5(–6) transseptate, 30–40 × 2·5–4·0 µm.

Chemistry: atranorin, pseudoplacodiolic acid; epithecium fleeting K+ purple-grey, acetone soluble apothecial pigment UV+ gold on t.l.c. plate.

This species is quite distinctive in almost all cases as the discs of the apothecia are normally heavily white pruinose, although in some older apothecia the pruina are present only as faint traces close to the margins. In some collections the thallus is rugose and quite thick, such collections also showing a thick and irregular margin to the apothecium. Specimens with thin smooth thalli and thin smooth margins may be found at the same location, and because a continuum of variation can be shown to link the two extremes, no taxonomic rank is proposed for them.

This species is common and widespread, especially in the South Island, where it is found mostly at lower altitudes than *H. alpinum.*

Selected specimens examined: **North Island:** Whakapapaiti Valley, 4150 ft, i 1974, on beech, *B. W. Hayward* (AK); Headwaters of Whangamomona Stream on podocarp in dense podocarp forest *c.* 300 m, 23 ix 1976, *J. K. Bartlett* (JKB); Horopito, on rimu in podocarp remnant, *c.* 900 m, 16 v 1980, *J. K. Bartlett* 31978 (JKB); Rangitiki Gorge, on *Sophora c.* 800 m, 7 iii 1979, *J. K. Bartlett* 21741c (JKB); edge of wood near Matamui, on living *Hoheria sexstylosa,* 28 iv 1884,

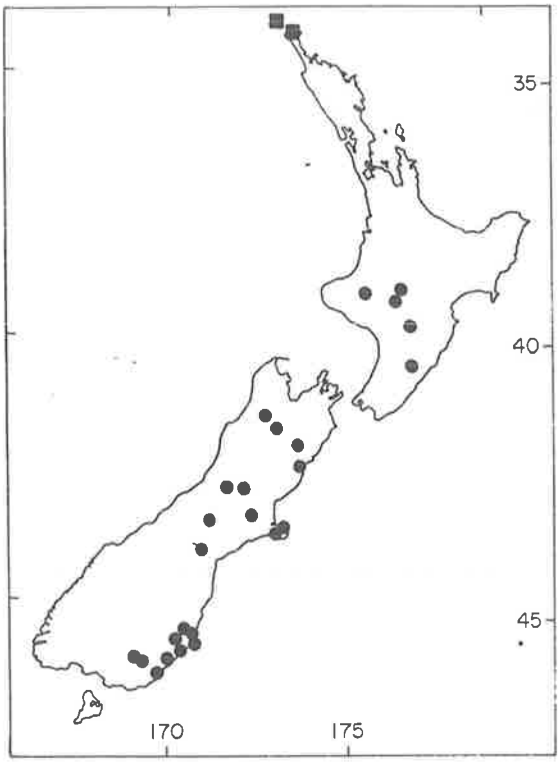

FIG. 4. Distribution of *H. saxicola* (■) and *H. babingtonii* (●) in New Zealand.

W. Colenso 1677 (WELT L2227); Te Kaikokirikiri on *Plagianthus*, *W. Colenso* 5044 (WELT L2229). **South Island:** Owen Range, headwaters of Gorge stream, *c.* 1000 m, 27 i 1982, *J. K. Bartlett* (JKB); Lake Rotorua, 16 xi 1966, *D. Galloway* (CHR 266599); Molesworth, on *Hymenanthera alpina*, 20 ii 1941, *H. H. Allen* (CHR 241756); Spotswood, on branches 10 vii 1958, *A. J. Healy* 58/477 (CHR 241751); 1 km south of Mt Palm, Lowry Peaks Range, on dead shrub, 24 i 1980, *J. A. Elix* 6900 (CANUC, CHR 267117); Castle Hill, 790 m, on dead matagouri, 9 vi 1980, *J. A. Elix* 8483 (CANUC); Lake Coleridge, 35 km north of Methven, on matagouri shrubs, 550 m, 26 i 1980, *J. A. Elix* 7634 (CANUC); Lake Rubicon, on *Aristotelia fruticosa*, 2 xi 1969, *L. B. Moore* (CHR 162151); Mt Torlesse Range, 17 viii 1961, *R. Prickett* (CHR 398328); Kowai Bush, near Springfield, on *Ribes uva-crispa*, 26 iii 1962, *A. J. Healy* 62/178 (CHR 398335); Gully behind Diamond Harbour, Banks Peninsula, on bark of *Sophora microphylla*, 12 iv 1962, *A. J. Healy* 62/213 (CHR 398332); 4 km south of Akaroa, 660 m, on shrubs in open grassland, 8 i 1980, *J. A. Elix* 6672 (CANUC); Alford Forest, on beech bark, 17 ix 1977, *Galloway* (CHR 240317); Mt Somers, on *Cytissus scoparius*, 7 ix 1962, *A. J. Healy* 62/262 (CHR 160464); Lynn Stream, south of Rangitata River on *Discaria*, 13 v 1964, *A. J. Healy* 64/93 (CHR 398324); West of Arundel, on *Malus sylvestris*, 13 v 1964, *A. J. Healy* 64/84 (CHR 398301); north of Mt Peel, on *Pittosporum*, 30 xii 1940, *A. J. D. Barker* (CHR 241758); *D. Galloway* (CHR 378570); Paradise, on matagouri, 1200 ft, 25 viii 1970, *J. Child* (CHR 384429); Waitati, sea-level, on willow bark, 22 vi 1969, *J. Child* (CHR 384439); Verter Burn on twigs, 2400 ft, 21 vi 1933, *J. S. Thomson* 361 (CHR 241760); Saddle Hill near Dunedin, on bark of *Hoheria angustifolia*, 17 v 1933, *J. S. Thomson* 147 (CHR 162831); summit of Mt. Maungatu on *Hymenanthera alpina*, 25 iv 1935, *J. S. Thomson* 2020 (CHR 241757); Abbots Hill, Dunedin, on *Pseudopanax crassifolium*, *J. Thomson* 932 (CHR 398334); Lake Waihola, sea-level, on willow twigs, 14 ix 1969, *J. Child* (CHR 384435); Manuka Gorge between Waitahuna and Milton, on *Cytissus scoparius*, 7 ix 1962, *A. J. Healy* 62/266 (CHR 160461); Kaiwera near Gore, on willows, 30 ix 53, *W. Martin* 777,783 (CHR 398342); Conical Hills, Otago, on tree trunk, *G. B. Rawlings* (CHR 241762).

Haematomma hilare Zahlbr.

Denkschr. Akad. Wiss., Math.-nat. Kl. 104: 267 (1941); type: New Zealand, Otago, Silver Peaks, on *Nothofagus menziesii*, *c.* 500 m, *J. S. Thomson* V82 (CHR 241752—lectotype; W—isolectotype).

(Figs 1C, 3, 5C)

Thallus thin, filmy, white to greyish, without developed granules or areoles, esorediate. *Apothecia* sessile, constricted at the base, up to 2 mm diam; margin thin, usually entire; disc reddish-orange to brownish-red; occasionally with sparse white pruina. *Asci* 8-spored. *Ascopores* helically coiled in the ascus, 5–13 transseptate, 30–60 × 2·5–4·0 µm.

Chemistry: Atranorin, pseudoplacodiolic acid, unknowns; epithecium K+ magenta, without acetone soluble apothecial pigments.

H. hilare is a particularly distinctive species, its apothecial disc is very much more orange than other species, and its thallus is very thin and filmy.

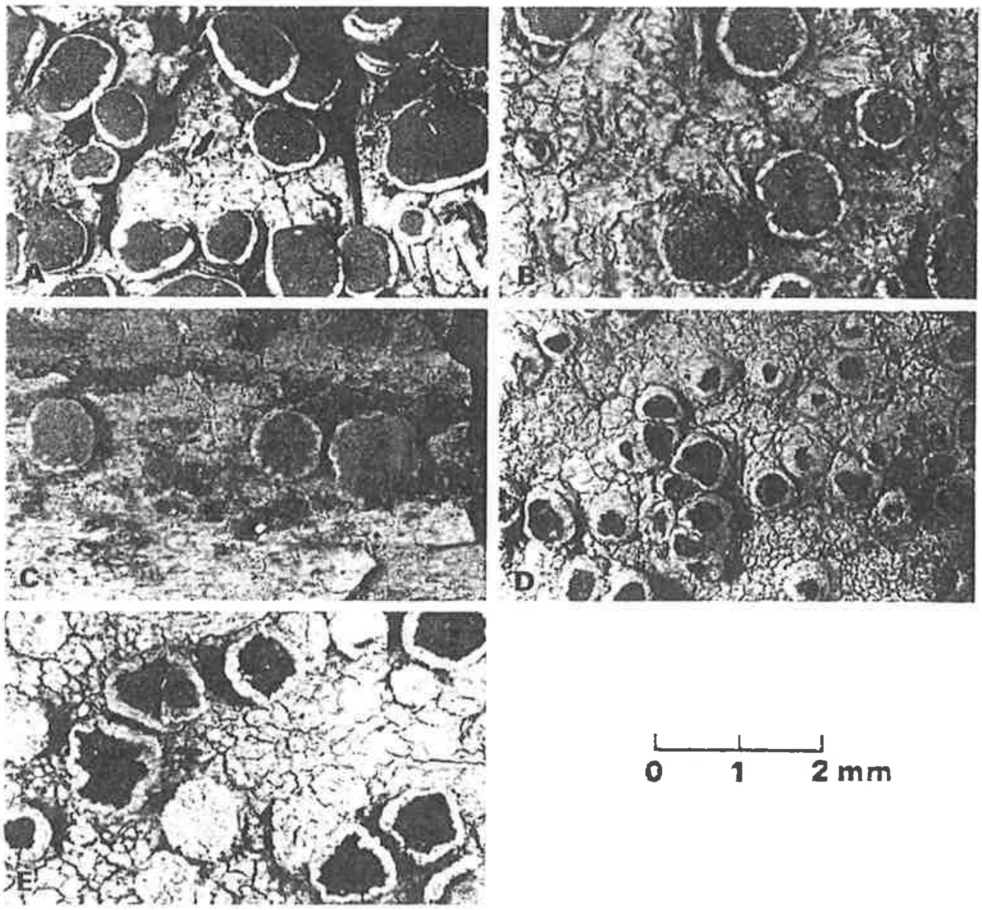

FIG. 5. Habit of: A, *H. alpinum*; B, *H. babingtonii*; C, *H. hilare*; D, *H. saxicola*; E, *H. sorediatum*. All photographs are to the same scale.

Only two species in New Zealand, *H. hilare* and *H. sorediatum*, have spores with 11–13 transsepta. This species is clearly rare, being known from only two locations.

Additional specimens examined: **South Island:** Hawdon River, Arthurs Pass National Park, on trunk of *Nothofagus solanderi*, 610 m, Tibell 9458 (CHR 378553); Silver Peaks, near Dunedin, on *Nothofagus menziesii*, *c.* 500 m, *J. S. Thomson* (CHR 378554, ?isotype), 6 xii 1936, *H. H. Allen* (CHR 378553).

Haematomma saxicola R. W. Rogers sp. nov.

Thallus albidus vel cinereo-griseus, rimosus vel granulosus, esorediatus, corticatus. Apothecia sessilia, basi constricta, usque ad 1 mm diametro; excipulum thallinum prominens, integrum vel discus aurantiaco-ruber vel ruber. Asci 8-spori. Ascosporae rectae vel helicae in asco, asymmetricae 2–5 transeptae 20–30 × 2·5–4 µm. Atranorin, acidum divaricatum continens. Pigmentum epithecii K+ magneteum, esolvum.

Typus: New Zealand, Pandora Beach, Mangonui Co., N. Auckland, sea level on coastal rocks 5 m above high tide, 14 xii 1979, *J. K. Bartlett* 29161 (WELT—holotype).

(Figs 1E, 4, 5D)

Thallus white to grey, continuous to somewhat areolate or granular; esorediate, corticate. *Apothecia* sessile, constricted at the base, to 1 mm diam, margin well-developed, entire, sometimes disappearing on older thalli, brownish-red to reddish-brown, epruinose. Asci 8-spored. *Ascospores* helically asymmetrical, 1–5 transseptate, 25–35 × 3–5 µm.

Chemistry: atranorin, divaricatic acid; epithecium K+ magenta.

H. saxicola is the only saxicolous species known for the genus in New Zealand. It is clearly related to the normally corticolous *H. puniceum* group, and not to the saxicolous *H. ventosum* group of the subarctic and alpine Northern Hemisphere. *H. subpuniceum* (Müll. Arg.) B. de Lesd. is another apparently similar species reported from South, Central and North America (Müller-Argoviensis 1888, Bouly de Lesdain 1929, Culberson 1964), but that species differs in the absence of divaricatic acid. While the presence or absence of an orcinol paradepside would not normally be considered sufficient grounds for the separation of two species, in this case the wide disjunction of the collections has also been taken into account. The species is confined to coastal rocks of the far northern parts of the mainland and adjacent islands.

Additional specimens examined: **Three Kings:** Great Island on cliffs 100 m above sea-level, *B. & G. Heywood* (AK); South-West Island on summit rocks, 1 xii 1970, *D. J. Galloway* (BM); Great Island, south-east slopes above cove on coastal cliff, xi 1970, *D. J. Galloway* (BM).

Haematomma sorediatum R. W. Rogers

Lichenologist **14:** 128 (1982); type:—Australia, Victoria, Lakes Entrance, ad corticem *Notolea ovata*, iii 1889, *F. R. M. Wilson* (MEL—holotype).

(Figs 1D, 3, 5E)

Thallus white to grey, chinky or granular; sorediate, corticate. *Apothecia* sessile, constricted at the base, to 1 mm diam, thalline margin well-developed, entire or somewhat irregular; disc orange-red, epruinose. *Asci* 8-spored. *Ascospores* helically asymmetric, 8–14 transseptate, 50–70 × 4–7 µm.

Chemistry: atranorin, placodiolic acid; epithecium K+ fleeting purple grey, acetone soluble apothecial pigment UV+ gold on t.l.c. plate.

This is an inconspicuous species, known otherwise from a single collection in Tasmania, and a few 19th century collections in Victoria. It is distinguished from all other Australasian species by the production of small orbicular soralia. The species is apparently quite common in the northern part of the North Island, but shows an interesting disjunction to the vicinity of Puponga in the South Island. A number of other species show a similar disjunction, including *Thysanothecium hookeri, Teloschistes flavicans, Megalospora bartlettii, Sticta babingtonii, Lichenothrix ridlei, Pseudocyphellaria montagnei,* and *Parmotrema mellisii.*

Additional specimens examined: **North Island:** Church Rd. scenic reserve, near Kaitaia, *c.* 200 m, 15 ii 1976, *J. K. Bartlett* 28321, 28322 (JKB); Mt Taratara, on *Rhopalostylus,* 230 m, 3 v 1984, *J. K. Bartlett* 28571 (JKB); Waipoua forest, on *Phyllocladus, c.* 250 m, 14 iii 1977, *J. K. Bartlett* 31478 (JKB); Mamuka plateau near Rotorua, on bark of tawa, *c.* 1200 m, 14 vii, 1979, *J. K. Bartlett* 20216c (JKB). **South Island:** Kaihoka Lakes, on *Rhopalostylus sapida, c,* 10 m, *J. K. Bartlett* 31496 (JKB).

Material for this study was kindly made available by the following herbaria: AK, BM, CANUC, CHR, G, WELT. Dr J. A. Elix identified pseudoplacodiolic acid as a metabolite in *H. babingtonii.* Mr A. Steginga assisted with t.l.c. studies.

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Haematomma and *Ophioparma* : two superficially similar genera of lichenized fungi.
Lichenologist **20**, 167-74.

Lichenologist **20**(2): 167–174 (1988)

HAEMATOMMA AND *OPHIOPARMA*: TWO SUPERFICIALLY SIMILAR GENERA OF LICHENIZED FUNGI

R. W. ROGERS* and J. HAFELLNER‡

Abstract: The genus *Haematomma* Massal. (type species: *H. ochroleucum* (Necker) Laundon) includes the pantropical and subtropical *H. puniceum* group, but differs in a range of characters including ascus structure, paraphyses, and chemistry from *Ophioparma* Norman (type species: *Ophioparma ventosa* (L.) Norman). The differences are such that a new family Ophioparmaceae Rogers & Hafellner is described with *Ophioparma* as its type genus, and the circumscription of the family Haematommaceae Hafellner is emended to take these changes into account. The combination *Rosellinula kalbii* (Hafellner) comb. nov. is proposed.

Introduction

The generic name *Haematomma* Massal. was proposed originally to house two species, *Haematomma vulgare* Massal. (i.e. *H. ochroleucum* (Necker) Laundon) and *H. ventosum* (L.) Massal. (Massalongo 1852). Since that time, many more species have been included in *Haematomma* without any detailed consideration of the circumscription of the genus. The great diversity of species in *Haematomma* was appreciated by Culberson (1964) who recognized four sections in the genus.

It has become clear that *Haematomma* as currently applied is a collective genus consisting of species with some morphological similarities which ought to be segregated (Rogers & Bartlett 1986). When discussing this problem Rogers & Bartlett (1986) erroneously associated the type species of *Haematomma*, *H. vulgare* Massal, with the *H. ventosum* group. On this basis, after considering the characterization of *Haematomma* and the family Haematommaceae in Hafellner (1984), they suggested that the subtropical species of *Haematomma* (the *H. puniceum* group) should be transferred out of the genus *Haematomma* and the family Haematommaceae, perhaps into the family Scoliciosporaceae.

To clarify the situation we have examined material from three species groups within the genus, *H. ochroleucum* (Necker) Laundon representing the holarctic *ochroleucum* group, *H. puniceum* representing the widespread subtropical *puniceum* group, and *H. ventosum* representing the arctic-boreal *ventosum* group.

From these observations (Table 1, Figs 1–3), it became apparent that the *puniceum* group was indeed closely related to the *ochroleucum* group, and could be retained in the genus *Haematomma*. The *ventosum* group, however, was very different, and must be segregated into its own genus, for which the name *Ophioparma* Norman is available. Because of its distinctive ascus structure, the

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*Botany Department, University of Queensland, St Lucia, Queensland 4067, Australia.
‡Institut für Botanik, Karl-Franzens Universität, Holteigasse 6, Graz A-8010, Austria.

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TABLE 1. *Comparison of the* H. ochroleucum *group*, H. puniceum *group and* Ophioparma

Attribute	*H. ochroleucum* group	*H. puniceum* group	*Ophioparma*
Ecology			
Distribution	Holarctic	Tropical–subtropical	Arctic–boreal
Substrate preference	Most species corticolous, a few saxicolous	Most species corticolous, a few saxicolous	Saxicolous, mostly on siliceous rocks
Reproduction			
Sexual	Apothecia rarely developed	Apothecia commonly developed	Apothecia commonly developed
Vegetative diaspores	Soredia	Soredia	Absent
Excipulum type			
Proper exciple	Thin	Thin	Thick
Thalline exciple	Thick and permanent or aspicilioid	Thick and permanent or aspicilioid	Thick or absent
Hymenial characters			
Asci	Lecanora-type, usually poorly developed	Lecanora-type, well developed	Ophioparma-type
Paraphyses	Thin, richly branched and anastomosing, not thickened at the tip	Thin, richly branched and anastomosing, not thickened at the tip	Thick, with few branches and anastomoses, thickened at the tip
Spores	Often helically twisted	Often helically twisted	Sometimes twisted
K reaction of epihymenium	K+ magenta in hymenial gel	K+ magenta in hymenial gel, or K+ purple-grey crystals rapidly fading in solution	K+ blue crystals fading to magenta and dispersing in solution
Red pigment	Acetone insoluble	Acetone insoluble	Acetone soluble
Hypothecium	Hyaline	Hyaline	Pigmented
Pycnidia			
Ostiole of pycnidium	Without green pigment	Without green pigment	With green pigment
Conidiophores	Vobis type V	Vobis type V	Vobis type VI
Chemistry			
Atranorin	Present	Present	Absent
Thamnolic acid	Absent	Absent	Present or absent
Lichenicolous fungi	*Rosellinula kalbii**	*Rosellinula kalbii**	*Muellerella pygmaea*

***Rosellinula kalbii (Hafellner) Hafellner & Rogers comb. nov.** Basionym: *Roselliniella kalbii* Hafellner, *Herzogia* 7: 152 (1985).

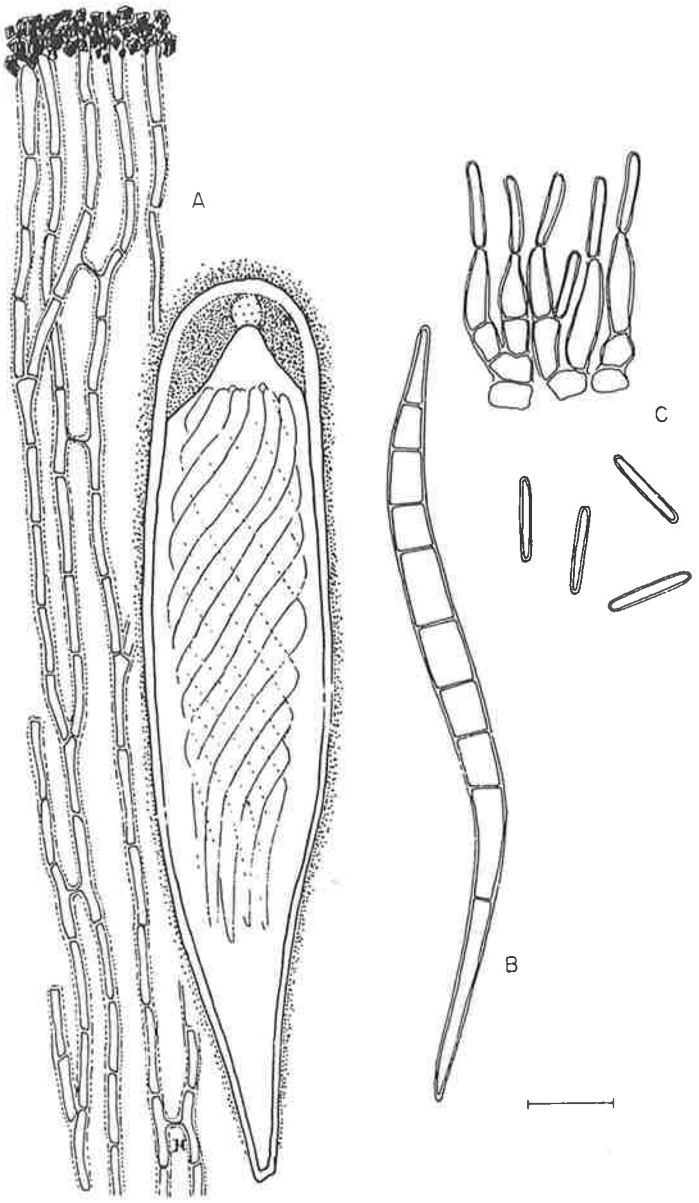

FIG. 1. *Haematomma puniceum* (*Rogers* 884, BRIU). A, young ascus and paraphyses; B, mature ascospore; C, conidiophores and conidia [see also Fig. 3E]. Amyloid parts of the ascus stippled. Scale = 10 µm.

genus *Ophioparma* is best placed in a new family Ophioparmaceae Rogers & Hafellner. Consequent upon these decisions, emended descriptions of the genera *Haematomma* and *Ophioparma* are necessary.

Emended descriptions

Haematommaceae Hafellner

Beih. Nova Hedwigia **79:** 281 (1984).

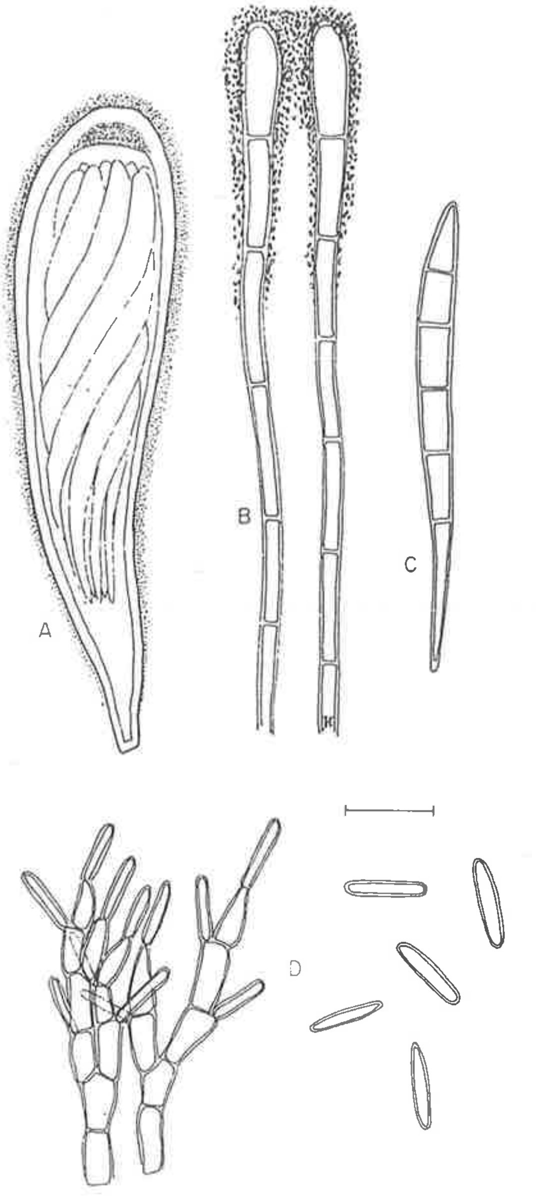

FIG. 2. *Ophioparma ventosa* (*Santesson* 31089, BRIU). A, young ascus; B, paraphyses; C, mature ascospore; D, conidiophores and conidia. Amyloid parts of the ascus stippled. Scale = 10 μm.

Lichenized ascomycetes containing a coccoid green algal symbiont. *Thallus* crustose. *Apothecia* sessile to immersed, proper margin thin, thalline margin usually well developed, disc pigmented red. *Asci* of the *Lecanora*-type with an I+ tholus, distinct ocular chamber and axial mass, encased in I+ blue gel; eight-spored. *Paraphyses* richly branched and anastomosing. *Ascospores* hyaline, transversely septate, without a halo.

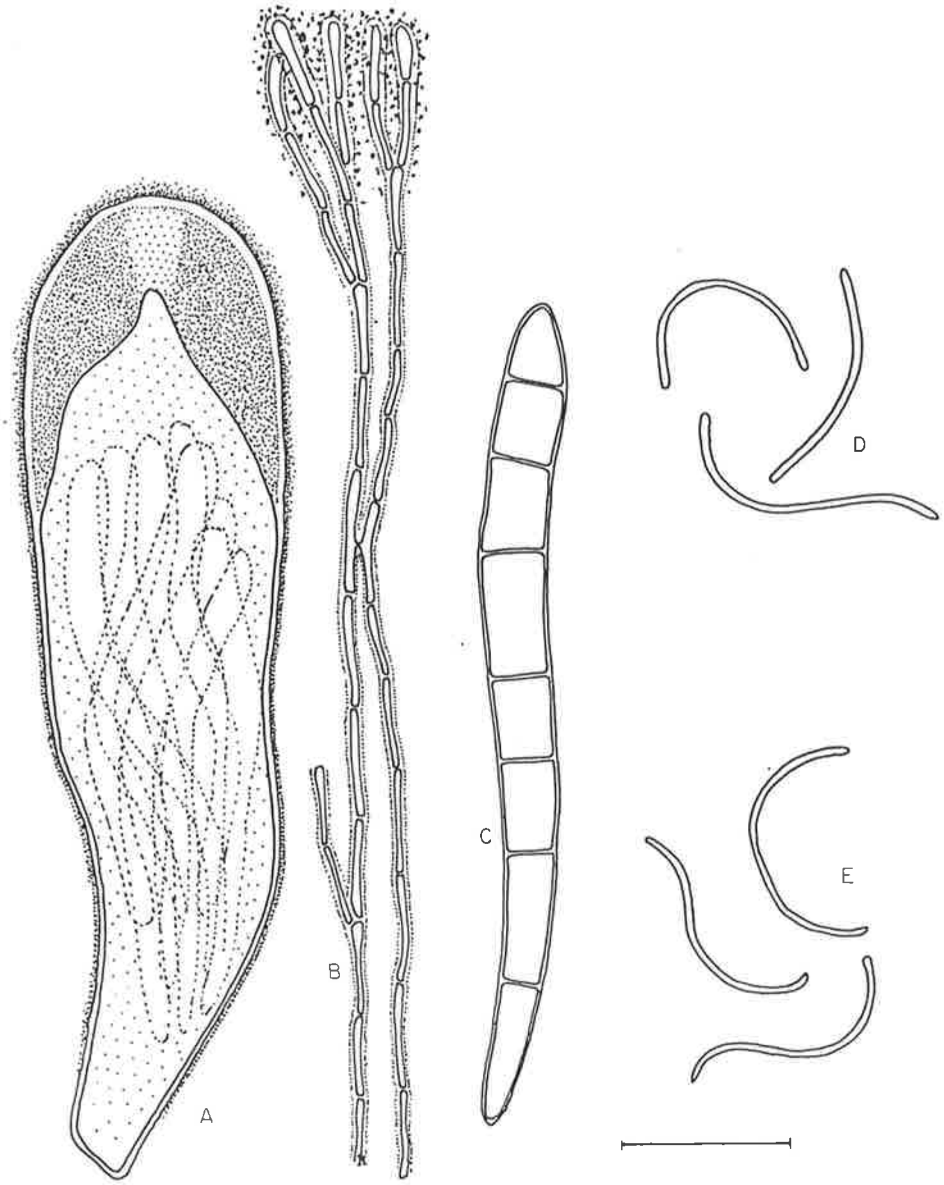

FIG. 3. *Haematomma ochroleuceum*. A, young ascus B, paraphyses; C, mature ascospore (Magnusson, *Lich. Sel. Scand.* no. 74, GZU). D, *H. ochroleucum* var. *porphyrium*, conidia (Buschardt *et al.* s.n., GZU). E, *H. puniceum* conidia (Kalb, *Lich. Neotrop.* no. 17, GZU); see also Fig. 1C. Scale = 10 μm.

Haematomma Massal.

Ric. Lich. Crost.: **32** (1852)

Type species: *Haematomma vulgare* Massal. (lectotype, selected by Fink 1910: 186). [= *Haematomma coccineum* (Dickson) Körber, *Haematomma ochroleucum* (Necker) Laundon.]

Haematomma sect. *Haematomma sensu* Culb., *Bryologist* **66:** 226 (1964).

(Figs 1 & 3).

Lichenized ascomycetes. *Thallus* crustose, corticate, with or without soredia. *Apothecia* with an open disc, sessile or adnate to immersed in the thallus; the disc red, round or somewhat irregular; proper exciple thin, thalline margin well developed and coloured like the thallus in species with sessile apothecia, less developed to absent in species with adnate to immersed apothecia; hymenial layers with a red acetone insoluble pigment mostly concentrated above the ascus tips; hypothecium hyaline. *Paraphyses* less than 2 µm thick, richly branched and anastomosing, not thickened at the apices. *Asci* of the *Lecanora* type, tholus I+ blue with an ocular chamber and faintly I+ blue axial mass. *Ascospores* hyaline, transversely 3–25-septate, thin-walled usually helically coiled in the ascus. *Pycnidia* immersed with ostiole region red (K+ magenta) or hyaline, never with a green pigment; conidiophores type V (Vobis 1980).

Ophioparmaceae R. W. Rogers & Hafellner fam. nov.

Ascomycetes lichenisati algas coccales continentes. Thallus crustaceus. Apothecia sessilia; discus sanguineus vel castaneus; margine proprio crassa; margine thallino presentia vel absentia. Asci tholis amyloideis, sine 'masse axiale' et 'chambre oculaire', gelatina amyloidea circumdati, octospori. Paraphyses crassae, parce ramosae et anastomosantes. Ascosporae hyalinae, aciculares, transversaliter septatae, non halonatae.

Typus familiae: *Ophioparma* Norman.

Lichenized ascomycetes with coccoid green algal symbiont. *Thallus* crustose. *Apothecia* dark blood red to chestnut, sessile, proper margin thick, thalline margin present or absent. *Ascus* with an I+ blue tholus, without an ocular chamber, axial plug or ring structure, encased in I+ blue gel, eight-spored. *Paraphyses* thick, little branched, with thickened apices. *Ascospores* hyaline, broadly acicular with transverse septa, helically contorted in the ascus, without a halo.

Ophioparma Norman

Nytt Mag. Naturv. **7:** 230 (1853); type species: *Ophioparma ventosa* (L.) Norman (lectotype selected by Hafellner 1984: 283).

Lepadolemma Trevisan, *Riv. period Lav. I. R. Acad. Padua* **1:** 267 (1853); type species: *Lepadolemma ventosum* (L.) Trevisan (lectotype selected by Hafellner 1984).

Haematomma sect. *Ventosa* Culb, *Bryologist* **66:** 229 (1964); type species: *Haematomma ventosum* (L.) Massal. (holotype).

(Fig. 2)

Lichenized ascomycetes. *Thallus* crustose, corticate esorediate. *Apothecia* sessile, disc round to irregular, blood red to chestnut brown, proper margin thick, concolorous with the disc, thalloid margin present or absent, concolorous with the thallus; hymenium pigmented orange to umber throughout; hypothecium hyaline in the upper parts but pigmented rose to buff in the lower parts. *Paraphyses* 1·5–2·5 µm thick, rarely branched and anastomosing, somewhat thickened at the tip. *Asci* with an I+ blue tholus, but without an ocular chamber or axial mass. *Ascospores* hyaline, thin-walled, transversely 3–7-septate. *Pycnidia* immersed; ostiole region pigmented dark green (pigment K-, HNO_3+ purple-red); conidiophores type VI (Vobis 1980).

Additional European taxa requiring inclusion are:

Ophioparma lapponica (Rasänen) Hafellner & R. W. Rogers comb. nov.

Haematomma lapponicum Rasänen, *Ann. Acad. Sci. fenn., A*, **34**(4): 67 (1931).

Ophioparma ventosa var. cuprigena (Poelt) Hafellner & R. W. Rogers comb. nov.

Haematomma ventosum var. *cuprigenum* Poelt, *Verh. zool.-bot. Ges. Wien* **95:** 112 (1955).

Discussion

It is apparent from Table 1 that *Haematomma* as treated here (including the *H. ochroleucum* group and the *H. puniceum* group) is an homogeneous genus, although the two groups differ somewhat in distribution pattern and in the degree to which reproductive effort is concentrated in vegetative propagules. The *H. puniceum* group is found in both Hemispheres, mostly in the tropics and subtropics, but is known (e.g. *H. infuscum, H. sorediatum*) from cool temperate areas in both Australia and New Zealand (Rogers & Bartlett 1986, Rogers 1982, 1985), and from alpine areas of New Zealand (*H. alpinum,* Rogers & Bartlett 1986). The *H. ochroleucum* group is found in cool, coastal holarctic regions, and can be considered ecologically to be a northward extension of the *H. puniceum* group, occupying essentially similar habitats. The variation in conidial morphology in material determined as *H. puniceum* (Figs 1c & 3e) is puzzling: it may be that these are actually different species, or that *Haematomma* has dimorphic conidia in at least some species.

Some species of the *H. ochroleucum* group have extensive development of soredia, the whole thallus effectively dissolving into soredia in *H. ochroleucum.* Apothecia are normally rare in this group. In the *H. puniceum* group soredia are rare, occurring in small punctiform soralia on a few species; apothecia are common in all species.

In contrast to *Haematomma, Ophioparma* is restricted to the Northern Hemisphere where it is found in arctic-boreal regions and, whereas most *Haematomma* species occur only on bark, all species of *Ophioparma* are restricted to rocks. In *Ophioparma* there are no vegetative diaspores, and apothecia are common.

All species of *Haematomma* examined have a thin proper exciple and either have a well-developed thalline exciple or are aspicilioid. This contrasts with *Ophioparma,* in which a thick proper exciple is always present, and in which a thalline exciple may or may not be present.

Hymenial characters are critical for the demonstration of differences between the genera. *Haematomma* has a *Lecanora*-type ascus, although in the *H. ochroleucum* group the apical apparatus of the ascus may be poorly developed. Such poor development is not uncommon in the asci of species which rely primarily on vegetative diaspores for their propagation (e.g. *Hypocenomyce*). The ascus of *Ophioparma* is quite different, having well-developed amyloid structures in a continuous dome over the apical region (Fig.

2), with no ocular chamber or axial mass visible under a light microscope. This is a distinct and different ascus type, here named the *Ophioparma* type.

When comparisons are made between these two genera it is apparent that they have very little in common besides a more or less red apothecial disc (but with different pigments) and acicular, transversely septate spores. It is likely that the brown-fruited European species until now referred to *Haematomma* ought to be placed in the genus *Loxospora* Massal., and that the east Asian species with brown fruits ought also to be transferred to another genus.

Specimens examined: ***Haematomma ochroleucum*** (Necker) Laundon: **Sweden:** Bohuslän, par. Stala, Varekil, on perpendicular or slightly overhanging rocks, 17 July 1928, *A. H. Magnusson* [Lich. Sel. Scand. no. 74, as *H. coccineum* var. *ochroleucum*], (GZU). ***H. ochroleucum*** var. ***porphyrium*** (Persoon) Laundon: **Norway:** Hordaland, Insel Stord, Sandvikag, Gem. Fitjar, Wald und Felshange aus teilweise metamorphen Gestein, 10 September 1976, *A. Buschardt, P. M. Jørgensen & J. Poelt,* (GZU).—***H. puniceum*** (Ach.) Massal.: **Australia:** Queensland, Keppel Sands on bark of *Rhizophora,* 10 July 1975, *R. W. Rogers 884* (BRIU); **Brazil:** Sao Paulo, Serra da Mantiqueira, bei der Stadt Campos do Jordao, etwa 150 km NE von Sao Paulo, 1700 m, am Rand eines feuchten Cerrado, 25 May 1978, *K. Kalb & G. Plöbst* [Kalb, *Lich. Neotropici* no. 17] (GZU).—***Ophioparma ventosa*** (L.) Norman: **Norway:** Härjedalen, Tannas parish, between Giertebaune and Rössvålen, (*c.* 6 km W of Mt Stora Mittåkläppen) *c.* 980 m, on rocks on an alpine heath, 1 August 1984, *R. Santesson 31089* (BRIU).

Professor R. Santesson kindly provided the material of *Ophioparma ventosa* used in this study. The differences in ascus structure between *Ophioparma* and *Haematomma* first became apparent when R. Rogers was a guest on a Deutscher Akademischer Austauschdienst fellowship in Professor Dr A. Henssen's Laboratory in Marburg. J. H.'s contribution to this work was aided by a University of Queensland travelling fellowship.

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Aust. J. Bot., 1986, **34**, 131-54

The Genus *Pyxine* (Physciaceae, Lichenized Ascomycetes) in Australia

R. W. Rogers

Botany Department, University of Queensland,
St Lucia, Qld 4067.

Abstract

Following morphological, anatomical and chemical studies, 15 species of *Pyxine* (Physciaceae, lichenized ascomycetes) are recorded for Australia. Their classification, distribution and habitats are discussed. The following taxa are reduced to synonymy: *Pyxine cocoes* var. *endoxantha* Müll. Arg. and *P. meissneri* var. *rinodinoides* Vainio with *P. berteriana* (Fée) Imshaug; *P. brachyloba* Müll. Arg., *P. nitidula* Müll. Arg. and *P. microspora* Vainio with *P. minuta* Vainio; *P. meissneri* var. *convexula* Malme, *P. albida* Magnusson and *P. pringlei* Imshaug with *P. petricola*; *P. meissneri* var. *subobscurascens* Malme with *P. pungens* Zahlbr.; *P. retirugella* var. *laevior* Vainio, *P. retirugella* var. *capitata* Zahlbr., *P. copelandii* Vainio, *P. asiatica* Vainio, and *P. patellaris* Kurok. with *P. retirugella* Nyl.; and *P. prominula* Stirton with *P. cocoes* (Sw.) Nyl. The new species *P. isidiolenta* R. W. Rogers is described and the new name *P. linearis* R. W. Rogers is proposed for *P. retirugella* var. *endoxantha* forma *sorediosa* Müll. Arg.

Introduction

The genus *Pyxine* was established by Elias Fries in 1825 with *Lecidea sorediata* Ach. as its type species. He placed *Pyxine* in the tribe Pyxinae along with *Umbilicaria*, the common character being a naked proper exciple. By 1885 Nylander had recognized four species in the genus, with essentially the same delimitation as now: a small foliose lichen with black apothecia usually without algae in the margin; spores thick-walled, brown and two-celled.

Pyxine is one of a number of genera similar in thallus size and morphology (*Pyxine*, *Physcia*, *Dirinaria* and *Physconia*) in the Physciaceae. Fertile material of *Pyxine* can be distinguished from the others easily, for in sections of the apothecium the epithecium reacts K+ faint purple-violet. Both *Dirinaria* and *Pyxine* have a dark hypothecium which is not present in the other genera and *Pyxine*, unlike *Physcia*, *Dirinaria* or *Physconia*, often has apothecia with a margin devoid of algae. The apothecial margin in *Pyxine* is not lecideine as reported in some earlier papers, but is a modified lecanorine structure (Swinscow and Krog 1975*a*).

Sterile material is more difficult to determine but *Pyxine* does have a number of attributes that help to identify specimens. First, many species contain lichexanthone in the upper cortex, and therefore react UV+ gold; no other foliose Physciaceae show this. Species of *Dirinaria* tend to have lobes which fuse laterally, which no *Pyxine* does. Many *Pyxine* species develop pseudocyphellae which show as white lines on the margins of the thallus or on the upper cortex, where they may form a reticulate pattern: such pseudocyphellae are not found in the other genera. The chemistry of *Pyxine* is also characteristic, all *Pyxine* species (except *Pyxine nubila*) producing a range of triterpenes, often in association with norstictic acid. *Dirinaria* also produces triterpenes, but in association with divaricatic or sekikaic acids.

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It is clear that *Dirinaria* is the genus closest to *Pyxine* in terms of both apothecial structure and chemistry. Both *Dirinaria* and *Pyxine* are genera of the tropics and subtropics, and have at times been combined (e.g. Stirton 1898). Examination of collections from the Brisbane area showed that the genus *Pyxine* in Australia was in need of careful study, although a great deal of ground work had already been done by Stirton (1898), Imshaug (1957), Swinscow and Krog (1975*a*, 1975*c*) and Kashiwadani (1977*a*–1977*c*).

Materials and Methods

In this study taxa have been delimited by examination of a large number of Australian collections of *Pyxine*. Having established the number of species in Australia, and what are the limits of their variation, type materials from Australia and elsewhere were examined in order to find appropriate names for the species. The result is a relatively broad species concept, with the type sometimes representing an extreme variant of the taxon as in the case of *Pyxine retirugella*. The species descriptions given here are, therefore, not descriptions of the type but a description which circumscribes the taxa as they appear in the Australian environment.

Most of the material examined was collected by the author or by Nell Stevens. Collections were borrowed from other Australian herbaria, CANB, NSW, MEL, BRI, PERTH, and the herbarium of Dr J. A. Elix in the Chemistry Department of Australian National University, abbreviated CANUC. The Australian material in BM was examined and that in G borrowed for study. If no location is indicated specimens are housed in BRIU.

Full synonymies are not given: those names reported for Australia are disposed of, and synonyms discovered during the study indicated. Many additional synonyms based on modern species concepts are reported by Swinscow and Krog (1975*a*).

Type specimens were kindly made available for this study by BM, G, FH, UPS, O, W, H, S, GLAM, TNS, TUR and C.

All specimens were examined under u.v. light and where material permitted, thin-layer chromatography (TLC) and microchemical spot tests were performed on the thallus.

Thallus Morphology

The thallus is normally composed of neatly radiating subdichotomous to linear lobes, although irregular substrates and age disturb this pattern. The lobes are often noticeably crenate or complicate along the margins. They are commonly more or less flat, although *P. convexior* and *P. pungens* are characterized by convex lobes. The colour of the lobes is fairly uniform white to pearl grey or dull yellow. (Colour terminology is after Kornerup and Wanscher 1967.) The lower surface is black, except in *P. nubila*, usually with plentiful, well developed black rhizines.

Soredia, pustules and isidia occur in a continuum in this genus. The intermediate forms have been noted by Kashiwadani (1977*a*) and by Swinscow and Krog (1975*a*). Some species show well developed soralia, which may be orbicular and laminal as in some *P. retirugella* collections (Fig. 4) or orbicular and pedicillate as in others. The closely related *P. consocians* shows pustules, often with proliferating tissue on the margins. *P. subcinerea* shows marginal soralia that appear to develop from the marginal pseudocyphellae, often spreading continuously along lobe margins (Fig. 9) but in other cases remaining discrete. *P. cocoes* produces laminal and marginal erose soralia (Fig. 5) which may form extensive sorediate patches. In *P. sorediata* the soredia are marginal and very coarse, although sometimes they are restricted to the tips of marginal lobules and may look rather like insidia (Figs 6 and 7). The soredia of *P. coccifera* have their origin in the pseudocyphellae and are brilliant red (Fig. 8).

Soralia are sometimes restricted to older parts of the thallus, with extensive non-sorediate areas near the perimeter. Great care must therefore be taken when looking for soralia, and very small thalli ought to be matched to both sorediate and non-sorediate descriptions.

In the Australian material only *P. isidiolenta* shows true isidia. In this species the isidia are thin somewhat branched cylindrical structures (Fig. 10). Isidium-like pustules are developed in *P. consocians* (Fig. 11).

Pseudocyphellae are common in a number of species but the degree of development is very variable. Species should not be separated on differing degrees of pseudocyphellation as the character varies greatly from lobe to lobe on the same thallus. Marginal pseudocyphellae, which appear as a white line along the margin of the lobe, are especially common. They often carry over onto the upper surface as short white lines (Fig. 12) which may link up irregularly or more or less reticulately (Fig. 13). In some cases the pseudocyphellae develop as cracks or splits between ridges. This is particularly marked in the *P. retirugella* complex, in which the type of *P. retirugella* shows an extreme development of reticulate pseudocyphellae. *P. coccifera* commonly shows deeply split pseudocyphellae (Fig. 8).

Colour of the medulla is fairly constant within a species. Three colours can usually be distinguished: white, yellow and buff. In *P. coccifera*, the medulla is white except immediately under the pseudocyphellae where it is red.

Pruina is present in most species, the amount varying from specimen to specimen and lobe to lobe. It may be present in continuous sheets, e.g. in *P. cocoes* (Fig. 14), or only in a sparse scatter of crystals as in *P. linearis* (Fig. 15).

Apothecium Morphology

Variation in apothecium morphology has been well discussed by Swinscow and Krog (1975*a*) and there is little to add. It is clear that the nature of the margin of the apothecium is variable, sometimes with an apparently thalloid margin and sometimes without one. The margin is in all cases lecanorine but often without algae and carbonized, thus appearing lecideine. In the past many species have been created on the grounds of a margin coloured like the thallus or not; such separations are spurious, a single thallus often having apothecia of both forms. The presence of an 'internal stipe' (Imshaug 1957) has been found to be a useful taxonomic attribute.

Chemistry

Cortical chemistry is an important taxonomic character in *Pyxine*, the presence or absence of atranorin or lichexanthone being a useful character for identifying species.

Medullary chemistry is variable within and between species. The medulla may contain norstictic acid, testacein, triterpenes and pigments. Testacein is the unknown UV+ substance reported by Swinscow and Krog (1975*a*), first isolated from *Parmelia testacea* (J. A. Elix, personal communication). Triterpenes are present in all species except *P. nubila*, but in variable quantities. They appear to be constant or present as only a limited number of variants in a species.

Medullary chemistry is regarded here as a confirmatory character only. Neither the presence or absence of norstictic acid or testacein nor a different pattern of triterpenes was considered sufficient in itself to separate species. In this respect the treatment of chemistry in this study is akin to that of Swinscow and Krog (1975*b*) in their treatment of *Usnea* rather than their account of *Pyxine* in East Africa (Swinscow and Krog 1975*a*). Permitting chemical variation within species has had particular significance in the *P. retirugella* and *P. minuta* complexes, in which fewer species are recognized than would be if the criteria used in some other studies (e.g. Swinscow and Krog 1975*a*; Kashiwadani 1977*a*) were applied.

The chemistry of the species discussed in this paper is presented in Fig. 1.

Distribution Patterns

Virtually all of the collections of *Pyxine* made in Australia are from a narrow band near the coast. They were gathered mostly along the east coast except for a small number of collections from the north and north-west, two from the extreme south-west and one from Tasmania (Fig. 2).

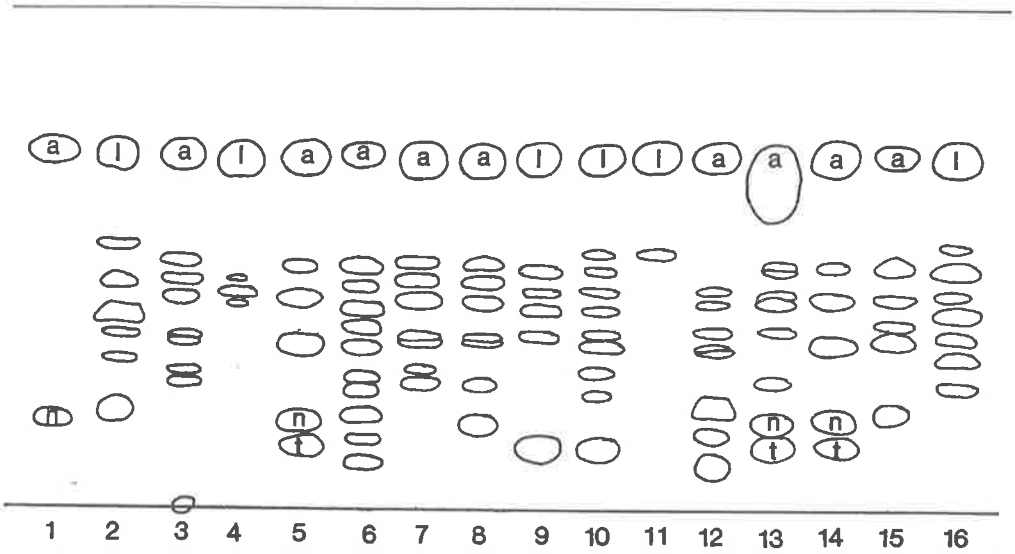


Fig. 1. TLC of *Pyxine* species in Australia (except *P. nubila*). 1, Control with norstictic acid and atranorin. 2, *P. berteriana*. 3, *P. coccifera*. 4, *P. cocoes*. 5. *P. consocians*. 6, *P. convexior*. 7, *P. isidiolenta*. 8, *P. linearis*. 9 and 10, *P. minuta* (2 chemoforms). 11, *P. petricola*. 12, *P. pungens*. 13 and 14, *P. retirugella*. 15, *P. sorediata*. 16, *P. subcinerea*. *a*, atranorin, *l*, lichexanthone, *n*, norstictic acid, *t*, testacein. Unidentified spots are mostly triterpenes. Chromatogram run in 20 : 3 toluene/acetic acid mixture (solvent C of Culberson 1972) on Merck 5554 DC-Alufolien Kieselgel 60 F254 Plates.

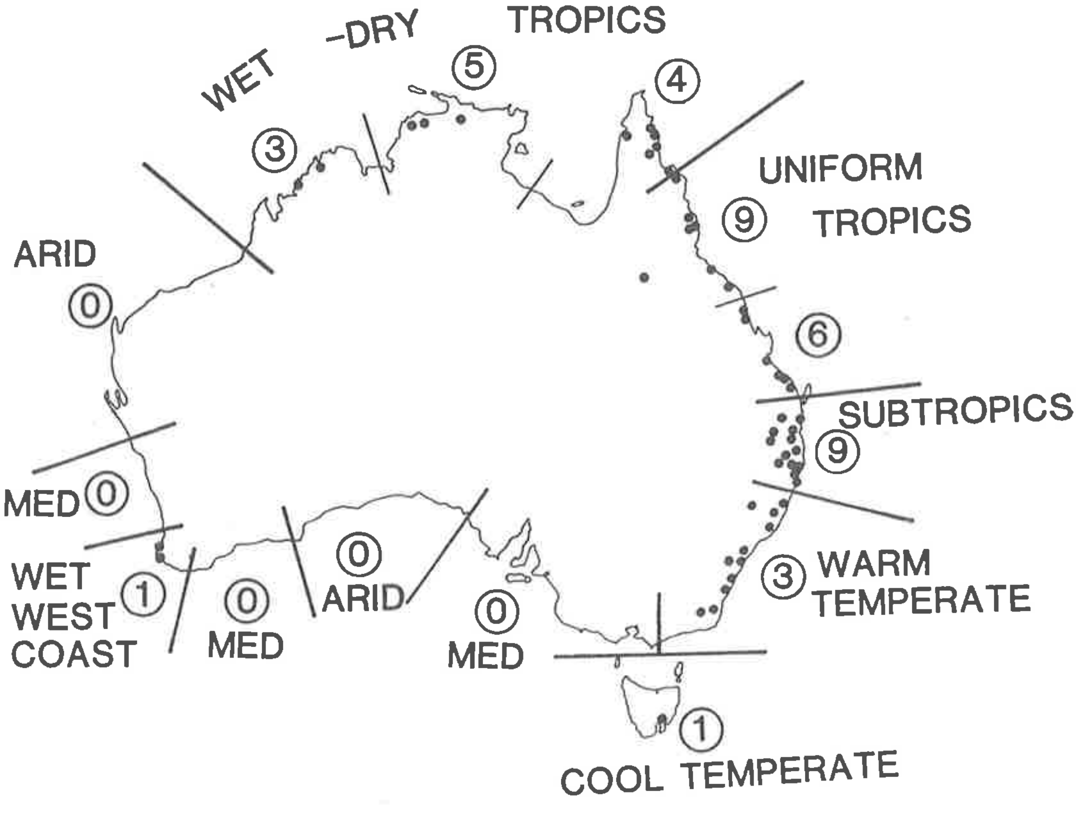


Fig. 2. Locations within Australia from which collections of *Pyxine* have been made, and the number of species in coastal zones with differing climates.

If the coastal strip is divided into segments representing climatic regions and the total number of species of *Pyxine* present in each is accumulated (Fig. 2), it is apparent that the genus shows its greatest development in the tropics and subtropics, which have a more or less year-round rainfall. A number of species is also known from the 'Wet–Dry' tropics, a region with an extreme winter drought and a relatively short wet summer season.

Only one species occurs in the cool-temperate region, *Pyxine nubila*, known only from a single site in Tasmania. One species, *P. subcinerea*, has a disjunct distribution from southern New South Wales to the far south-west of Western Australia.

On the maps of individual species it is likely that any disjunctions apparent along the eastern and southern coasts where collections of lichens are numerous represent real distribution gaps. However, gaps along the northern coast (e.g. in the Gulf of Carpentaria) may represent gaps in collection rather than distribution.

Table 1. Distribution of *Pyxine* species within Australia and occurrence in other regions of species known from Australia

Sources: Japan (Kashiwadani 1977*b*, 1977*c*); Papua New Guinea (Kashiwadani 1977*a*); East Africa (Swinscow and Krog 1975*a*, 1975*c*); North and Mid America (Imshaug 1957); Philippines (Vainio 1913); South America (Malme 1897); Hawaii (Magnusson 1955)

	Australia												
	Wet-dry tropics	Uniform tropics	Subtropics	Warm temperate	Wet west coast	Cool temperate	Japan	Papua New Guinea	East Africa	N. & M. America	Philippines	S. America	Hawaii
P. berteriana	+	+	+	+				+	+	+		+	+
P. coccifera	+								+			+	
P. cocoes	+	+	+				+		+	+	+	+	+
P. consocians	+	+	+						+				
P. convexior		+							+				
P. isidiolenta	+	+											
P. linearis	+	+											
P. minuta			+						+	+	+	+	
P. nubila						+			+				
P. petricola			+						+	+	+		
P. pungens	+	+	+							+		+	
P. retirugella	+	+	+				+	+	+		+	+	+
P. sorediata		+	+	+			+		+	+			
P. subcinerea			+	+	+		+	+	+	+			
14	8	9	9	3	1	1	4	3	11	7	4	6	3

The distribution of *Pyxine* in Australia (Fig. 3) can be explained in climatic terms. The genus occurs only in those areas which are at least seasonally humid and wet and warm simultaneously. This explains the absence of *Pyxine* from the inland, from the south-central coast and the western coast, which have a cool wet winter and a dry summer or are uniformly dry all year round. Exceptions to this are Tasmania, where a single collection of *P. nubila* (Fig. 3*F*) is known from a region which is uniformly cool and moist, and the extreme south-west of Western Australia where *P. subcinerea* occurs (arrowed in Fig. 3*J*).

In the north the seasons are strongly differentiated with a warm, very dry winter and a hot wet summer. This climate supports a number of species, one of which (*P. coccifera*, Fig. 3*B*) is restricted to the region. Along the central and southern east coast rain falls throughout the year, but tends to be mostly summer rain in the north and mostly winter in the south. Along this strip species appear to be zoned in response to temperature trends: e.g. *P. retirugella* (Fig. 3*H*) is restricted to the warmer northern coast and *P. sorediata* (Fig. 3*I*) to the cooler southern region, except for a collection from the tropical highlands.

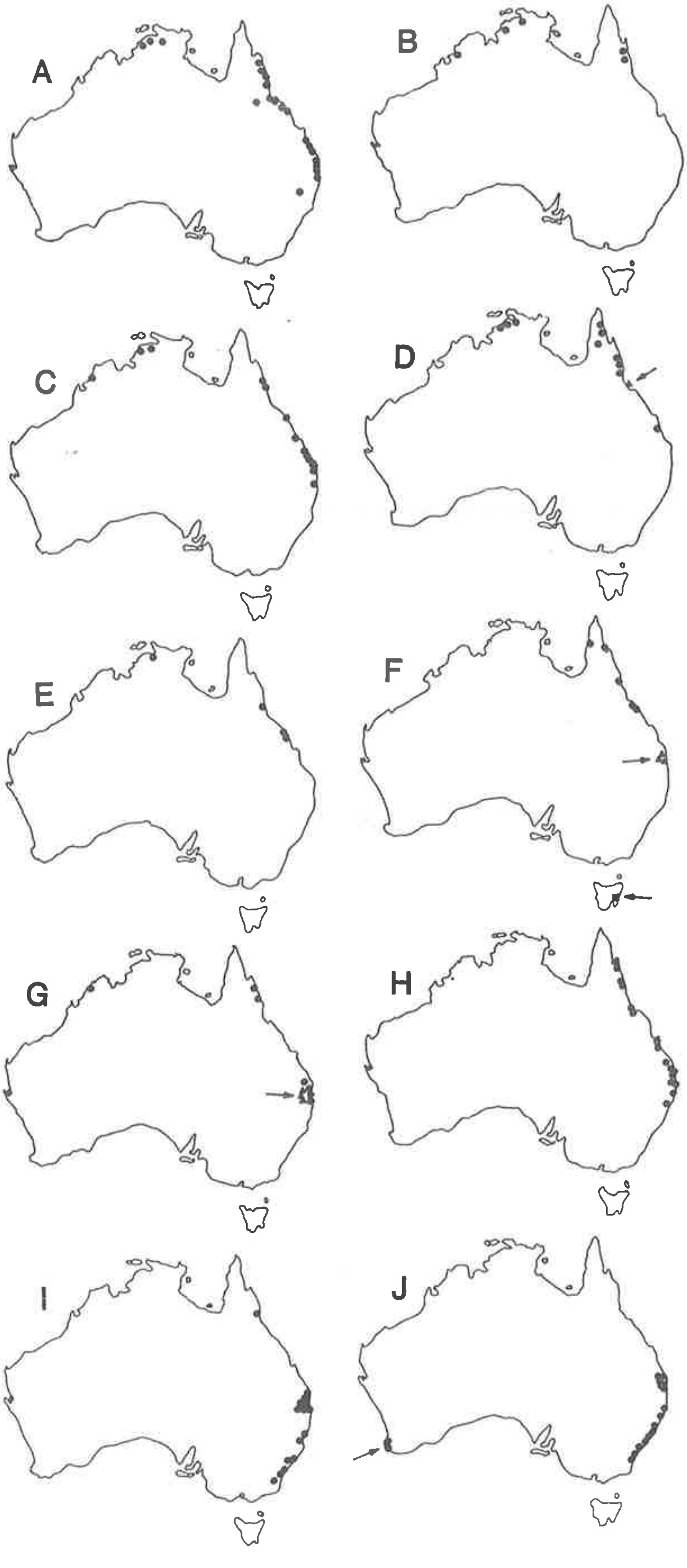


Fig. 3. Distribution of species of *Pyxine* in Australia.
A, *P. berteriana. B*, *P. coccifera.*
C, *P. cocoes. D*, ● *P. consocians*,
▲ *P. convexior (arrowed)*.
E, *P. isidiolenta. F*, ● *P. linearis*,
▲ *P. minuta (arrowed)*,
■ *P. nubila (arrowed)*. *G*,
▲ *P. petricola (arrowed)*,
● *P. pungens.*
H, *P. retirugella. I*, *P. sorediata.*
J, *P. subcinerea.*

Table 1 shows the distribution of the Australian species within Australia and in some other regions. It is particularly striking that all but four of the species reported for Australia are also known from East Africa. This is consistent with the observation of Rogers and Stevens (1981) that the tropical and subtropical lichen flora of Australia shows a close affinity with Africa. The disjunct distribution of *P. nubila* between Australia and East Africa and Saudi Arabia is extraordinary in this context.

Key to the Genus *Pyxine* in Australia

1.	Thallus isidiate, pustulate or sorediate	2
1.	Thallus without isidia, pustules or soredia	11
2(1)	Thallus isidiate or pustulate (pustules pedicillate)	3
2.	Thallus with laminal or marginal soralia	5
3(2)	Medulla white, thallus pustulate (cortex UV –)	*Pyxine consocians* Vainio
3.	Medulla yellow, thallus isidiate or pustulate	4
4(3)	Cortex brownish grey, K –, with coarse soredia without isidia (UV –)	*Pyxine sorediata* (Ach.) Mont. in Sagra
4.	Cortex grey, K + yellow, isidiate, without soredia (UV –)	*Pyxine isidiolenta* R. W. Rogers
5(2)	Soralia red (cortex UV –)	*Pyxine coccifera* (Fée) Nyl.
5.	Soralia white, yellow or grey	6
6(5)	Medulla white	7
6.	Medulla yellow	9
7(6)	Cortex K + yellow (UV –)	*Pyxine retirugella* Nyl.
7.	Cortex K – (UV + or UV –)	8
8(7)	Thallus pale grey to white, soralia marginal and laminal, cortex UV +	*Pyxine cocoes* (Sw.) Nyl.
8.	Thallus grey-brown, soralia marginal, cortex UV –	*Pyxine nubila* Moberg
9(6)	Cortex K + (UV –)	*Pyxine linearis* R. W. Rogers
9.	Cortex K – (UV + or UV –)	10
10(9)	Soredia fine, white to pale yellow (UV +)	*Pyxine subcinerea* Stirton
10.	Soredia coarsely granular, grey (UV –)	*Pyxine sorediata* (Ach.) Mont. in Sagra
11(1)	Medulla yellow or brown	12
11.	Medulla white	13
12(11)	Medulla yellow, cortex K – (UV +)	*Pyxine berteriana* (Fée) Imshaug
12.	Medulla greyish yellow, cortex K + (UV –)	*Pyxine pungens* Zahlbr.
13(11)	Cortex UV –	*Pyxine convexior* (Müll. Arg.) Swinscow & Krog
13.	Cortex UV +	14
14(13)	Lobes < 0·5 mm broad, without pruina	*Pyxine minuta* Vainio
14.	Lobes 1–2 mm broad, heavily pruinose	*Pyxine petricola* Nyl. in Crombie

Pyxine berteriana (Fée) Imshaug, Trans. Am. Microsc. Soc. 56, 254 (1957).

Circinaria berteriana Fée, Ess. Cryptog. Ecorc. Exot. Offic. 128 (1824). *Holotype*: on bark of *Quassia* (G).

Pyxine meissneri Tuck. ex Nyl., Ann. Sci. Nat. Ser 4, 11, 255 (1859). *Lectotype*: *Wright 95*, Cuba (FH).

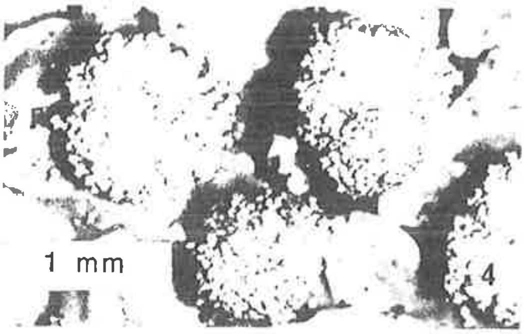
Pyxine cocoes var. *meissneri* (Tuck. ex Nyl.) Tuck., Proc. Amer. Acad. Arts Sci. 12, 166 (1877).

Pyxine cocoes var. *endoxantha* Müll. Arg., Flora 65, 318 (1882). *Holotype*: Nouv. Caledonie, Balade, 1881, *Vieillard* (G).

Pyxine meissneri var. *rinodinoides* Vainio, Suom. Tiedeak. Toimit. A(6), 69 (1915). *Holotype*: Indias Occ. S. Jan. ad corticem arboris prope Coral Bay (Caroline), 22.2.1906. *Raunkiaer*. (C).

(Fig. 16)

Thallus up to 100 mm diameter composed of radiating lobes usually forming a neat plaque but sometimes irregular; lobes 0·5–1·2 mm broad, greenish grey or yellowish grey to silver-white, branching subdichotomous, commonly discrete, rarely imbricate, adnate to the substrate, concave to convex; pseudocyphellae marginal and also irregularly distributed as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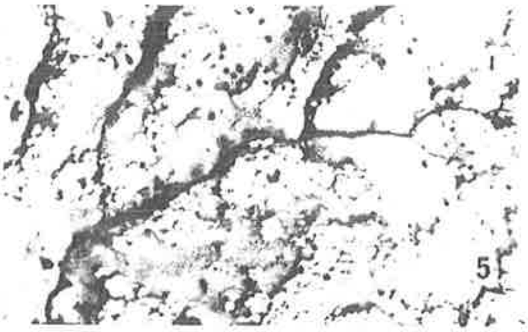
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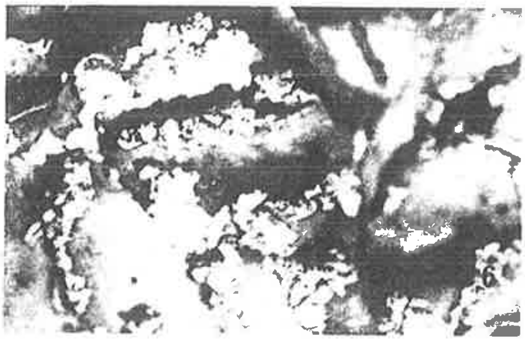
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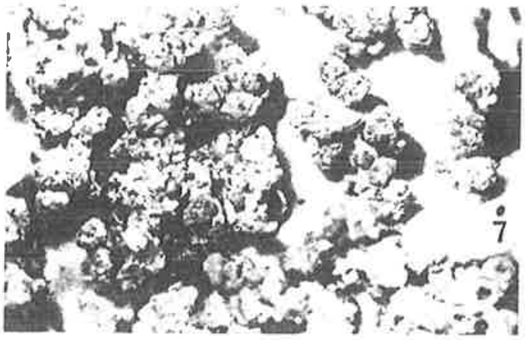
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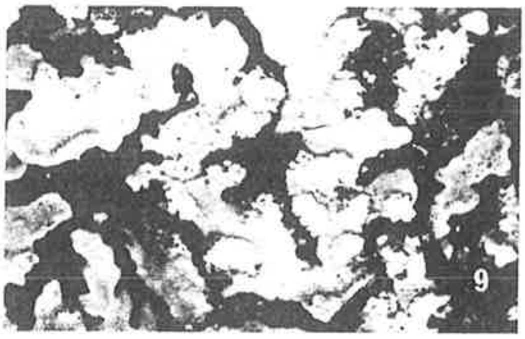
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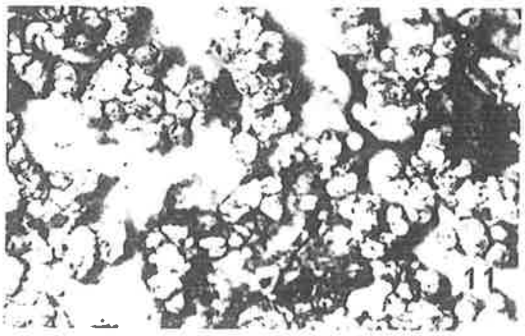
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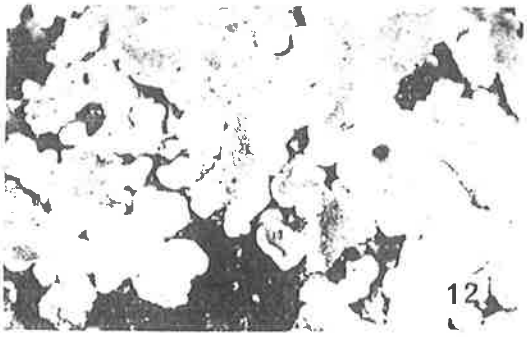
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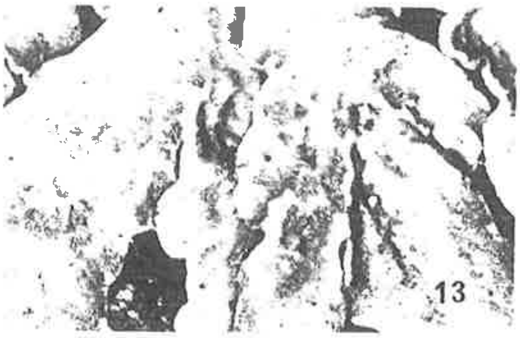
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linear to subreticulate, white lines on the upper surface; pruina sparse on lobe tips or absent; devoid of isidia, pustules and soredia. Medulla yellow or light yellow. Apothecia very common, up to 1·5 mm diameter, margin commonly devoid of algae and black but sometimes with an algal layer when young, and thus coloured like the thallus, disc flat; internal stipe colourless to brown, K–; ascospores 15–22 × 6–8 μm.

Chemistry: lichexanthone, triterpenes; cortex K–, UV+ yellow; medulla K– or K+ reddish, PD–.

Substrate: bark.

Selected Specimens Examined (Fig. 3*A*)

NORTHERN TERRITORY. 12 km NE. of Gunn Pt Rd on turn-off 6 km N. of Koolpingah, on *Acacia auriculiformis*, 3.v.1983, *C. Scarlett s.n.*; Howard Springs, 1982, *N. Stevens s.n.*; Kapalga Landing on *Barringtonia acutangula*, 5.v.1983, *C. Scarlett s.n.* QUEENSLAND. Cook District: Endeavour River at McIvor River road crossing 10·5 km from Cooktown, 4.ii.1983, *D. Verdon 5429* (CANB); Cook District, Four Mile Beach, 1 km S. of Port Douglas, undulating foredunes, on coconut palm trunk, 6.ii.1983, *D. Verdon 4438* (CANB); Cairns harbour, sea level on mangrove trees, 25.viii.1976, *J. Elix 2576* (CANUC); Bellenden Ker District, *Austral. or.* 1899, *F. M. Bailey* (G); Mission Beach on *Excoecaria*, 21.viii.1978, *N. Stevens 2673*; Hinchinbrook Is., N. end of Wet Desert on *Ceriops*, *N. Stevens 3581*; Toomba, on the bark of a bottletree, *c.* 300 m, 31.vii.1976, *N. C. Stevens*; Dry Creek Rd, Bowen, on *Rhizophora apiculata* 25.viii.1974, *N. Stevens 3962*; Keppel Sands (Fitzroy R. estuary), on bark of *Excoecaria*, 10.vi.1975, *R. Rogers 773*; Port Alma on bark of *Rhizophora*, June 1975, *R. Rogers 700*; Boyne R. estuary south of Gladstone on bark of *Aegiceras*, 10.vi.1975, *R. Rogers 824*; Noosa Sound, dead twig in mangroves, June 1972, *D. Tarte s.n.*; Maroochydore Yacht Club, Maroochy Pt, on branches of *Avicennia*, 22.viii.1976, *N. Stevens 1314*; Mud Is. on *Ceriops tagal*, 18.viii.1978, *N. Stevens 2763*; mangrove swamp 1 mile N. of Dunwich, North Stradbroke Is. on bark of *Avicennia marina*, 10.viii.1972, *R. Rogers 2037*; Victoria Point, 19 km SE. of Brisbane, *Eucalyptus* scrub, on tree trunk, 19.i.1980, *H. Streimann 9945* (CANB). NEW SOUTH WALES. Hastings Point on old *Avicennia*, 20.viii.1977, *N. Stevens 1944*; Park Beach Coffs Harbour, on tree in coastal scrub, 29.vi.1977, *J. Elix 3418* (CANUC); Tamworth, Sept. 1909, *J. L. Boorman s.n.* (NSW).

Pyxine berteriana is a maritime species common on the east coast of Australia, where it is rarely found more than 100 m from water. Most collections are from mangroves, but it is also found on other trees on river banks and flood plains.

Australian material appears not to have testacein in the medulla, as reported by Swinscow and Krog (1975*a*) for African collections. The medulla does, however, react K+ pink to red-brown in many collections as apparently does the type specimen. *Pyxine pungens* is morphologically very similar to *P. berteriana* but differs chemically in the absence of lichexanthone, presence of atranorin, different triterpenes, and in having a distinctly ochraceous not yellow medulla.

The holotype of *Circinaria berteriana* Fée housed in G is composed of three minute fragments with a distinctly yellow medulla which turns pink with KOH. The thallus is minute and poorly developed but cannot be shown to be different from the lectotype of *P. meissneri* Tuck. ex Nyl. which is a well developed thallus and clearly the same taxon as the Australian material. The holotype of *P. cocoes* var. *endoxantha* Müll. Arg. is small like the type of *Circinaria berteriana*, and chemically identical to *P. meissneri* Tuck. ex Nyl. *Pyxine meissneri* var. *rinodinoides* Vainio is also chemically identical to *Pyxine meissneri* and, like *P. cocoes* var. *endoxantha* Müll. Arg., has apothecia with algae in the margin.

Figs 4–13. Thallus structures in *Pyxine*: all to same scale as Fig. 4. Fig. 4. Globular soralia of *P. retirugella*. Fig. 5. Erose soralia of *P. cocoes*. Fig. 6. Coarse marginal soralia of *P. sorediata*. Fig. 7. Strongly developed marginal soralia in *P. sorediata*. Fig. 8. Soredia developing in deeply fissured pseudocyphellae of *P. coccifera*. Fig. 9. Labriform soralia of *P. subcinerea*. Fig. 10. True isidia of *P. isidiolenta*. Fig. 11. Pustules of *P. consocians*. Fig. 12. Marginal and laminal pseudocyphellae (white markings) in *P. retirugella*. Fig. 13. Subreticulate pseudocyphellae in *P. linearis*.

Pyxine coccifera (Fée) Nyl., Mem. Soc. Imp. Sci. Nat. Cherbourg 5, 108 (1857).

Parmelia coccifera Fée, Ess. Cryptog. Ecorc. Exot. Offic., 126 (1824). Type not located.

(Figs 8 and 17)

Thallus up to 60 mm diameter composed of radiating lobes forming a neat plaque or more commonly irregular; lobes 0·4–1·0 mm broad yellowish grey to grey or dull yellow in colour, branching subdichotomous, lobes usually discrete or almost so, sometimes scattered, adnate to the substrate, usually convex; pseudocyphellae well developed on the margins and in an irregular linear pattern over the lamina, exposed medulla vivid red (carmine), becoming excavate and sometimes producing soredia; soralia laminal or marginal usually with vivid red farinose soredia but sometimes developing yellowish grey granular soredia which in turn grow into irregular isidia-like structures; pruina absent or very sparse. Medulla pale yellow in upper layers, white below and vivid red close to pseudocyphellae and soralia. Apothecia not known.

Chemistry: atranorin, triterpenes, cocciferin; cortex K+ yellow, UV–; medulla K– or K+ purple in areas pigmented vivid red, PD–.

Substrates: sandstone and dead wood.

Specimens Examined (Fig. 3*B*)

NORTHERN TERRITORY. Koongarra Saddle Lookout, 2 km from Baroalba airstrip, on sandstone and on wood, 7.v.1983, *C. Scarlett s.n.*; 12 km NE. of Gunn Pt Rd on turn-off 61 km N. of Koolpingah, on dead *Acacia auriculiformis* tree and on sandstone 3.v.1983, *C. Scarlett s.n.*; Kakadu National Park, on sandstone, 19.vii.1981, *M. Day s.n.* (CANUC). QUEENSLAND. Cook District, Chester River: E. of McIlwraith Range escarpment, on dead wood, 28.vi.1978, *G. Butler 430* (CANB); Abbey Park, Cape Melville, on dead wood, Aug. 1983, *C. McCracken*. WESTERN AUSTRALIA. Prince Regent River Reserve, NW. Kimberley, Aug. 1974, *A. George 12301* (PERTH).

Pyxine coccifera in Australia is restricted to those parts of the tropics with very marked wet and dry seasons. It grows only on dead wood and rocks, suggesting a requirement for xeric environments.

The vivid red pigment in pseudocyphellae and soralia characterizes this species and often gives the whole thallus a reddish cast. As in some other species of *Pyxine*, the nature of the asexual reproductive structures is obscure. In *P. coccifera* the excavate vivid red soralia sometimes produce grey granular soredia which in turn appear to develop into irregular coralloid isidia (cf. *Pyxine sorediata*) and even into lobules. Under these conditions the thallus shows isidiate soralia in the centre of the thallus and excavate farinose soralia on younger lobes. No taxonomic status is recognized for such variants.

Pyxine cocoes (Sw.) Nyl., Mem. Soc. Imp. Sci. Nat. Cherbourg, 108 (1857).

Lichen cocoes Sw., Nov. Gen. Sp. Pl., 146 (1788). *Holotype*: Jamaica, leg. *Swartz* (S).

Pyxine prominula Stirton, Trans. Proc. N.Z. Inst. 30, 397 (1897). *Holotype*: India, corticola prope Chinsurah *P. Watt* (BM).

(Figs 5, 14 and 18)

Thallus up to 60 mm diameter, composed of radiating lobes usually forming a neat plaque but sometimes irregular; lobes 0·6–1·0 mm broad, silver-white or yellowish white, usually discrete, branching more or less dichotomous, adnate to the substrate, concave to somewhat convex, pseudocyphellae present on the margins and as scattered irregular white lines on the lamina; soralia develop from marginal and laminal pseudocyphellae, initially punctiform but eventually coalescing into extensive patches; pruina usually present as glistening white sheets on young lobes but occasionally very sparse; isidia and pustules absent. Medulla white. Apothecia uncommon, to 1·5 mm diameter, margin usually without an algal layer and therefore black, disc flat; internal stipe colourless or brown, K – ; ascospores, 15–22 × 6–8 μm.

Chemistry: lichexanthone, traces of triterpenes; cortex K – , UV+ yellow; medulla K – , PD – .

Substrates: bark and rocks.

Selected Specimens Examined (Fig. 3*C*)

NORTHERN TERRITORY. Kapalga Billabong, east of ruins in monsoon forest, on *Diospyros calycanthus*, 5.v.1983, *C. Scarlett s.n.*; South Alligator Inn, on *Celtis philippensis* 6.v.1983, *C. Scarlett s.n.* QUEENSLAND. Green Island, 27·4 km NE. of Cairns on trees along the foreshore, 26.viii.1976, *J. Elix 2591* (CANUC); Yorkey's Nob, 12 km N. of Cairns, on schist rocks along the foreshore, 29.viii.1976, *J. Elix 2645* (CANUC); Trinity Bay *Sayer s.n.* (G); Boreen Point, Lake Cootharaba on *Callitris*, *N. Stevens 2870*; Kinrara Basalt flow, 80 km SE. of Mt Surprise, July 1983, *T. Kahn s.n.*; Heron Island on *Casuarina equisetifolia*, s.i. 1985, *E. Yeoman 32*; Devils Kitchen, Noosa Heads National Park on *Casuarina*, 2.iv.1982, *J. Elix 10386* (CANUC); Bribie Island White Patch, 1977, *N. Stevens 1657*; Cribb Island on *Avicennia*, 19.ix.1975, *N. Stevens 1093*; Point Lookout on rocks in cliff overlooking beach, 4.xii.1981, *R. Rogers 2472*; North Stradbroke Island, S. of Dunwich, on bark of *Avicennia*, *R. Rogers & N. Stevens 529*; St Lucia on *Eucalyptus major*, 7.v.1975, *R. Rogers & C. Beasley 3261*; Sunnybank on *Casuarina*, 11.xi.1975, *R. Rogers & C. Scarlett 5837*; Mt Cotton on *Bauhinia*, 16.xii.1975, *R. Rogers & C. Scarlett 7214*; between Little Rocky Point and Jacob's Well on coastal fringe of *Ceriops tagal*, 17.i.1977, *N. Stevens 1482*; South Nobby, Miami, on cliff face exposed to the sea, 30.x.1981, *R. Rogers 2402*. NEW SOUTH WALES. Richmond River *c.* 1896, *Hodgkinson s.n.* (G); Nambucca Heads Golf Course, 23.viii.1977, *N. Stevens 2009*. WESTERN AUSTRALIA. Prince Regent River Reserve, NW. Kimberley, Aug. 1974, *A. George 12301* (PERTH); Repulse Point, South Disaster Bay, Dampier Peninsula, 23.vi.1981, *K. Kenneally 7650*, August 1974, *A. George 12301* (PERTH).

Pyxine cocoes is a variable species which appears to be favoured by at least some urbanization. It inhabits a range of environments, and grows on a multiplicity of substrates. Although not often collected from coral cays it is common on tree trunks on many of them (E. Yeoman, personal communication), suggesting the species is a nitrophile, as trees on coral cays are heavily used as bird perches. This is consistent with the observation that urbanization favours the species.

Pyxine cocoes is unlikely to be confused with other Australian species, as it has distinctive punctiform or coalescing soralia, white medulla, and a UV+ cortex. The morphologically similar African species *P. katendei* Swinscow & Krog, which has only laminal (no marginal) soralia, has not been found in Australia.

Pyxine consocians Vainio, Philipp. J. Sci. 8, 109 (1913). *Holotype*: The Philippines, Comiran Island, Sulu Sea, ad corticem arboris frondosae, Sept. 1910 (TUR), *E. D. Merrill 7167*. *Isotypes*: BM.

(Figs 11 and 19)

Thallus usually small, rarely up to 40 mm diameter, composed of irregular lobes which may at times form a discrete plaque; lobes 0·3–0·6 mm broad, yellowish white or yellowish grey, often quite moniliform, branching subdichotomous, lobes discrete or imbricating, flat or slightly convex; pseudocyphellae marginal and laminal, irregular or showing a well developed reticulate pattern; pruina absent or on tips of lobes; pustules which may appear to be isidia scattered over the lobes, often with marginal proliferations. Medulla white. Apothecia rare, devoid of algae, ascospores 16–20 × 6–9 μm; internal stipe colourless, K – .

Chemistry: atranorin, norstictic acid, triterpenes; cortex K+, UV – ; medulla K+ yellow turning red Pd+.

Substrate: bark.

Selected Specimens Examined (Fig. 3*D*)

NORTHERN TERRITORY. Kapalga Landing on *Barringtonia acutangula*, 5.v.1983, *C. Scarlett s.n.*; U.D.P. Falls, halfway up the eastern track to the top of the falls, on *Alphitonia excelsa*, 9.iii.1983, *C. Scarlett s.n.*; Koongarra Saddle Lookout, 2 km from Baroalba Airstrip, 7.v.1983, *C. Scarlett s.n.*; opposite South Alligator Inn, 161 km N. of Arnhem Highway, on *Cupaniopsis anacardioides*, 6.v.1983, *C. Scarlett s.n.* QUEENSLAND. Claudie R., Charley Taylors Landing, on mangrove, 30.vi.1983, *N. Stevens 4205*; S. end of McIlwraith Range on bark of trees in a dry creek, altitude *c.* 200 m, 28.vi.1983, *N. Stevens 4210*; Daintree River, 1882, *F. von Mueller s.n.* (G); Mulgrave River, 1886, *F. von Mueller s.n.* (G); Airlie Beach on rock near sea, July 1982, *C. Scarlett s.n.*; Russell Ck boat ramp (Bellenden Ker area) on rainforest tree beside water, 6.vii.1983, *Stevens 4272*; Bellenden Ker District, 1889, *Bailey 589* (BRI); mangroves at Noosa, on bark, June 1972, *D. Tarte 2019*.

Pyxine consocians is widespread especially along the northern coast of the continent. It is morphologically and chemically related to *P. retirugella* but can be distinguished by the presence of well developed pustules or pustulate isidia. Marginal proliferations of the pustules sometimes appear to be soredia but true soredia do not seem to be produced. *Pyxine consocians* is chemically inseparable from some forms of *P. retirugella*: the relationships of the group of species around *P. retirugella* are discussed under that species.

Pyxine convexior (Müll. Arg.) Swinscow & Krog, Norw. J. Bot. 22, 52 (1975).

Pyxine cocoes var. *convexior* Müll. Arg., Bot. Jb. 20, 262 (1894). *Holotype*: D.O.Afr. (Tanzania), Usambara, *Holst 3137* (G).

(Fig. 20)

Thallus up to 50 mm diameter, composed of irregular lobes; lobes 0·5–0·8 mm broad, white or pale grey, irregularly branched, discrete, convex, loosely adnate to the substrate, sparsely pruinose or epruinose; isidia, soredia and pustules absent; without pseudocyphellae. Medulla white. Apothecia common, devoid of algae, ascospores 15–20 × 6–8 μm, internal stipe white, K−.

Chemistry: atranorin, triterpenes; cortex K+ yellow, UV−; medulla K−.

Substrate: bark.

Specimens Examined (Fig. 3*D*)

QUEENSLAND. Hinchinbrook Island, Missionary Bay, on *Ceriops*, Aug. 1979, *N. Stevens 3404*; on *Bruguiera*, *N. Stevens 3927*.

This species is known from only two Australian collections, both on Hinchinbrook Island. The material is similar to but smaller than the type and quite different from any other taxon reported from Australia. The species has a very distinctive range of triterpenes and is chemically identical with *P. reticulata* (Vainio) Vainio, which, however, is sorediate. It is apparently close to *P. papuana* Kashiwadani and *P. philippina* Vainio in its morphology; however, *P. philippina* produces copious norstictic acid and different triterpenes whereas *P. papuana* produces different triterpenes. More collections may allow clarification of the taxonomy of this group.

Pyxine isidiolenta R. W. Rogers, sp. nov.

(Figs 12 and 21)

Thallus usque ad 80 mm diametro; lobi radiati, vel irregularis, latitude 0·3–0·7 mm, alboflavidis vel subflavogrisei, subdichotomi, discreti, laxe adnati vel ascendens, plani vel aliquanti convexi; pseudocyphellae marginalis et laminalis, sublinearis vel subreticulati; epruinosus; isidia vulgo erecta, cylindrica, simplica vel ramosa, non pustulata, interdum caespitosa. Medulla flava vel subflava. Apothecia ad 1·4 mm diametro; margo sine algarum, atra, stipes internus flavus, K+ rubescens. Sporae 12–18 × 6–7 μm. Cortex atranorin, triterpenae continens.

Holotype: Australia, Queensland. Little Ramsay Bay. Hinchinbrook Island on bark of *Heritiera littoralis* at sea level. 18.viii.1975, *A. B. Cribb 1138* (MEL). *Isotypes*: BRI, BM, U.

Thallus up to 80 mm diameter of radiating or irregular lobes; lobes 0·3–0·7 mm wide, pale yellowish white to yellowish grey, branching subdichotomous, discrete, loosely adnate to the substrate or somewhat ascending, flat to somewhat convex; pseudocyphellae marginal and laminal, irregularly linear to more or less reticulate; without pruina; isidia usually erect, cylindrical, simple or little branched, sometimes bunched. Medulla yellow to light yellow. Apothecia 1·4 mm diameter, margin black, without algae, disc slightly convex; internal stipe yellow, K+ red; ascospores 12–18 × 6–7 μm.

Chemistry: atranorin, triterpenes. Cortex K+ yellow, UV–; medulla K–, Pd–.

Substrate: bark in mangrove communities.

Specimens Examined (Fig. 3*E*)

NORTHERN TERRITORY. Field Island, at the mouth of South Alligator R. on *Rhizophora stylosa*, 30.iv.1979, *E. Hegerl 3110*. QUEENSLAND. Little Ramsay Bay, Hinchinbrook Is. on bark of *Heritiera littoralis*, 18.viii.1975, *A. Cribb 1138*; AIMS Broadwalk, Hinchinbrook Island on *Bruguiera*, 23.viii.1979, *N. Stevens 1868*, *3403*, *3403a*, *3439*; Bishop Creek, Hinchinbrook Is. on *Rhizophora*, 23.viii.1979, *N. Stevens 3405*; Hinchinbrook Is. on *Ceriops tagal*, *N. Stevens 3440*; N. end of Wet Desert, Hinchinbrook Is. on *Ceriops tagal*, *N. Stevens 3581a*; Mandalay Point, near Mackay, on *Rhizophora stylosa*, 30.vi.1982, *J. Conran & C. Scarlett*; Eimeo Beach on *Rhizophora apiculata*, 14.viii.1976, *N. Stevens 1870*; Sunset Beach (Eimeo Beach Creek) on old *Rhizophora*, *N. Stevens 1867*; Eimeo Beach on *Bruguiera*, 14.viii.1976, *N. Stevens 3936*, *3949*.

The species is named for its often copious production of true isidia (not pustules).

P. isidiolenta is one of the few species of *Pyxine* to produce true isidia: the only other with a coloured medulla is the saxicolous *P. kibweziensis*.

Specimens are notably variable from fragile lobes with thin, often recumbent isidia to thick lobes with stout, erect isidia. It is chemically identical with *Pyxine linearis* and is possibly an isidiate species pair of that sorediate taxon, although no specimen was found which showed the very large thallus with strikingly linear greenish lobes that occurs at times in *P. linearis*.

The species is known from Hinchinbrook Island where it is apparently very common, from the vicinity of Mackay, and by one collection from the Alligator River mouth. All collections to date are from mangroves (*Bruguiera*, *Rhizophora*, *Heritiera* and *Ceriops*) in regions of high rainfall.

Pyxine linearis R. W. Rogers, nom. nov.

Pyxine retirugella Nyl. var. *endoxantha* Müll. Arg. forma *sorediosa* Müll. Arg., Bull. Herb. Boiss. 4 : 91 (1896). *Lectotype* (here selected): Queensland, 1887, *Knight 16* (G). *Syntypes*: Queensland, 1887, *Knight 17* (G), Java, 1882 (G).

(Figs 13, 15 and 22)

Thallus up to 200 mm diameter, of radiating lobes usually forming a neat but extensive plaque; lobes 0·3–1·2 mm wide, grey to dull yellow, linear or subdichotomous, discrete or imbricate, slightly convex; laminal pseudocyphellae irregular and slightly developed to reticulate and well developed, pruina sparse on lobe tips or absent; soredia in well developed


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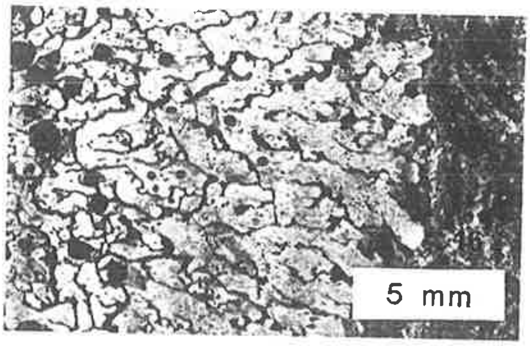

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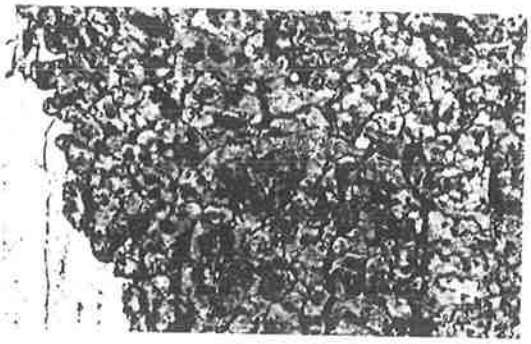

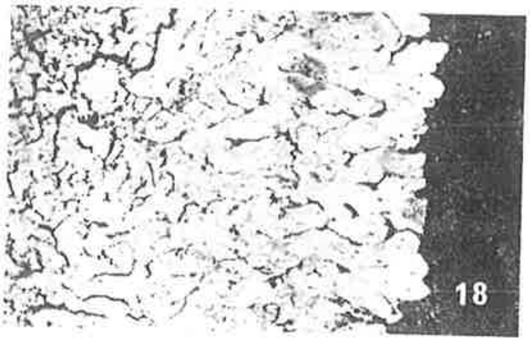
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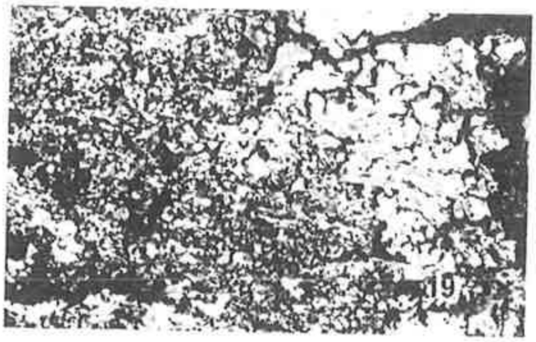
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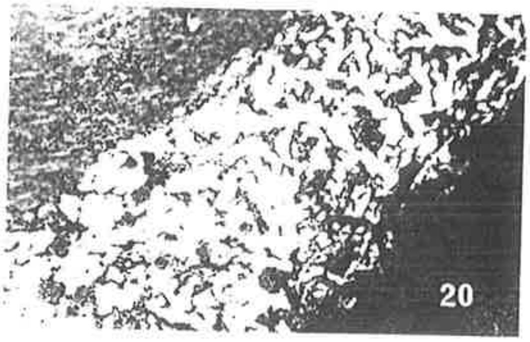
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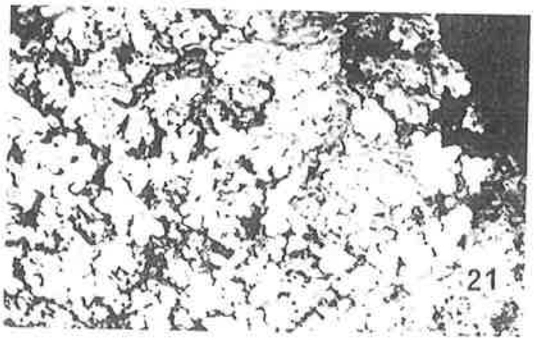
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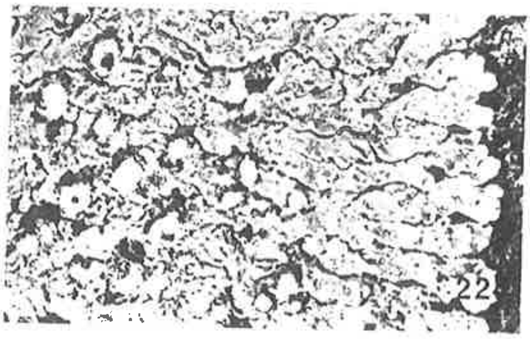
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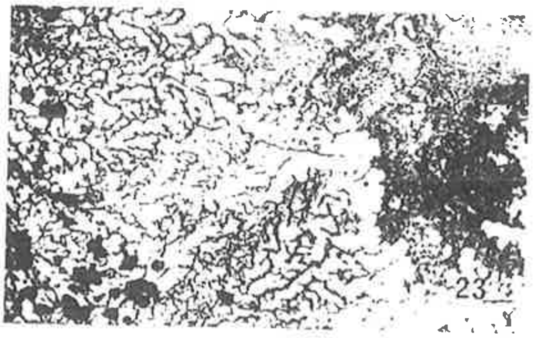
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orbicular laminal soralia; isidia absent. Medulla light yellow to yellow. Apothecia rare, to 0·5 mm diameter, margin devoid of algae and prominent, disc flat.

Chemistry: atranorin, triterpenes; cortex K+ yellow, UV−; medulla K+ pink, Pd−.

Substrate: bark.

Specimens Examined (Fig. 3*F*)

QUEENSLAND. Portland Roads on *Ceriops*, 30.vii.1983, *N. Stevens 4206*; on *Rhizophora apiculata*, 30.vii.1983, *N. Stevens 4207*; dead branch, 30.vii.1983, *N. Stevens 4209*; Weipa in fringing forest, 25.vii.1974, *R. Specht s.n.*; Bingil Bay on bark of *Ficus*, 23.vi.1983, *N. Stevens 4211*; Eimeo Beach near Mackay on *Rhizophora apiculata*, 14.viii.1976, *N. Stevens 1967*; Funnel Bay on *Ceriops tagal*, *C. Scarlett & J. Conran s.n.*

Pyxine linearis is a tropical species known from a few locations only, but is abundant in the vicinity of Portland Roads. All collections are from bark of mangroves or in coastal forests. Specimens are quite variable in thallus size and lobe size but distinctly different from other taxa reported in Australia. One specimen, *Stevens 4211* from Bingil Bay, differs from the others in that its lobes are rather contorted and overlapping, making it very similar in appearance to the syntype from Java. The differences would not, however, justify a new taxon at this stage.

As observed by Swinscow and Krog (1975*a*) the species is close to *P. meissnerina* but differs in having very little or no pruina and laminal rather than marginal soralia, as well as often having very marked pseudocyphellae and linear lobes. The material resembles *P. retirugella* but has no norstictic acid, has a yellow medulla and is usually very much larger.

Pyxine minuta Vainio, Acta Soc. Fauna Flora Fenn. 7 (2), 156 (1890). *Holotype*: [Brazil] Supra rupem prope Rio de Janeiro, *Vainio 211* (TUR).

Catolechia pyxinoides Müll. Arg., Flora 34, 508 (1881). *Holotype*: Bresil, Apiahy, 1880, *Puiggari 1237* (G).

Pyxine brachyloba Müll. Arg., Bull. Soc. Bot. Belg. 32, 131 (1893). *Lectotype* (here selected): [Costa Rica] Saxicole, San Marcos, *Pitt 3470* (G). *Syntype*: BM.

Pyxine nitidula Müll. Arg., J. Bot. Fr. 7, 74 (1893). *Holotype*: [Nova Caledonia] Saxicole, plaine de la Tamoa, *B. Balansa* (G).

Pyxine microspora Vainio, Philipp. J. Sci. (C) 8, 110 (1913). *Holotype*: [Philippines] Luzon, Subprov. Benguet, prope Cabayan, ad lapides, *McGregor 8804* (TUR). *Syntype*: BM.

(Fig. 23)

Thallus, up to 15 mm diameter, of radiating lobes which usually form a neat plaque but sometimes aggregate; lobes 0·2–0·5 mm broad, white to pale grey, greyish yellow or beige, branching subdichotomous, discrete or slightly imbricate, closely adnate to the substrate, plane; pseudocyphellae marginal and sometimes laminal, not reticulate; pruina sparse and subterminal or absent; devoid of isidia, pustules and soredia. Medulla white. Apothecia very common, up to 0·8 mm diameter, with a distinct black margin and plane disc when young, emarginate and convex when older, never with a margin coloured like the thallus; internal stipe not developed, subhymenial layers K−, ascospores 10–15 × 5–8 µm.

Chemistry: lichexanthone, triterpenes; cortex K−, UV+ yellow; medulla K−, Pd−.

Substrate: rocks in open communities.

Figs 14 and 15. Thallus structures in *Pyxine*: to same scale as Fig. 4. Fig. 14. Extensive development of pruina on lobe tips of *P. cocoes*. Fig. 15. Sparse development of pruina of lobe tips of *P. linearis*. **Figs 16–23**. Habit of *Pyxine* species: all to same scale as Fig. 16. Fig. 16. *P. berteriana*. Fig. 17. *P. coccifera*. Fig. 18. *P. cocoes*. Fig. 19. *P. consocians*. Fig. 20. *P. convexa*. Fig. 21. *P. isidiolenta*. Fig. 22. *P. linearis*. Fig. 23. *P. minuta*.

Specimens Examined (Fig. 3*F*)

QUEENSLAND. N. face of Mt Coolum on exposed rock face, alt. 150 m, 8.vii.1983, *R. Rogers 2765*; Settlement Rd, Keperra, on granite boulders in eucalypt forest, 15.vi.1983, *R. Rogers 2643*, *2712*; Moggill State Forest on quartzitic rock in eucalypt forest, 8.x.1981, *R. Rogers 2362*; Mt Gravatt on rocks on S. facing slope in eucalypt woodland, 30.vi.1983, *R. Rogers 2744*, *2745*, *2746*, *2747*; Brisbane 1891, *F. M. Bailey s.n.* (G); Queensland, 1893, *Shirley s.n.* (G).

P. minuta is chemically identical with *Catalechia pyxinoides*, *Pyxine brachyloba* and *P. nitidula* but slightly different from *P. microspora*. Specimens with the *P. minuta* chemistry (9 on Fig. 1) are found in the Brisbane area but a morphologically identical form also in the Brisbane area shows a third triterpene chemistry (10 on Fig. 1). The types of the described species are morphologically very similar, and given the morphological variation shown within chemical strains in the Brisbane area ought not be separated on morphological grounds. Variations in triterpenes alone seems a trivial ground for the separation of ecologically and morphologically like material. All the Australian material is therefore included in *P. minuta*, and the other names synonymized.

The thallus of this species is so closely appressed to the substrate, thin, and with narrow lobes, that it could be mistaken for a crustose lichen at first sight. It is morphologically rather like *Pyxine petricola* which is also UV+ yellow, and devoid of isidia and soredia. However, *P. petricola* is larger, less closely adnate, often with an apothecial margin coloured like the thallus, and has a well developed K+ red internal stipe and subhymenial zone.

The species has been collected only in the Brisbane area: this is most probably an artefact of collecting, for it is inconspicuous and Australian collectors have tended to ignore apparently crustose saxicolous material. The species is clearly widely distributed (Uganda, Brazil, Costa Rica, New Caledonia, Australia, Philippines) and, judging by the material found near Brisbane, not uncommon.

Pyxine nubila Moberg, Norw. J. Bot. 27, 189 (1980). *Holotype*: Kenya; Rift Valley Prov. (K3), Lake Naivasha Hotel, 0°46′S., 36°24′E., alt. *c.* 200 m, 1979, *Moberg 4488a* (UPS). (Type not seen.)

Thallus, up to 100 mm diameter, composed of radiating to irregular lobes; lobes up to 3 mm broad, olive shading to yellowish grey at the tips, branching subdichotomous, somewhat imbricate and irregular, slightly concave; without pseudocyphellae; pruina developed near the lobe tips; soredia marginal in extensive longitudinal soralia, olive; isidia and pustules absent. Medulla white. Apothecia not known on Australian material.

Chemistry: no lichen substances detected; cortex K−, UV−; medulla K− Pd−.

Substrate: rocks.

Specimen Examined (Fig. 3*F*)

TASMANIA. Dysart area, near the Hunting Ground, Jordan River, on sandstone under overhangs in dry bushland, iv.1982, *G. Kantvilas 253/82* (HO).

Although known from a single Australian collection only, there is no doubt about the identity of the material determined by Dr Roland Moberg. *Pyxine nubila* is apparently known from five other locations, three in Kenya, and one each in Ethiopia and Saudi Arabia (Moberg 1980). An Australian record makes this a most interesting disjunction indeed. It grows on trees and shaded rocks in the other areas but the sole Australian record is on a coarse sandstone.

The lobes are unusually wide for a *Pyxine* and the soralia different from those in other *Pyxine* species. The lower surface is grey-brown, not black. Unlike other *Pyxine* species this material has no cortical or medullary substances. Moberg retained this species in *Pyxine* because of its K+ purple reaction in the upper and lower cortex, visible only in a microscope preparation. Taking the above evidence and the gross ecological dissimilarity between this and other *Pyxine* species, it is possible that a careful investigation of genus limits could result in the segregation of a new genus for this taxon, or its relocation perhaps to *Physcia* or *Physconia*.

It is of interest that no other species of *Pyxine* has been found in Tasmania or in Victoria. *Pyxine* is, other than this species and *P. sorediata*, a genus of the tropics and subtropics.

Pyxine petricola Nyl. in Crombie, J. Bot. Lond. 14, 263 (1876). *Holotype*: Island of Rodriguez, *I. B. Balfour 2391*, Venus Transit Expedition, 9.xii.1874 (BM).

Pyxine meissneri Tuck. ex Nyl. var. *endoleuca* Müll. Arg., Flora, Jena 62, 290 (1879). *Lectotype* (the specimen annotated by Müller Arg. in G is here chosen): In africano Djur, ad sepimenta magnae Seriba Ghattas, *Schweinfurth* (G).

Pyxine meissneri Tuck. ex Nyl. var. *convexula* Malme, K. Svenska Vetensk. Akad. Handl. (3)23, 37 (1897). *Lectotype* (here selected): Matto Grosso; Corumba, *no. 3889*. *Isotypes*: G, BM. *Pyxine endoleuca* (Müll. Arg.) Vainio, Hedwigia (Beiblatt) 37, 42 (1898).

Pyxine subvelata Stirton, Trans. Proc. N.Z. Inst. 30, 396 '1897' (1898). *Holotype*: Queensland, Jimbour on *H. oleifolium*, June 1895, *F. M. Bailey* (BM).

Pyxine albida Magnusson in Magnusson & Zahlbruckner, Ark. Bot. 32A(2), 57 (1945). *Holotype*: (Hawaiian Islands) Maui, near Wailuku, in dry valley at about 350 m altitude on basaltic stone, 1922, *Skottsberg (1012)* (U).

Pyxine pringlei Imshaug, Trans. Amer. Micros. Soc. 7, 263 (1957). *Holotype*: Mexico Plains, Monterey, 19.vi.1889, *C. G. Pringle no. 52* (FH).

(Fig. 24)

Thallus rarely more than 40 mm diameter, of irregular or radial lobes; lobes 0·3–1·2 mm broad, white or greyish white, branching subdichotomous, commonly imbricate, closely adnate to the substrate to somewhat ascending, plane to somewhat convex; pseudocyphellae seen as white lines on the margin and on the upper surface where they may be reticulate; isidia, pustules and isidia absent, pruina present or absent. Medulla white. Apothecia common, usually retaining algae in the exciple; internal stipe brown, K+ red; ascospores 12–20 × 6–8 μm.

Chemistry: lichexanthone, triterpenes; cortex UV+ yellow K−; medulla K− Pd−.

Substrates: Rocks and trees (not mangroves) on the coast and in inland areas.

Specimens Examined (Fig. 3G)

QUEENSLAND. Monogorillay, Mundubbera Shire, 30.vi.1980, *P. Forster 181a*; Brookvale Park, 12 km W. of Oakey, alt. 600 m., 11.i.1980, *B. Ballingall 363* (CANB); Apex Park, Oakey, on willowtree, 15.v.1979, *N. Stevens 3827*; Maclagan, near Oakey, on *Acacia aulacocarpa*, 15.v.1979, *N. Stevens 3823*, *3792*; University of Queensland, St Lucia, on palm, Jan. 1975, *R. Rogers & C. Beasley 3063*, *3064*; Nudgee Beach on *Cupaniopsis anacardioides*, 8.viii.1975, *R. Rogers & C. Scarlett 4267*; Gaythorne on *Erythrina* sp., 11.iv.1975, *R. Rogers & C. Scarlett 4704*; Cribb Island on *Cupaniopsis anacardioides*, 4.iv.1975, *C. Scarlett & N. Stevens 4487*; Kalinga on *Spathodea* sp., 13.v.1975, *R. Rogers & C. Beasley 3464*; Pullenvale on *Acacia*, 12.xii.1975, *R. W. Rogers & C. Scarlett 6724*. Queensland, 1889, *Knight* (G).

The type of *Pyxine petricola* is saxicolous, but all Australian material referred to the species is corticolous. The species, however, appears to be somewhat variable, as discussed by Swinscow and Krog (1975*a*). The type has narrower, more closely adnate lobes than the Australian material and also much lower concentrations of terpenes. If a separate taxon was to be retained for the corticolous material the name *Pyxine subvelata* Stirton is available.

Imshaug (1957) described *P. pringlei* to accommodate material like *P. endoleuca* but having a red stipe, a characteristic of *P. petricola* and *P. endoleuca*. Magnusson described *P. albida* from a saxicolous specimen which falls within the range of morphological variation shown by *P. petricola* and which is chemically identical with it.

Pyxine petricola is not common in Australia, occurring in drier subtropical communities and in the city of Brisbane.

Pyxine pungens Zahlbr., Ann. Crypt. Exot. 1, 210 (1928). *Holotype*: in horto botanico Buitenzorgensis, ramicola (*C. van Overeem no. 23*) (W). *Isotype*: O.

Pyxine meissneri var. *subobscurascens* Malme, Bih. Kgl. Svensk. Vet.-Akad. Handl. (3) 23, 37 (1897). *Isotypes*: Paraguay, Colonia Risso pr. Rio Apa (No. 3872 21/10 1893), Minas Geraes; Sao Joao del Rey (No. 228 20/8 1892).

Pyxine berteriana var. *subobscurascens* (Malme) Imshaug, Tr. Amer. Micros. Soc. 76, 256 (1957).

(Fig. 25)

Thallus, up to 100 mm diameter, composed of radiating lobes usually forming a neat plaque but sometimes irregular; lobes 0·5–1·2 mm broad, yellowish white to yellowish grey, commonly imbricate, rarely overgrowing each other, adnate to the substrate, concave to convex, dichotomously branched. Pseudocyphellae very variable from faint marginal white lines to laminal and almost reticulate; pruina very sparse or absent; isidia, pustules and soredia absent. Medulla greyish yellow to yellowish grey. Apothecia common, to 1·5 mm diameter, margin sometimes coloured like the thallus, disc flat, internal stipe brown, K – ; ascospores 13–16 × 6–7 μm.

Chemistry: atranorin, triterpenes; cortex K+ yellow, UV – ; medulla (pigment) K+ purple or purple-brown Pd+ orange.

Substrates: bark and rock.

Specimens Examined (Fig. 3*G*)

QUEENSLAND. Slopes of Mt Whitfield, Cairns (120 m), on forest tree, 24.viii.1976, *J. Elix 2558* (CANUC); 3 km SW. of Kingaroy (450 m), dry shrub on rock in exposed grazing land, 29.vii.1979, *H. Streimann 9363* (CANB); Old North Road, Pine Rivers, on *Eucalyptus drepanophylla*, 11.ix.1975, *R. Rogers & C. Scarlett 4735*; Nudgee Creek on *Ceriops tagal*, 31.viii.1978, *N. Stevens 2697a*; Corner of Crestview St and Kenmore Rd, Kenmore, on *Eucalyptus drepanophylla*, 15.xii.1975, *R. Rogers & C. Scarlett 7095*; Mud Island on *Ceriops tagal*, 30.iv.1979, *N. Stevens 3059*; McCrae Rd., Bardon, on fallen ironbark branches, 12.v.1975, *R. Rogers & C. Beasley 3461*; Birdwood Terrace, Toowong, on *Acacia* sp., 12.v.1975, *R. Rogers & C. Beasley 3422*; O'Brien Rd., Pullenvale, on *Acacia* sp., 12.xii.1975, *R. Rogers & C. Scarlett 6723*; Moggill Forest, near Ugly Gully, on *Acacia* sp., 3.ii.1975, *R. Rogers & C. Beasley 3047*; Myora Springs, N. Stradbroke Is., 12.vi.1978, *N. Stevens 1834*, *2611*; intersection of roads from Mudgeeraba and Natural Arch to Springbrook, on rock by roadside in eucalypt forest (600 m), 14.i.1982, *R. Rogers 2673*; *F. M. Bailey 761* (G), *J. H. Shirley* (BRI).

This relatively uncommon species is externally indistinguishable from *Pyxine berteriana*. It differs, however, in the colour of the medulla (browner in *P. pungens*) which is strongly K+ purple to purple brown. *P. pungens* is chemically distinct, having no lichexanthone (hence UV –) and different triterpenes. *Pyxine pungens* is ecologically more diverse than *P. berteriana*, occurring in drier areas well away from watercourses.

P. meissneri var. *subobscurascens* Malme is morphologically identical to *P. pungens*, has the same cortical chemistry and shares most of the same triterpenes. It is clear that neither taxon is closely related to *P. berteriana* which has lichexanthone in the cortex, not atranorin. *Pyxine rhodesiaca* Vainio ex Lynge is clearly very similar to *P. pungens* but differs in its triterpenes and degree of reticulation: given the variability in the reticulation of *P. pungens* in Australia, and the variation in triterpenes allowed here in other species, *P. rhodesiaca* could well be synonymized with *P. pungens*. Studies on more African material would then be required.

Pyxine retirugella Nyl., Ann. Sci. Nat. (Bot) Ser 4, 11, 240 (1859). *Holotype*: Nukahiva, ad cortices et saxa. (H-NYL no. 31789.)

Pyxine retirugella var. *laevior* Vainio, Bot. Tiddskr. 29, 104 (1909). *Lectotype* (here selected): Thailand, Koh Chang, prope Lem Ngob ad corticem arborum no. ix, *Johs. Schmidt* (TUR).

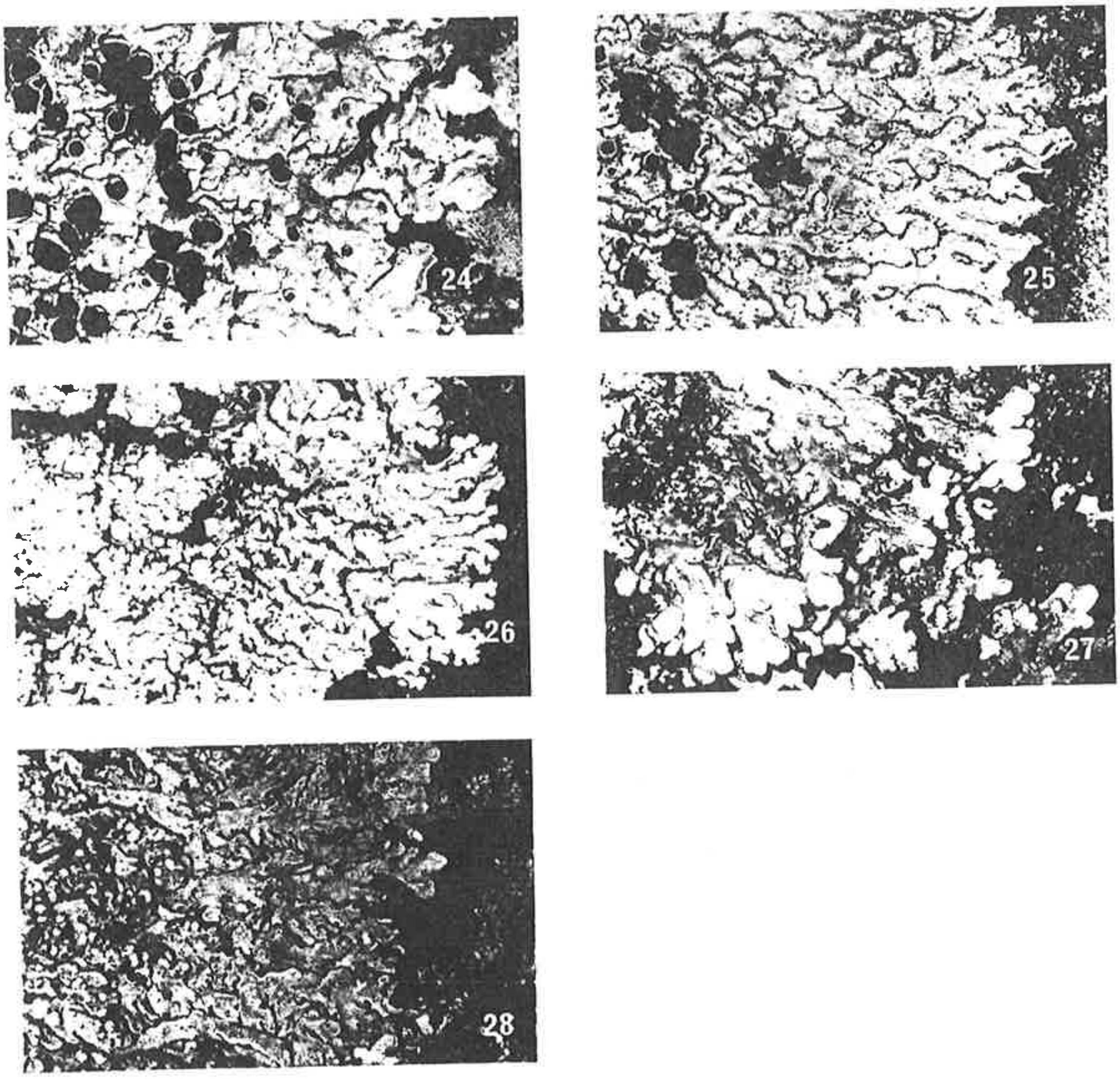
Pyxine retirugella var. *capitata* Zahlbr. in Magnusson & Zahlbr., Ark. Bot. 32(A)2, 59 (1945). *Lectotype* (here selected): United States, Hawaii, Kauai, Haena, S. of Hilo. *Pandanus* forest, 1922, *Skottsberg 1267* (S).

Pyxine copelandii Vainio, Philipp. J. Sci. (C)8, 110 (1913). *Holotype*: Philippines, Panay, Capiz, ad corticem arborum frondosarum, *Copeland*, 10.i.1904 (TUR).

Pyxine asiatica Vainio, Hedwigia 46, 17, 1 (1907). *Lectotype* (here selected): Thailand, Insula Koh Chang prope Lem Dan, ad corticem *Areca catechu*, *J. Schmidt X* (TUR).

Pyxine patellaris Kurok., Bull. Natnl: Sci. Mus. Tokyo 12, 689 (1969). *Holotype*: Bonin Islands, Chichijima, between Okumara and Ohigiura along trail in forest of *Calophyllum inophyllum–Terminalia catappa*, alt. 0–100 m, *H. Inoue 19027*, 21.xi.1968 (TNS).

(Figs 4, 12 and 26)



Figs 24–28. Habit of *Pyxine* species: all to same scale as Fig. 16. Fig. 24. *P. petricola*. Fig. 25. *P. pungens*. Fig. 26. *P. retirugella*. Fig. 27. *P. sorediata*. Fig. 28. *P. subcinerea*.

Thallus usually small, rarely 40 mm diameter, of irregular lobes that may at times form a discrete plaque; lobes 0·3–0·6 mm broad yellowish white or yellowish grey, often quite moniliform, branching subdichotomous, lobes discrete or imbricate, flat or slightly convex; pseudocyphellae marginal and laminal, irregular or showing a well developed reticulate pattern; pruina absent or on tips of lobes; soralia laminal and orbicular to sessile or shortly stipitate and pustular. Medulla white. Apothecia rare, devoid of algae; ascospores 16–20 × 6–9 μm; internal stipe colourless, K–.

Chemistry: atranorin, norstictic acid, testacein, triterpenes; cortex K+, UV–; medulla K+ yellow turning red, Pd+.

Substrate: bark.

Selected Specimens Examined (Fig. 3*H*)

QUEENSLAND. Claudie R., Charley Taylors Landing, on mangrove, 30.vi.1983, *N. Stevens 4204*; Cardwell, on bark of *Rhizophora* sp.; Cairns, Trinity Inlet, on *Ceriops* sp.; Hinchinbrook Is., side board walk (site 2), 24.viii.1979, *N. Stevens 3437*; Hinchinbrook Is., N. end of Wet Desert, on *Ceriops* sp., 25.viii.1979, *N. Stevens 3402*; Hinchinbrook Is., Bishop Ck. on *Ceriops* sp., 24.viii.1979, *N. Stevens 3436*; Eimeo Ck (Sunset Beach) on tall *Excocaria* sp., on trunk and branches of land fringe of grove, 16.viii.1976, *N. Stevens 1869*; Eimeo Salt Marsh, on *Lumnitzera* sp. near rock, 14.viii.1976, *N. Stevens 1858*; Mandalay Point, on *Argyrodendron trifoliatum*, 30.vi.1982, *C. Scarlett, s.n.*; Gladstone, on bark of *Rhizophora* sp., 9.vi.1975, *R. Rogers 717*; Gladstone, between town and power house, on bark of *Ceriops* sp., 14.vi.1975, *R. Rogers 1009*; Boyne River Estuary, S. of Gladstone, on bark of *Rhizophora* sp., 14.vi.1975, *R. Rogers 816*; Imbil State Forest (26°27'S., 152°37'E.), on bark of *Alphitonia* sp., on fringe of rainforest, 2.ix.1981, *R. Rogers 2474*; Softwood scrub near Yabba Rd., 6 km N. of Jimna, on liane in rainforest, alt. 650 m, 4.v.1981, *R. Rogers 2240*; Bribie Island, 5 km N. of Bribie bridge, on *Rhizophora* sp., in *Ceriops* glade, 31.i.1976, *N. Stevens 1545*; Myora Springs, S. of creek, on very old *Avicennia* sp., 12.vi.1978, *N. Stevens 2613*; Amity Point, Stradbroke Is., on *Rhizophora* sp. in mid zone, *N. Stevens 2081*; Mt Ommaney Rd, Mt Ommaney, 9.xii.1975, *R. Rogers & C. Scarlett 6204*; Coochie Mudlo Is., in landward fringe on old *Bruguiera* sp., 9.iv.1977, *N. Stevens 1685*. NEW SOUTH WALES. Moss Garden Walk, the Head Rd., along border in rainforest, alt. 1000 m, 4.ix.1981, *N. Stevens 3855*; Park Beach, Coffs Harbour, on tree in coastal scrub, 28.vi.1977, *J. Elix 3376* (CANUC).

The holotype of *Pyxine retirugella* is a small specimen, partly overgrown with algae. It is over an uneven surface, and on the ridges of the bark the thallus has been crushed and abraded, but detail has been preserved in the crevices. The surface of the thallus is strongly pseudocyphellate, and markedly ridged. The soralia apparently begin as digitate structures, and could be confused with isidia: however, these burst and develop as stipitate soralia in crevices or as sessile soralia on the rest of the thallus. These structures are, therefore, not much different in nature from the pustules produced by *P. consocians*.

As interpreted in this study, *P. retirugella* is sorediate with two chemical variants, having different triterpenes. The chemistry of the type (14 on Fig. 1), is identical with that of *P. consocians*. Given the similarity in thallus morphology and chemistry, the difference between asexual reproductive structures which develop as soralia and those which develop as pustules may seem insufficient justification for distinguishing species (Tehler 1982). However, the two species have distinct although overlapping ranges and can be distinguished even when they occur at the same location. The two species are therefore maintained. A third species, *P. cylindrica* Kashiwadani, not found in Australia, also has an identical chemistry but differs in producing isidia.

A second chemistry is found in the type of *P. patellaris* (13 on Fig. 1), differing from the type of *P. retirugella* in the range of triterpenes present. Material with this chemistry is widespread in eastern Australia, coextensive with material morphologically like the type of *P. retirugella*. Specimens showing the two chemistries cannot be separated on morphological grounds and, therefore, have been treated as a single species.

Yet another variant (not yet reported from Australia) is represented by the type of *P. asiatica*, which is like the type of *P. patellaris* except for the absence of norstictic acid: however, this absence is not held to justify maintenance of a species.

The variation in asexual reproductive structures and chemistry in some similar species is summarized in Table 2.

Table 2. Characteristics of isidiate and isidiate–pustulate species of *Pyxine*

A, cortex containing atranorin; L, cortex containing lichexanthone; N, medulla containing norstictic acid; T, medulla containing testacein; I, thallus isidiate; P, thallus pustulate; S, saxicolous; C, corticolous

Species	Cortex	Medulla		Thallus	Substrate
		Chemistry	Colour		
P. isidiolenta	A	—	Yellow	I	C
P. kibweziensis	A	—	Orange	I	S
P. maculata	A	—	White/yellow	P	S
P. heterospora	A	—	White	P	C
P. coralligera	A	T	Yellow/white	P	C
P. consocians	A	N, T	Yellow/white	P	C
P. isidiophora	A	N	White	I	C, S
P. cylindrica	A	N	White	I	C
P. endochrysina	—	—	Yellow	P	S
P. physciaeformis	L	—	Yellow/white	P	C
P. lyei	L	—	White	I	S
P. lilacina	L	T	White	P	S

Pyxine sorediata (Ach.) Mont. in Sagra, Hist. Cuba 9, 188 (1842) (reference not seen).

Lecidea sorediata Ach., Syn. Meth. Lich. 54 (1815). Isotypes: American Septentrionali (S, UPS).

(Figs 6, 7 and 27)

Thallus often forming very extensive patches; lobes 1·0–2·0 mm broad, pearl-white to light grey or dull yellow, branching subdichotomous, in close contact with each other, sometimes overgrowing each other, tightly or loosely adnate to the substrate, concave usually with thickened margins; pseudocyphellae well developed along the margins but rare on the lamina; pruina restricted to the lobe tips; soredia common and well developed, often very coarse, grey. Medulla yellow or light yellow, the yellow colour sometimes visible in the soralia which may be on marginal isidia-like lobules. Apothecia very rare, internal stipe colourless to pale brown, K – ; ascospores 12–17 × 6–8 μm.

Chemistry: atranorin in trace to considerable amounts, triterpenes, pigment; cortex UV – , K + yellow; medulla K – , Pd – .

Substrates: rock, moss, bark.

Specimens Examined (Fig. 3*I*)

QUEENSLAND. Tinaroo Perimeter Rd, 14 km NE. of Atherton, 28.ii.1983, *H. Streimann 16989* (CANB); Cedar Creek, Samford, 26.x.1979, *N. Stevens s.n.*; entrance to Cedar Creek National Park, Mt Tamborine, 28.x.1983, *R. Rogers 2789*; Higher slopes of Mt Cordeaux, 5.vii.1984, *R. Rogers 2912*; Neranwood, 14.i.1982, *R. Rogers 2550*, 15 km S. of Stanthorpe along Hwy 15, 2.ix.1976, *J. Elix 2662* (CANUC); *Bailey 1891* (G); *Shirley* (BRI). NEW SOUTH WALES. Toonumbar State Forest, 29 km NW. of Kyogle, 18.ix.1978, *D. Verdon 3945* (CANB); Bolivia Hill, 11 km NE. of Deepwater, 23.i.1983, *H. Streimann 9960* (CANB); 25 km NW. of Coffs Harbour below Waihou trig. station, 7.vii.1982, *D. Verdon 3791* (CANB); Port Macquarie, Shelley's Beach, 19.viii.1975, *J. Elix 1084* (CANUC, MEL);

Dharug National Park, 5.ii.1977, *J. Elix 2899* (CANUC); Kiama foreshore, 29.iii.1975, *J. Elix 688* (CANUC); Bungonia Gorge, 28 km ESE. of Goulburn, 14.viii.1978, *J. Elix 4911* (CANB); Gladesville, Sept. 1910, *M. Flockton* (NSW); 5 km NE. of Nerriga, 30.iii.1977, *J. Elix 3122* (CANUC, MEL); below Tianjara Falls, 33 km NNW. of Ulladulla, 21.vi.1979, *J. Elix 5948, 5979* (CANUC) *5874* (CANB); Currowan State Forest, 12 km W. of Nelligan, *J. Elix 3565* (MEL, CANUC); Wadbilliga River Gorge, 41 km ESE. of Cooma, 13.vi.1976, *D. Verdon 2485* (CANB).

This species commonly occurs some distance from the coast and often at considerable altitude (up to nearly 1000 m in Queensland). Most collections are from somewhat shaded rocks, often with a layer of peaty material accumulated beneath the lichen thallus, but some are over moss or on bark.

Specimens are very variable, especially in soredial formation, ranging from small almost pustular marginal soralia to very large coralloid marginal soralia with masses of coarse grey soredia. There is variation too in the amount of atranorin in the cortex, a few specimens having large amounts, most only a trace. Some specimens show one less triterpene bar than the others but, although some are small-lobed, there is no reason to regard them as a separate taxon.

Pyxine subcinerea Stirton, Trans. Proc. N.Z. Instit. 30, 397 (1898). *Holotype*: Queensland, *F. M. Bailey 22* (BM).

Pyxine chrysantha Vainio, Cat. Afr. Pl. Welwitsch 2(2), 412 (1901). *Lectotype*: Golungo Alto ad truncos arb. vigent. in sylvis primaevis prope Sange, 1857, *Welwitsch* (BM).

Pyxine chrysanthoides Vainio, Suomal. Tiedeakat. Toim. Ser. A, 6, 71(1914). *Lectotype*: Antilles, Morne Rouge, 480–600 m (TUR).

Pyxine meissneri var. *sorediosa* Müll. Arg., Flora 62, 290 (1879). *Lectotype* (here chosen): Djur ad saxa, Braunenstein, *Schweinfurth* (G).

(Figs 9 and 28)

Thallus often larger than 50 mm diameter, composed of radiating lobes usually forming a neat plaque but sometimes irregular; lobes 0·5–1·5 mm broad, yellowish grey to grey, branching subdichotomous, more or less imbricate, plane, with short marginal or submarginal pseudocyphellae which develop into soralia; lobe tips often heavily pruinose; isidia and pustules absent; soredia grey, in orbicular to linear marginal or submarginal soralia which often coalesce. Medulla yellow. Apothecia rare, *c.* 1·2 mm diam., without an algal layer, margin well defined, disc flat; internal stipe colourless or pale brown K– or K+ in patches; ascospores 15–22 × 6–9 μm.

Chemistry: lichexanthone, triterpenes; cortex K–, UV+ yellow; medulla K–, Pd–.

Substrates: on bark or rarely rock.

Selected Specimens Examined (Fig. 3*J*)

QUEENSLAND. 2 km W. of Bargara, on rock wall by roadside, 22.iv.1984, *R. Rogers 2820*; beside road to Mt Mee forest station, near the forest boundary, on exposed quartzite rocks, 9.x.1981, *R. Rogers 2356*; Maroochydore Yacht Club Is., Maroochy River, on branches of old *Avicennia* sp., 22.vii.1976, *N. Stevens 1325*. Pine River Estuary, on *Ceriops* sp., 14.x.1978, *N. Stevens 2640*; Deception Bay, on trunk of *Avicennia* sp. in mangrove glade, 11.v.1977, *N. Stevens 1716*; Serpentine Ck, Cribb Is., on bark of *Avicennia* sp., 19.ix.1975, *N. Stevens 1083*; Douglas Street, Oxley, on *Eucalyptus drepanophylla*, 2.xii.1975, *R. Rogers & C. Scarlett 5170*; mangrove swamp, about 1 mile N. of Dunwich, N. Stradbroke Is., on bark of *Avicennia marina*, 10.viii.1972, *R. Rogers 2038*; Coochie Mudlo Is., Moreton Bay, along foreshore on mangroves, 9.v.1982, *J. Elix 10220* (CANUC); Burleigh Heads National Park, on basalt boulders, altitude 8 m, 22.viii.1975, *J. Elix 1091* (CANUC). NEW SOUTH WALES. Hastings Point, Cudgera Creek, on old *Avicennia* sp., 20.viii.1977, *N. Stevens 1946*; Ballina, township edge, on *Avicennia* sp. at edge of ditch, Aug. 1977. *N. Stevens 1967*; 2 km N. of Coffs Harbour, alt. 2 m on *Casuarina* sp. along the foreshore, 31.viii.1975, *J. Elix 1285* (CANUC); Yamba, on *Avicennia* sp., 24.viii.1977, *N. Stevens*

2615; Boambie Creek, Sawtell, on *Avicennia* sp., 24.viii.1977, *N. Stevens 2025*; Nambucca Heads Golf Course, on *Avicennia* sp., 23.viii.1977, *N. Stevens 2005*; Port Macquarie, on *Avicennia* sp., 22.viii.1977, *N. Stevens 1988*; Laurieton, on *Avicennia* sp., 23.viii.1977, *N. Stevens 2024*; Saltwater, E. of Taree, on tree in coastal forest, 7.x.1977, *J. Elix 4017* (CANUC); Patonga via Gosford, on old *Avicennia* sp., 11.i.1978, *N. Stevens 2306*; along Erina Creek, 3 km E. of Gosford, on mangrove trees, 8.v.1978, *J. Elix 4710* (CANUC); Lane Cove, Sydney, on old *Avicennia* sp. in mid zone, 11.i.1978, *N. Stevens 2321*; Kurnell, Botany Bay, on mangrove trees, 6.ii.1977, *J. Elix 2907* (CANUC); Sussex Inlet, on *Avicennia* sp., 5.i.1977, *R. Rogers 2616*; Clyde River, Batemans Bay, on *Avicennia* sp., 6.i.1977, *R. Rogers 2617*; Guerilla Bay, 11·5 km SE. of Batemans Bay, on bark of *Casuarina* sp. along foreshore, 16.iv.1976, *J. Elix 2051* (CANUC); Narooma, on old *Avicennia* sp., sea level, 11.i.1978, *N. Stevens 2207*; along the eastern shore of Wallaga Lake, 5 km N. of Bermagui, on *Casuarina* sp., 4.iii.1978, *J. Elix 4557* (CANUC); Merimbula airport, on stunted *Avicennia* sp., 20.i.1978, *N. Stevens 2344*. WESTERN AUSTRALIA. Cosy Corner, 10 km NW. of Augusta, along foreshore on granite rocks, sea level, 27.x.1982, *J. & L. Elix 10772* (CANUC); Bunkers Bay, Cape Naturaliste, along the foreshore on tree trunk, sea level, 26.x.1982, *J. Elix 10755* (CANUC).

Pyxine subcinerea is a common species of the coastal woodlands in subtropical and warm-temperate eastern Australia, although two very depauperate specimens are recorded from the south-west of Western Australia. The most common substrate is bark, but a few saxicolous collections have been made. The species is weedy, occurring on a wide range of tree barks (*Acacia*, *Alphitonia*, *Bauhinea*, *Casuarina*, *Erythrina*, *Eucalyptus*, *Ficus*) and on trunks of palms in the Brisbane city area. It is also very common on the bark of the mangrove *Avicennia*.

The distinctive yellow medulla and marginal soralia make this a species unlikely to be confused with any other.

Pyxine meissneri var. *sorediosa* Müll. Arg. is represented in G by several collections. Swinscow and Krog (1975*a*) indicated the Schweinfurth collection was holotype; it is, however, one of a number of syntypes but closely matches the description and is therefore selected as the lectotype. *Kurz 164*, a syntype of *P. meissneri* var. *sorediosa* Müll. Arg., is different and is probably also an isotype of *P. meissnerina* Nyl.! No Australian material that might be a syntype of *P. meissneri* var. *sorediosa* Müll. Arg. has been located.

Notes on Other Species Reported

Pyxine obscurior Stirton in Bailey, Proc. R. Soc. Vict. 17, 70 (1880). *Holotype*: near Brisbane, *Bailey 235* (BM), is a specimen of *Rinodina*.

P. caesiopruinosa auct. Aust. = *P. subcinerea*.
P. endochrysina auct. Aust. = *P. sorediata*.
P. eschweileri auct. Aust. = *P. sorediata*.
P. farinosa auct. Aust. auct. Aust. = *P. linearis*.
P. papuana auct. Aust. = *P. linearis*.
P. physciaeformis auct. Aust. = *P. isidiolenta* or *P. consocians*.

P. rugulosa Stirton Trans. Proc. N.Z. Inst. 30, 396, is a collection with an unusual chemistry which may prove to be a distinctive inland species, but is currently known only from the fragmentary type.

Acknowledgments

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23. **Rogers, R.W.** (1986). *Pyxine rugulosa* Stirton (Pyxinaceae, Lichenised Ascomycetes) in Queensland. *Brunonia*, **9**, 229-32.

Brunonia, 1986, 9, 229–32

Pyxine rugulosa Stirton (Pyxinaceae, Lichenised Ascomycetes) in Queensland

R. W. Rogers

Botany Department, University of Queensland, St Lucia, Qld 4067.

Abstract

Rogers, R. W. *Pyxine rugulosa* Stirton (Pyxinaceae, lichenised Ascomycetes) in Queensland. *Brunonia* 9: 229–32. The collection of material chemically identical to the fragmentary type of *Pyxine rugulosa* Stirton has allowed clarification of the application of that name. *P. rugulosa* can be distinguished from other species of *Pyxine* in Australia by its combination of a broad-lobed, heavily pruinose thallus without vegetative propagules, yellow medulla, and presence of atranorin but not lichexanthone in the cortex. It is apparently restricted to regions west of the Great Dividing Range in Queensland.

Introduction

In a recent revision of the genus *Pyxine* (Physciaceae, Ascomycotina) (Rogers 1986) the status of *P. rugulosa* Stirton was unresolved. The type collection in the British Museum (Natural History) is a fragment which consists only of crowded lobes that once formed the centre of a thallus: none of the marginal lobes commented on by Stirton remain. Chemical examination of this specimen showed that it differed from other Australian collections seen by the author. The type locality 'prope Jimbour' is almost 200 km west of Brisbane, an area not visited by a lichen collector this century.

A number of collections which proved to be chemically identical with the type of *P. rugulosa* and matched the description given by Stirton were made recently in central Queensland and a collection from north Queensland became available for examination. It is clear that *P. rugulosa* is a good species which is common at least in part of Queensland.

Pyxine rugulosa Stirton, Trans. Proc. N.Z. Inst. 30, 396 (1896). *Holotype*: Queensland, prope Jimbour (*F. M. Bailey*) (BM).

Thallus up to 40 mm diam., composed of radiating lobes usually forming a neat plaque; lobes 0·3–1·2 mm wide, white or greyish white, branching subdichotomous, often overlapping, closely adnate to the substrate or somewhat ascending, plane to somewhat concave at the margins; central lobes becoming crowded, markedly convex and ultimately rugose; pseudocyphellae, soredia, pustules and isidia absent; pruina very dense especially near the lobe tips. Medulla yellow or light yellow in the upper region and white below. Apothecia common, the margin devoid of algae at maturity, up to 1 mm broad, internal stipe white; spores 15–25 × 5–7 μm.

Chemistry: atranorin, triterpenes (see Fig. 2). Cortex UV –, K + yellow; medulla K + purple-brown in pigmented areas, otherwise K –; internal stipe K –.

Substrates: twigs or bark of trees in inland areas.

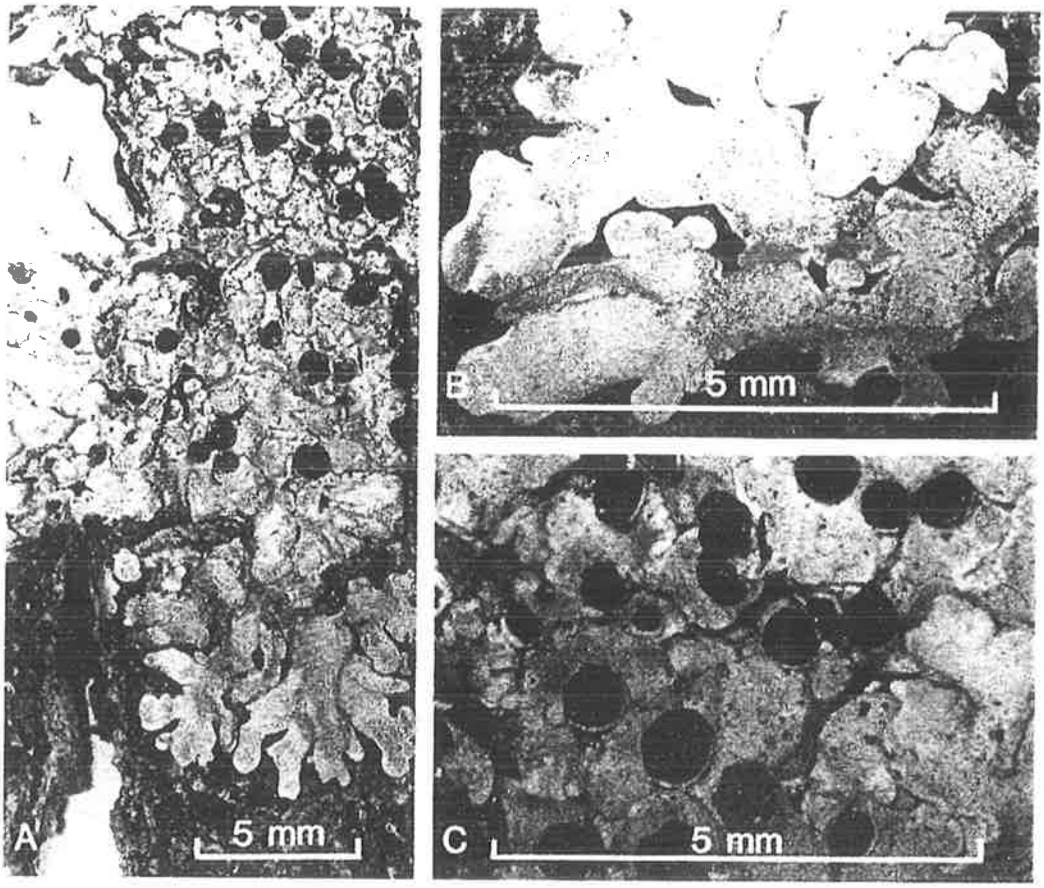

Fig. 1. *A*, thallus of *P. rugulosa*; *B*, tips of lobes showing the extensive development of pruina; *C*, apothecia showing the presence of a margin coloured like the thallus in at least some cases.

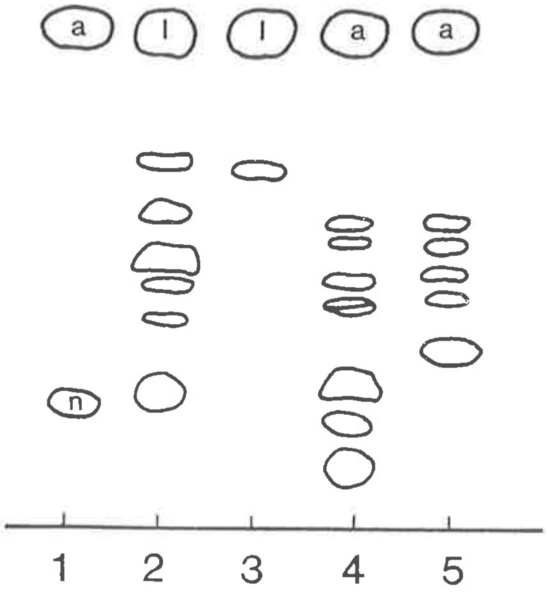

Fig. 2. TLC of 1, control; 2, *P. berteriana*; 3, *P. petricola*; 4, *P. pungens* (Australian material); 5, *P. rugulosa*. *a*, atranorin; *l*, lichexanthone; *n*, norstictic acid. Chromatogram run on 20 : 3 toluene : acetic acid mixture (solvent C of Culberson 1972) on Merck 5554 DC-Alufolien Kieselgel 60 F254 plates. Unidentified spots are mostly triterpenes.

Specimens Examined

QUEENSLAND: 30 km S. of Taroom in brigalow woodland, 31.viii.1985, *R. W. Rogers 7789, 7792, 7796, 7801* (MEL); 5 km E. of Taroom, 31.viii.1985, *R. W. Rogers 7809* (BM), Broken River, on bark of a bottle tree on a ridge ?1981, *N. Stevens*. All collections are housed in BRIU with duplicates as indicated.

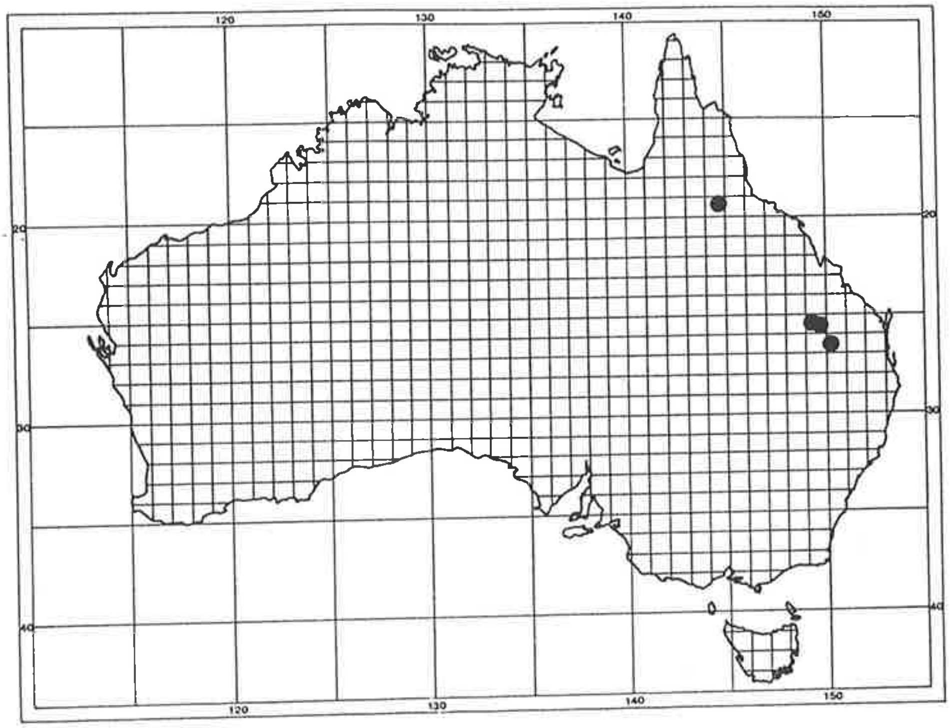

Fig. 3. Known distribution of *P. rugulosa*.

Discussion

Morphologically, *P. rugulosa* is very similar to *P. petricola*, having relatively broad lobes with a very dense cover of pruina, and being devoid of isidia, soredia and pustules. The yellow pigmentation present in the medulla of *P. rugulosa*, however, clearly separates it from *P. petricola*. The presence of lichexanthone in the cortex of *P. petricola* results in it fluorescing gold in u.v. light, whereas *P. rugulosa* which has atranorin in the cortex does not fluoresce at all.

The two Australian species most like *P. rugulosa* are *P. berteriana* (Fee) Imshaug and *P. pungens* Zahlbr. Both have a coloured medulla and neither have isidia, pustules or soredia. *P. berteriana*, however, has lichexanthone in the upper cortex and therefore fluoresces yellow under u.v. light. Like *P. rugulosa*, *P. pungens* Zahlbr. has atranorin in the upper cortex (UV –, K+ yellow) but differs in morphology, as *P. pungens* has lobes that are usually narrower and more convex than *P. rugulosa* and have well developed pseudocyphellae (absent in *P. rugulosa*). *P. pungens* has little or no pruina (very well developed in *P. rugulosa*) and also has an ochraceous coloration in the medulla while the medulla of *P. rugulosa* is yellow. There are also differences in the triterpenes found in these species (Fig. 2), but caution is needed when interpreting such differences, as it appears there is variation in the triterpenes within species (Rogers 1986).

P. rhodesiaca Vainio and *P. richardsii* Swinscow & Krog are two African species which resemble *P. rugulosa*; however, both have pseudocyphellae and neither has extensive development of pruina. *P. richardsii* is also distinctive chemically as it contains testacein, and the medulla of *P. rhodesiaca* is ochraceous, not yellow as in *P. rugulosa*.

In the key to the species of *Pyxine* in Australia (Rogers 1986), *P. rugulosa* keys out as *P. pungens*. The following couplet allows separation of these two species:

Lobe tips flat to concave, densely pruinose .... *P. rugulosa* Stirton
Lobe tips convex, pruina sparse or absent .... *P. pungens* Zahlbr.

P. rugulosa is clearly different ecologically from the other species of *Pyxine* in Australia. While it occurs together with *P. petricola* and *P. subcinerea*, it is not found within 200 km of the ocean (Fig. 3); whereas those two species and most of the others in the genus in Australia are most commonly found, and in some cases are restricted to, a narrow strip of land close to the sea (Rogers 1986).

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Aust. Syst. Bot., 1988, 1, 355–61

The *Usnea baileyi* Complex (Parmeliaceae, Lichenised Ascomycetes) in Australia

Roderick W. Rogers and G. Nell Stevens

Botany Department, University of Queensland, St Lucia, Qld 4067.

Abstract

The *Usnea baileyi* complex exhibits considerable morphological and chemical variation throughout its range, including Australia. Two chemically distinct but morphologically inseparable species are recognised in the complex for Australia. *U. baileyi* (Stirton) Zahlbr. is widespread in eastern Australia and is characterised by the presence of eumitrins and depsidones (especially norstictic acid). *U. elata* Motyka is known from only one Australian location and contains depsides (diffractaic acid being the major secondary constituent) but no eumitrins. Fourteen taxa are treated as synonyms of *U. baileyi*, and *U. vainioi* Motyka is lectotypified.

Introduction

The *Usnea baileyi* complex is widely distributed in tropical and subtropical regions, including Australia. Within Australia taxa attributed to the complex have a very wide latitudinal distribution and show great morphological and chemical variation.

Many of the taxa described in the complex are no more than trivial morphological variants and must be reduced to synonymy (Motyka 1936–38; Swinscow and Krog 1974). The complex also shows significant chemical variation and the resulting variation in spot tests with KOH was used taxonomically by Stirton (1882) and Motyka (1936–38); however, spot chemical tests have proved unreliable. The chemical variation detected in East African species of *Usnea* subgenus *Eumitria* by Swinscow and Krog (1974) did not parallel the observed morphological variation and variations in chemistry therefore were treated by them simply as chemical strains of morphologically defined taxa, no matter how disparate the chemistry.

Chemistry

The chemistry of this group is diverse with only usnic acid common to all collections. Eumitrins (modified bixanthones) occur in collections ascribed here to *Usnea baileyi*, but not in *U. elata*. In most specimens there is a cluster of b-orcinol depsidones or b-orcinol depside derivatives.

There are three eumitrins found in *U. baileyi* (Yang *et al.* 1973): eumitrin A1 and eumitrin A2, which are here treated as a single complex (eumitrin A); and eumitrin B, an isomer of eumitrin A2. Eumitrin B co-occurs with eumitrin A but never occurs alone. Eumitrin A, on the other hand, is commonly found without eumitrin B. The closely related secalonic acid is also found in *Usnea baileyi*, but its presence is usually masked in chromatograms by eumitrin A.

In the material examined which contains eumitrins (A or A and B) there are usually b-orcinol depsidone or b-orcinol meta-depside derivatives. In some non-Australian material which contained no eumitrins (Table 1) b-orcinol para-depsides were found. No collections

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containing any two of meta-depsides, para-depsides and depsidones have been found either in the Australian material or the non-Australian types examined.

Because eumitrins, meta-depsides, para-depsides and depsidones probably represent the end-points of separate biosynthetic pathways (Culberson 1986) chemical differences at that level warranted recognition at the species level, whereas variation within one of those four major groups only warranted taxonomic recognition if correlating morphological or biogeographic patterns were evident.

Working on this basis it seems likely that the diffractaic acid strain of *U. baileyi* reported by Swinscow and Krog (1974) is misplaced, and should be transferred to another species, possibly *U. elata*. The two new varieties of *U. baileyi* described by Swinscow and Krog (1974) (*U. baileyi* var. *pinnatifida* Swinscow & Krog and *U. baileyi* var. *planiuscula* Swinscow & Krog) contain no eumitrin but do contain protocetraric acid, indicating they should be transferred to another species, perhaps *Usnea firmula* (Stirton) Motyka, which is chemically similar. A thorough review of the African material, however, would be necessary before such action were taken.

Table 1. Chemistry of type specimens examined

The occurrence of selected secondary metabolites in species of *Usnea* subgenus, based on analysis of type specimens undertaken by the authors. *Eumitria:* EA, eumitrin A; EB, eumitrin B; Nor, norstictic acid; Sal, salazinic acid; Diff, diffractaic acid; Tham, thamnolic acid; Hypo, hypothmanolic acid; Prot, protocetraric acid

	EA	EB	Nor	Sal	Diff	Tham	Hyp	Prot
U. antillarum (Vainio) Zahlbr.	+	–	+	+	–	–	–	–
U. baileyi (Stirton) Motyka	+	–	+	–	–	–	–	–
U. baileyi var. *pinnatifida* Swinscow & Krog	–	–	–	–	–	–	–	+
U. baileyi var. *planiuscula* Swinscow & Krog	–	–	–	–	–	–	–	+
U. creberrima Vainio	+	+	+	+	–	–	–	–
U. chrysopoda Steiner	+	+	+	–	–	–	–	–
U. cristata Motyka	–	–	–	–	+	–	–	–
U. eizanensis Asahina	+	+	–	–	–	+	–	–
U. elata Motyka	–	–	–	–	+	–	–	–
U. endochroa var. *farinosa* Vainio	+	+	+	–	–	–	–	–
U. endochroa var. *papillata* Vainio	+	+	+	–	–	–	–	–
U. endorhodina Vainio	+	+	+	–	–	–	–	–
U. firmula (Stirton) Motyka	–	–	–	–	–	–	–	+
U. formosa (Stirton) Zahlbr.	+	+	–	–	–	–	–	–
U. implicita (Stirton) Zahlbr.	+	+	+	+	–	–	–	–
U. perplectata Motyka	–	–	–	–	+	–	–	–
U. perrubescens Vainio	+	–	+	+	–	–	–	–
U. vainioi Motyka	–	–	–	–	+	–	–	–

Morphology

The thallus in the *U. baileyi* group is normally erect or subpendulous, although a few pendulous specimens more than 20 cm long have been found. The thallus is tough, and when dry has a firm, rough or prickly texture. The thallus is attached to the substrate by a well developed holdfast which penetrates the substrate, and may be blackened. From the holdfast, one or more main branches arise that do not branch very frequently, although they are often densely beset with fibrils. The cortex of the branches is often transversely cracked.

Isidia are present on all the Australian material examined and on most of that seen from other regions. The isidia are easily dislodged from the thallus and herbarium packets often contain a deposit of detached isidia. Isidia are borne either singly or in clusters on the cortex and when they fall off leave behind a pseudocyphella. Small isidium-like enations referred to as papillae by Swinscow and Krog (1974) are common. The relationship between isidia, papillae, fibrils, and branches needs detailed ontological examination. Although the pseudocyphellae resulting from abscission of isidia sometimes become large they do not form soredia and should not be called soralia. However, true soralia are formed in *Usnea vainioi* Motyka, a North American species.

The medulla varies in thickness and usually contains a well defined pigmented layer immediately outside the chondroid axis. The colour of this layer ranges from pale yellow to deep red-brown, although no pigment can be seen in some specimens. The pigment gives a K+ purple reaction, making K testing of the medulla for secondary chemical products an unreliable procedure. The pigmented layer is also found in the fibrils. It must be stressed that the pigment that produces the red colouration is not an acetone-soluble substance and cannot be taken as evidence of the presence of eumitrins.

The chondroid axis is extremely tough, and has a hollow of variable shape and diameter running through it.

Apothecia are found only rarely in the *Usnea baileyi* group, and appear to have no taxonomic significance at the specific or subspecific level.

Materials and Methods

The bulk of materials examined for this study were collected by the authors in Queensland and New South Wales. In addition, herbarium collections from G, MEL, NSW, CANB, and CANUC were examined.

All material was examined under a dissecting microscope to assess morphological characteristics. Chemistry was determined using standard techniques for thin-layer chromatography (Culberson 1972).

Species Recognised

Two species are recognised from Australia that cannot be distinguished morphologically. *Usnea baileyi* is characterised by the presence of one or more eumitrins, together with b-orcinol depsidones, especially norsticitic acid, and salazinic acid. *Usnea elata* contains the depside diffractaic acid, but no eumitrins. The differences between these two species are not only the absence of a product but the absence of whole classes of product and the presence of different classes of product in the two taxa.

Because of the importance placed on variation of basic molecular structures in this revision, identifications cannot be made with certainty without resorting to thin-layer chromatography. Regrettably, only chemical methods allow reliable identification.

Distribution

In Australia, species in the *Usnea baileyi* complex are restricted to warm moist environments. *Usnea baileyi* is common in Queensland and New South Wales, and two collections are reputedly from Tasmania. *U. baileyi* is widespread in Africa, Asia and the Americas. *Usnea elata* has been collected from only one Australian location, Kroombit Tops, an isolated tableland just west of Gladstone, Qld, but is also reported from Africa (Swinscow and Krog 1974) and a specimen from Papua-New Guinea has also been examined. The only collections of *U. baileyi* available from the Sydney region date from the 19th and early 20th centuries, suggesting that the complex has disappeared from that region with the extension of urbanisation.

Key to Species of the *Usnea baileyi* Group in the Australian Region

1. Thallus containing eumitrins, and usually depsidones, especially norstictic acid .... *U. baileyi* (Stirton) Zahlbr.
1. Thallus without eumitrins but containing the depside diffractaic acid .... *U. elata* Motyka

Usnea baileyi (Stirton) Zahlbr., Denkschr. math.-naturw. Classe Kais. Akad. Wiss. Wien 83, 182 (1909). *Eumitria baileyi*, Stirton Scottish Naturalist 6,100 (1881). *Lectotype* (here selected) (Australia): Queensland, prope Brisbane; undated *F.M. Bailey, 164* (BM). This specimen is concordant with the protologue, and has been treated as holotype by Motyka (1936) and Swinscow and Krog (1974), although in the protologue Stirton also referred to a second specimen collected by G. Thomson from Fernando Po.

Eumitria implicita Stirton, Scottish Naturalist 6,100 (1881); *Usnea implicita* (Stirton) Zahlbr., Cat. Lich. Univ. 6,582 (1930). *Lectotype* (here selected): Madeira, Funchal; undated, *Jos Payne s.n.* (BM). Stirton cited two specimens, one from Sikkim, one from

Madeira. The Sikkim specimen is a mixture of *U. baileyi* and *U. propinqua* Stirton. Motyka (1936) cited the Madeira specimen as the type, a decision which is formalised here, as that specimen is concordant with the protologue and of a single species.

Eumitria formosa Stirton, Scottish Naturalist 6,297 (1883). *Usnea formosa* (Stirton) Zahlbr., Cat. Lich. Univ. 6,575 (1930). *Holotype:* in montibus Australia, Peak Range, undated, *Statter* (BM).

Usnea barbata var. *asperrima* Müll.Arg., Flora 65,299 (1882), *Usnea percava* f. *asperrima* Steiner, Verhandl. zool.-bot. Gesellsch. Wien 53,231 (1903). *Eumitria asperrima* (Müll.Arg.) Vainio, Suomalainen Tideakat. Toimit. A6(7),10 (1915) *Type:* Australia, Illawarra (holotype G, isotype MEL).

Usnea barbata var. *tasmanica* Müll.Arg., Flora 65,299 (1882). *Eumitria tasmanica* (Müll.Arg.) Vainio, Suomalainen Tideakat. Toimit. A6(7),10 (1915). *Usnea tasmanica* (Müll.Arg.) Zahlbr., Cat. Lich. Univ. 5,594 (1930). *Holotype:* Van Diemans Land, 1878, *de Franquer* (G).

Usnea chrysopoda Steiner, Verhandl. Gesellsch. Vaterl. Kultur 1882,4 (1882) (not seen). *Holotype:* Insulae Philippenses, Mindanao, in ascensu ad Apo, in Lauraceis *c.* 2000 m 1882 *Schadenberg* (Univ. Vratislava).

Usnea barbata var. *substrigosa* Müll.Arg., Flora 72,143 (1889). *Usnea dasypogoides* var. *substrigosa* (Müll.Arg.) Zahlbr., Cat. Lich. Univ. 6,652 (1930) (holotype G, isotype MEL).

Eumitria endochroa var. *farinosa* Vainio, Philipp. J. Sci. 4,652 (1909). *Usnea endochroa* var. *farinosa* (Vainio) Zahlbr., Cat. Lich. Univ. 6,564 (1930). *Holotype:* (Philippines) Luzon, Laguna Province, Mt Banajao. Ad truncum arboris. Nov. 1907, *H.M. Curran & M.L. Merritt* (TUR herb. Vainio).

Usnea endochroa var. *papillata* Vainio, Philipp. J. Sci. 4,651 (1909). *Usnea endochroa* var. *papillata* (Vainio) Zahlbr., Cat. Lich. Univ. 6,564 (1930). *Lectotype* (here chosen): (Philippines) Luzon, Prov. Laguna, mons Banajao. Nov. 1907, *H.M. Curran & M.L. Merritt* (TUR herb. Vainio).

Eumitria endorhodina Vainio, Philipp. J. Sci. 4,651 (1909). *Usnea endorhodina* (Vainio) Zahlbr., Cat. Lich. Univ. 6,564 (1930). *Holotype:* (Philippines) Luzon, Benguet, Pauai, 7000 ft alt., 2.viii.1907, *E.A. Mearns* (TUR herb. Vainio).

Eumitria antillarum Vainio, Suomalainen Tideakat. Toimit. A6(7),9 (1915). *Usnea antillarum* (Vainio) Zahlbr., Cat. Lich. Univ. 5,536 (1930). *Holotype:* Antilliae, insula St. Thomas, Signal Hill, ad saxa, alt. 1250 m. 1876, *Eggers.* (TUR herb. Vainio).

Eumitria perrubescens Vainio, Ann. Soc. zool.-bot. Fenn. 1(3),35 (1921). *Usnea perrubescens* (Vainio) Zahlbr., Cat. Lich. Univ. 6,589 (1930). *Usnea implicita* ssp. *perrubescens* (Vainio) Motyka, Lich. Gen. Usnea Stud. 1,62 (1936). *Holotype:* (Thailand) Doi Sutep, alt. 1675 m, 1904, *Hosseus* (TUR herb. Vainio).

Usnea creberrima Vainio, Bot. Mag. Tokyo 35, 46 (1921).

Usnea implicita f. *creberrima* (Vainio) Asahina, J.Jap. Bot. 41,161 (1965). *Usnea baileyi* f. *creberrima* (Vainio) Asahina in Hara Flora Eastern Himalaya, p. 598 (1966) (not seen). *Holotype:* Japan, Rikuzen, Yuriage, on *Pinus thunbergi*, 4.vi.1916, *A. Yasuda* (TUR herb. Vainio).

Usnea implicita var. *yokawensis* Asahina, Lichens of Japan (3) *Usnea*, 41 (1956). *Usnea baileyi* var. *yokawensis* (Asahina) Asahina, J.Jap. Bot. 42,6 (1967). *Type:* (Japan) Hikawa, Prov. Musashi, Mt Fuji, Yamanaka, 1952, *Asahina* (TNS).

(Fig. 1)

Morphology: thallus erect to subpendulous, 5–15 (rarely 20) cm long; grey to greenish grey; branches terete or somewhat ridged, 1–1·5 mm thick apices attenuate, straight or arcuate. *Isidia* cylindrical, single or clustered, easily dislodged to leave pseudocyphellae, sparse to dense. *Pseudocyphellae* punctiform, scattered. *Fibrils c.* 5 mm long sparse to dense on the main branches. *Cortex* dull, cracked. *Medulla* dense with a layer of yellow, pink or red-brown pigment around the axis. *Apothecia* rare, terminal on short lateral branches, up to 8 mm diameter, margin and lower surface bearing fibrils or branches, disc buff to heavily white pruinose. *Ascospores* thin-walled, ellipsoid, 5–6 × 8–10 μm.

Chemistry: usnic acid and eumitrin A usually with eumitrin B and norstictic acid. Salazinic acid, conorstictic acid, galbinic acid, hyposalazinic acid, zeorin, and secalonic acid also may be present.

Selected Specimens Examined (Fig. 2)

QUEENSLAND: Stewart River (14°37′S., 143°37′E.) 1891, *J. Johnson* (G); Daintree River tributary, 16°16′S., 145°24′E., sea level, 5.vi.1983, *Nell Stevens* (BRIU); Millaa Millaa Falls, 17°31′S., 145°37′E., alt. 900 m 23.vii.1983, *Nell Stevens* (BRIU); Cardwell Range, 24 km WNW. of Cardwell, 18°12′S., 145°48′E., alt. 750 m, 20.vi.1984, *H. Streiman 2857* (CBG); Eimeo, Sunset Beach 21°05′S., 149°13′E., 13.viii.1976, *Nell Stevens 1372* (BRIU); Eungella National Park, 1–2 km ESE. of Broken River camping area, 21°10′S., 148°20′E., 11.xi.1985, *G. Thor 4995* (MEL); Blackdown Tableland National Park, (23°50′S., 149°18′E.) on path to South Mimosa gorge, 2.ix.1985, *S. Pearson s.n.* (BRIU); Kroombit Tops, 4·2 km past forestry barracks, 24°23′S., 151°00′E., 3.ix.1985, *Nell Stevens 4550* (BRIU); Bunya Mountains, western face of Mt Mowbullen, 26°53′S., 151°36′E., 3.ix.1986, *R.W. Rogers & J. Hafellner, 8202* (BRIU); Noosa, canal off the river 26°24′S., 152°07′E., 27.vii.1986, *Nell Stevens 4711* (BRIU); Gallengallen State Forest, 26°29′S., 152°17′E., 7.vi.1986, *Nell Stevens 4736* (BRIU); Perseverance Dam, 27°17′S., 152°08′E., 4.ix.1986, *R.W. Rogers & J. Hafellner 8292* (BRIU); Springbrook, 28°14′S., 153°18′E., *c.*600 m, 17.1.1982, *R.W. Rogers 2687* (BRIU); Beechmont, 28°07′S., 153°11′E., 540 m, 2.xi.1965, *S. Kurokawa 5541* (Syo Kurokawa: Lichenes Rariores et Criticae Exsiccati 197) (G,MEL). NEW SOUTH WALES: Goolmangar, 28°43′S., 153°14′E., 15.1.1982, *R.W. Rogers 7620* (BRIU); Mount Boss State Forest, Forbes River, 31°06′S., 152°21′E., 20.x.1978, *D. Verdon 4018* (CANBG); along the Shoalhaven River, Nowra, 34°51′S., 150°36′E., 16.xii.1978, *J.A. Elix 5468* (CANUC); Balmoral, xii.1905 *M. Flockton* (NSW); Nepean River, iv.1906, *W. Craigie s.n.* (NSW); Moruya, 35°55′S., 150°02′E., vi.1909, *Betts s.n.* (NSW); Mt Dromedary, 36°18′S., 150°02′E., *Reader s.n.* (MEL).

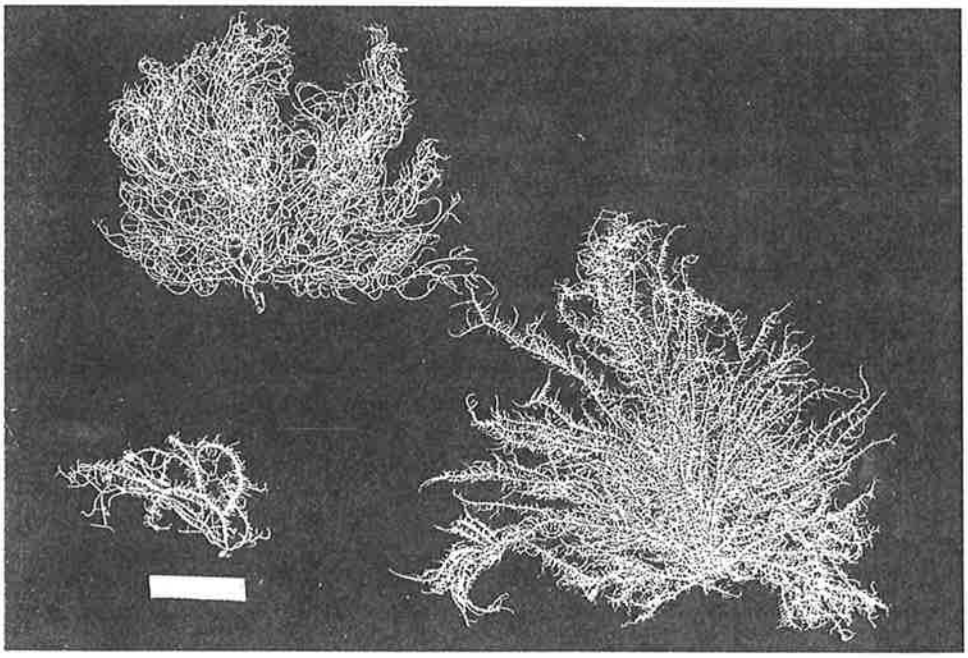

Fig. 1. Morphological variation of *Usnea baileyi*. Top left specimen shows dense branching, sparse fibrils and arcuate apices; bottom right specimen is less branched, has dense fibrils and straight attenuate apices. Bottom left specimen is fertile. Scale: 5 mm.

Usnea baileyi is a very variable species with a wide distribution range within Australia (Fig. 2). No relationship was found between chemistry and distribution. All attempts to segregate taxa on the basis of density of isidia, fibrils or papillae failed, the density varying strikingly on different branches of the same thallus. Ridging of the thallus also was of no taxonomic value, varying from perfectly smooth to markedly ridged (never almost winged which is the case in *Usnea cristata* Motyka).

Usnea baileyi is a species which apparently requires high light intensity and high humidity. In Australia it is associated with rainforests and eucalypt forests in moist areas. The thalli, however, are not found growing within rainforest but only in the tops of the canopy and on isolated trunks and posts in the vicinity of such forests. A few collections have been made of specimens growing on rock.

The type specimens of *Usnea barbata* var. *asperrima* Müll.Arg., *U. barbata* var. *substrigosa* Müll.Arg. and *U. barbata* var. *tasmanica* Müll.Arg. were all too small to examine chemically but, because of their morphology and the preponderance of *U. baileyi* in Australia, have been reduced to synonymy.

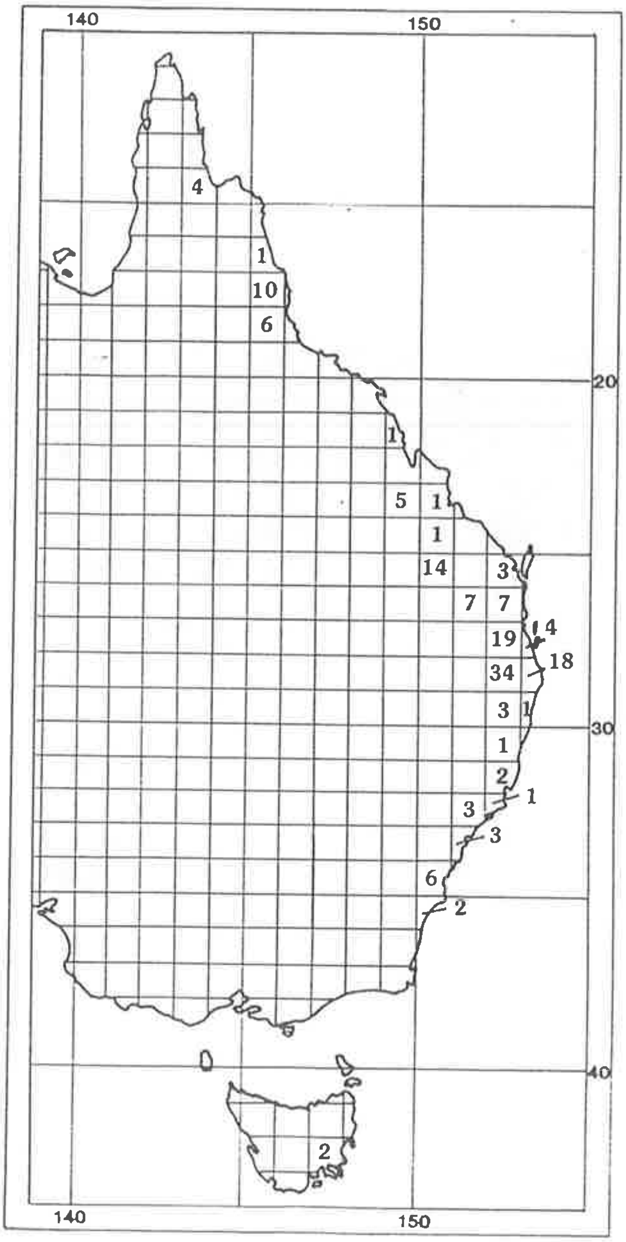

Fig. 2. Distribution of *Usnea baileyi* in Australia. The number of collections of *U. baileyi* examined from the relevant grid section is given.

Usnea elata Motyka, Lichenum Generis Usnea Studium Monographicum 1,57 (1936). *Holotype:* Africa centralis. M'Palas ad litus occidentalis lacus Tanganjika, 1898, *Guilleme* (TUR herb. Vainio).

Morphology: thallus erect to subpendulous, up to 15 cm long; branches grey to yellowish grey, terete. *Isidia* single or rarely clumped, sparse, falling off to form pseudocyphellae. *Pseudocyphellae* punctiform. *Fibrils* c. 5 mm long on the main branches. *Cortex* cracked. *Medulla* dense with a yellow to pink pigmented layer around the axis. *Apothecia* not known.

Chemistry: usnic acid, diffractaic acid, 2-o-methyl obtusatic acid, baeomycesic acid, 4-o-demethylbarbatic acid, 3-α-hydroxybarbatic acid.

This species has been collected from only one Australian location, Kroombit Tops. A specimen from New Guinea has also been examined, and is believed to be conspecific with the Australian and African material. The ridging commented on by Swinscow and Krog (1974) is not well developed in Australian material and that shown by the type is no greater than is sometimes found on *Usnea baileyi*.

Specimens Examined

QUEENSLAND: Kroombit Tops, road 4·2 km past forestry barracks, 24°23'S., 151°00'E., in open woodland on *Casuarina torquescens* on a misty ridge top, *c.* 700 m. Sept. 1985, *Nell Stevens 4434, 4435* (BRIU). PAPUA-NEW GUINEA: Aguan, Milne Bay Province, 1100 m, on *Araucaria*, UPNG 736 (CANBG).

Acknowledgments

We are grateful to the following herbaria for loan of material: BM, CANB, CANUC, G, MEL, NSW, TNS, TUR, W. We thank Dr J. A. Elix for his initial determination of the secondary chemicals present, and Mr A. Steginga for assistance with routine t.l.c. studies. This research was supported by a grant from the Australian Biological Resources Study.

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Appendix 1

Lectotypification of *Usnea vainioi* Motyka, Lich. Gen. Usnea Stud. 1,67 (1936).

The type collection of *Usnea vainioi* Motyka is a mixed collection of sorediate and non-sorediate thalli. A well developed sorediate thallus from the type collection, part of Ravenel 36655 (H-NYL), has been separated from that collection and labelled 'B'. This collection is here designated the lectotype of *Usnea vainioi* Motyka. The non-sorediate material contains usnic acid and diffractaic acid, but no eumitrins, and is *Usnea elata* Motyka.

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25. **Rogers, R.W.** (1989). Chemical variation and the species concept in lichenised ascomycetes. *Botanical Journal of the Linnean Society of London* **101** 229-239.

Botanical Journal of the Linnean Society (1989), *101:* 229–239. With 4 figures

Chemical variation and the species concept in lichenized ascomycetes

RODERICK W. ROGERS

Botany Department, University of Queensland, St. Lucia, Queensland 4067, Australia

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ROGERS, R. W., 1989. **Chemical variation and the species concept in lichenized ascomycetes.** Differences in secondary metabolites produced by lichens are not always genetically based, and even if genetically based may represent only a one gene difference. Taxonomic decision involving secondary metabolism should be based on the degree of difference demonstrated between biosynthetic pathways, not on the individual products. No taxonomic status should be accorded to entities which differ only in products from a single biosynthetic pathway, but varietal status should be given to those which have different biosynthetic pathways. Species status is justified if chemistry is correlated with morphological or proven physiological difference, or if more than one major biosynthetic system is involved. While ecological and biogeographic differences point to the likelihood of differences being found, if no differences can be demonstrated which in themselves justify taxonomic separation, then features ought not be allowed to influence the taxonomic decision.

ADDITIONAL KEY WORDS:—Secondary metabolism.

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INTRODUCTION

Whilst revising *Usnea* subgenus *Eumitria* Motyka for Australia, it became apparent that it included very great morphological and chemical variation amongst its species. Others who have worked on the group (e.g. Motyka, 1936–38; Swinscow & Krog, 1974) were aware of this phenomenon. The extent and nature of the chemical variation encountered forced a reappraisal of the role of chemistry in lichen taxonomy, the extent to which it is under genetic control, of the variation permissible in a species, and of the discontinuity necessary to recognize a species.

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SECONDARY METABOLITES

Secondary metabolites, in contrast to primary metabolites, are commonly restricted to a few organisms, and to only some cells in the organism. They are not essential for cellular processes.

Secondary metabolites have sometimes been interpreted as useless waste products, however it appears that they may have a range of functions (Wicklow, 1988). Lawrey (1986) demonstrated that secondary metabolites of lichens influenced the grazing behaviour of invertebrates. Secondary metabolites of lichens may also function as antibiotics controlling bacteria in the lichen environment, as allelopaths preventing plants overgrowing lichens, as agents in competition between lichens, as chelators in the weathering of rock, as photobiont control agents, and as secondary photosynthetic pigments (Lawrey, 1986; Wicklow; 1988). If the secondary compounds do play a significant ecological role, and this has been demonstrated in only very few cases, then in different environments there will have been selection for differences in the secondary metabolites produced, and the quantity of them produced, possibly independent of selection for other alleles.

Since secondary metabolites are commonly restricted to a small group of organisms, are non-essential and thus subject to genetic variation, they may be taxonomically useful. In lichens only extra-cellular secondary metabolites have been used taxonomically, but there is no theoretical reason why intra-cellular compounds could not also be investigated. However, the extra-cellular compounds are particularly convenient since thay may be extracted and examined with great ease.

The ease with which lichen secondary metabolities can be extracted, and the quantities found in many thalli, means that they are suited to examination using thin-layer chromatography (TCL) (Culberson, 1972). However, the presence of even a trace of a metabolite is sufficient to demonstrate the capacity to produce it, and TLC is not sufficiently sensitive to detect small amounts of substances which might be critical for taxonomic studies, and high performance liquid chromatography (HPLC) is necessary (Huovinen, 1987).

BIOSYNTHESIS OF SECONDARY METABOLITES

Although biosynthetic pathways have been postulated for lichen substances (e.g. Culberson, 1986) there is only limited biochemical information available. However, the general principles applicable to biosynthesis of antibiotics can be applied to other secondary compounds (Martin & Demain, 1980). Since many antibiotics are fungal in origin, and some lichen substances are antibiotic themselves (Lawrey, 1986) the biochemical analogy between antibiotics and secondary lichen chemicals is appropriate.

The enzymes which form the basic structure of a secondary metabolite show a relatively high substrate specificity, whereas those which modify such a structure, including, for example, dehydrogenases, mono-oxygenases, and methyl-transferases, show a relatively low substrate specificity (Luckner, 1984). Culberson & Culberson (1977) considered using a similar hypothesis involving low enzyme-substrate specificity to explain chemosyndromic variation in lichens, but rejected it because they could not find the original phenolic substrates

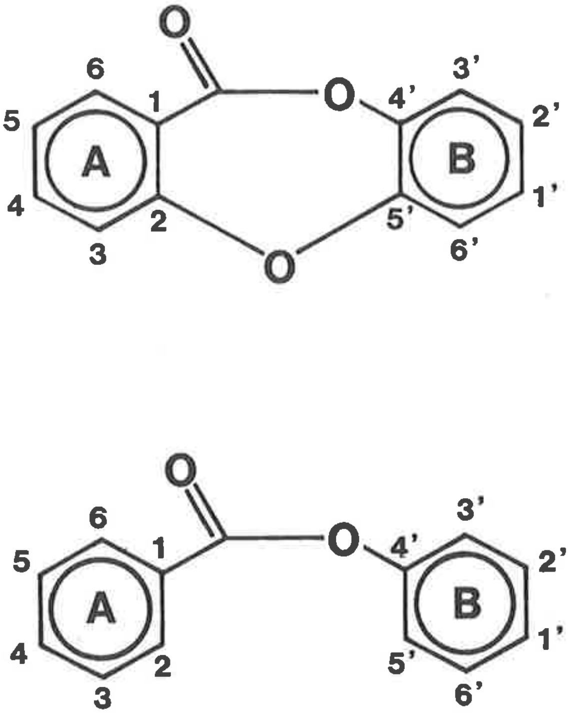

Figure 1. Characteristic structures of a *β*-orcinol depsidone (above) and a para-depside (below) numbered according to the scheme of Sala & Sargent (1981). Although these compounds differ essentially only on the 2–5′ oxygen link, they probably have quite different biosynthetic pathways.

accumulating in those lichen thalli which did not form the secondary substances being considered. However, metabolism of secondary substances does not proceed in a simple linear sequence, but rather in a metabolic grid in which one non-specific enzyme may act upon a variety of substrates, and one substrate may be acted on by a number of non-specific enzymes (Luckner, 1984). If, therefore, one portion of a pathway is blocked, or if a rate-limiting step tends to cause an accumulation of a substrate, another enzyme is likely to act upon that substrate. This results in the formation of 'shunt' products in place of, or in addition to, that normally produced, preventing the accumulation of the precursors. Thus, the ground on which Culberson & Culberson (1977) rejected their hypothesis may be rejected itself.

A consideration of the probable biosynthetic pathway for para-depsides and *β*-orcinol depsidones (general structures are shown in Fig. 1) is instructive. Both groups are synthesized by cyclation of polyketides from the acetate-polymalonate pathway (Huneck, 1968; Sala & Sargent, 1981). Orsellinic acid is a precursor to both, but it is not certain how they are related. One theory is that para-depsides are formed by esterification of one orsellinic acid by another, and that *β*-orcinol depsidones are derived from para-depsides by oxidation. However, there are nine pairs of para-depsides and *β*-orcinol depsidones which differ only in oxidation state but it is very rare for the pairs to occur in the same species (Elix, Whitton & Sargent, 1984). Sala & Sargent (1981), therefore, proposed a mechanism by which *β*-orcinol depsidones were derived not from para-depsides, but by acylation of one orsellinic acid with another, followed by intramolecular rearangements, a scheme adopted here.

Since both para-depsides and β-orcinol depsidones are produced from orsellinic acid derivatives, the formation of various orsellinates is of significance for their synthesis. The nature of some side chains of orsellinic acid are dependent on the position of the folding of the polyketide from which they are formed (Turner, 1975), but modifications to the orsellinic acid side chains which differentiate some depsides occur before cyclation in the polyketide stage (Huneck, 1968).

The simplest β-orcinol depsidone structure is that of hypoprotocetraric acid (Elix *et al.,* 1984). By a series of oxidations the precursor of hypoprotocetraric acid can be converted into a range of compounds, changes which probably occur before cyclation, and necessarily involve only a single enzyme for each type of transformation. Thus, oxidation of the methyl group at position 3 (Fig. 1) converts the precursor of hypoprotocetraric acid to that of virensic acid, which when linked to another precursor oxidized at the 3′ group becomes that of protocetraric acid. Oxidation of the 1′ and 6′ positions to form an additional heterocyclic ring converts the precursor of hypoprotocetraric acid to that of hyposalazinic acid, virensis acid to that of norstictic acid, and protocetraric acid to that of salazinic acid (Fig. 2). The precursors of hyposalazinic acid, norsticitic acid and salazinic acid are all linked in an oxidation sequence . Methylation of these compounds results in the compounds as shown in Fig. 2. Further modifications, including chlorination, acylation, additional methylations etc., can easily be added to the precursors in the grid, to produce a multi-dimensional structure linking many compounds to each other in simple steps. Of the twelve compounds in Fig. 2, ten are known from lichens, and all can be derived from the precursor of hypoprotocetraric acid by use of only three or four postulated enzymes. Such a rearrangement involving only a few enzymes can be envisaged whether the modifications occur before or after cyclation, or condensation of the phenolic rings to make the para-depside or β-orcinol depsidone.

The relationship between para-depsides and β-orcinol depsidones can be

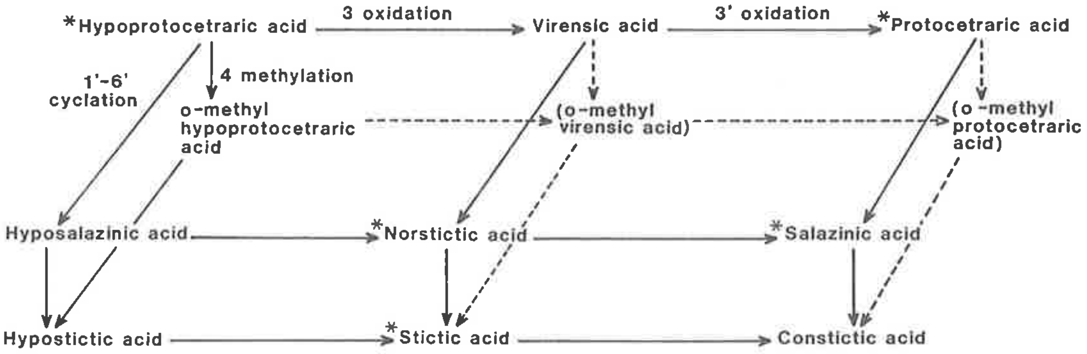

Figure 2. A possible three dimensional metabolic grid linking the precursors of the named β-orcinol depsidones to those of the simplest such compound, hypoprotocetraric acid. Horizontal lines refer to 3- or 3′-oxidation respectively, vertical lines indicate 4-methylation, and diagonals indicate 1′–6′oxidative cyclation. Since the enzymes involved in such reactions are not strongly substrate specific it is probable that all reactions of one type are carried out by a single enzyme, suggesting that only four enzymes (and hence four genes) are necessary for the biosynthesis of all 11 possible derivatives from the same precursors as hypopotocetraric acid. The number of enzymes involved is not necessarily varied if the reactions occur before or after cyclation of the original polyketides. Compounds in brackets appear not to have been isolated from lichens, and those asterisked are the metabolites used in the taxonomy of the *Ramalina siliquosa* group.

represented as a two branches separating at or before the formation of orsellinic acids (Fig. 3), which are then converted into para-depsides of β-orcinol depsidones on different multiple enzyme systems (Mosbach, 1973).

A large number of related end products may be the result of enzyme activity reflecting only a small number of genes. Single secondary metabolite differences may not, therefore, merit taxonomic weight.

CONTROL OF SECONDARY METABOLISM

Studies by Culberson, Culberson & Johnson (1983) confirm that accumulation of lichen secondary metabolites like that of antibiotics, is influenced by both heredity and environment, a general principal noted by Martin & Demain (1980). Hamada (1984) demonstrated the effect of temperature on the accumulation of secondary metabolites in *Ramalina siliquosa*. It has been shown that the presence of a cyanobacterial photobiont, in addition to or in place of an algal photobiont, may also effect the secondary metabolism of a lichen (Brodo, 1986), although variation in the strain of alga apparently does not (Culberson, Culberson & Johnson, 1985). Levels of usnic acid and atranorin were not influenced by light intensity in populations of *Cladonia stellaris* and *C. rangiformis*, whereas levels of perlatolic acid and fumarprotocetraric acid were (Fahselt, 1981). That the internal environment of the thallus determines metabolic activity is clear from simple observations on lichens as not all secondary compounds occur in all parts of the thallus, nor in equal proportions

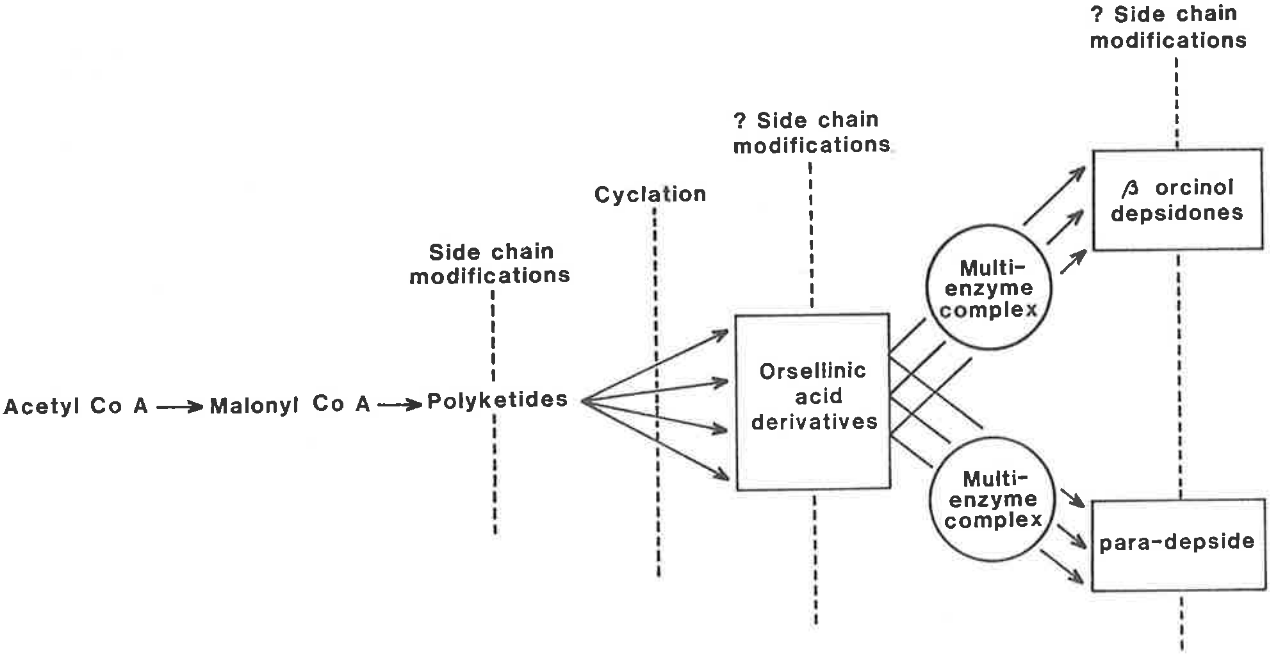

Figure 3. The generalized biosynthetic pathway for β-orcinol depsidones and para-depsides. It is likely that a number of different orsellinic acid derivatives are formed following modifications of the polyketide chains from the acetate-polymalonate pathway. Further side-chain modifications may occur either in the mononucleate orsellinic acid stage, or at the binucleate depsidone or depside stage. However, different multiple enzyme complexes are involved in the formation of para-depsides and β-orcinol depsidones.

in thalli (Brodo, 1986). Stevenson & Rundel (1979) and Culberson *et al.* (1983) showed that production of lichen secondary chemicals is age dependent, and that the relationship with differs from species to species. The environment, therefore, has a strong differential influence on secondary metabolism in lichens.

Glucose interferes with the production of many secondary metabolites (Martin & Demain, 1980), and it inhibits the formation of antranorin in *Pseudevernia furfuracea* (Garcia-Junceda, Gonzales & Vincente, 1987). A possible explanation for this phenomenon is the sharing of part of the biosynthetic chain with a primary metabolite, synthesis of which is controlled by an end product feed-back inhibition. Cessation of production of a secondary chemical may, therefore, be brought about by factors quite unrelated to that substance (Drew & Demain, 1977).

In production of natural and semi-natural antibiotics the nature and relative amounts of the side chains produced by fungi can be varied by modifying the amounts of different metabolites in the medium (Turner, 1975). Variation in the availability of materials used in the formation of side chains in secondary substances of lichens can be expected to have similar effects. Differences in activity in other biosynthetic pathways will, therefore, interfere with the synthesis of side chains of secondary metabolites.

The biosynthetic pathways for secondary products are complex and interact with primary metabolism. Their control processes are also varied, and may be independent of the metabolite concerned. Therefore, it is unwise to assume that the presence of related secondary metabolites or differences in the relative amounts of secondary metabolites, is evidence of genetic difference.

GENETIC DIFFERENCES AND SPECIES DIFFERENCES

Because asexual reproduction in lichens is more common than sexual reproduction, Brodo (1986) argued that it is difficult to apply the biological species concept to them. Although this is true it is not an adequate reason to apply a species concept which allows no variation at all. A single gene difference, or even a few different genes, is too little to justify the recognition of separate species as presently understood by botanists (e.g. Hawksworth, 1974; Jeffrey, 1982). Unlichenized ascomycete species, like those of other organisms, show considerable genetic polymorphy. Barrat (1974) reported 2200 genetic strains of *Neurospora crassa* in culture, Clutterbuck (1974) listed 344 genetic variants of *Aspergillus nidulans,* and Esser (1974) listed 80 variable loci for *Podospora anserina* each having from two to 50 alleles. In a study of DNA homology in strains of *Aspergillus flavus* Kurtzman *et al.* (1986) suggest that a level of homology less than 70% is necessary to separate species and, therefore, treated quite biochemically diverse populations as varieties and subspecies of *A. flavus*. Even in the lichens genetic polymorphy is clearly demonstrated in some well accepted species (Fahselt, 1986; Mattsson & Karnefelt, 1986).

W. Culberson (1986) advanced the proposition that chemical variants in lichens are sibling species, and that difference in a single secondary metabolite was sufficient to separate species. To assert that chemical variants are sibling species, however, presumes genetic isolation of the lichen populations, which is the nub of the argument. The most that can be sustained from experimental studies is that chemistry is in part genetically controlled (Culberson *et al.*, 1983).

Some chemical variation, however, is either genetically trivial or a consequence of environmental factors. Secondary chemical differences which are only variations on a basic molecular structure cannot be assumed to demonstrate either genetic isolation or substantial biological discontinuity between populations and, therefore, should not be used as the sole basis for the erection of a new species.

Even if a variation in secondary lichen products is genetically based, and the difference has ecological significance, it cannot be assumed that a species difference is involved. The significance of chemical variation as a taxonomic character has been closely examined for the *Ramalina siliquosa* (Huds.) A. L. Smith complex in western Europe. The different interpretations of this complex—a two species model with chemical variation in each or a six species model without chemical variation within the species (W. Culberson, 1986)—warrant careful examination.

W. Culberson (1967, 1986) argued that since the chemical variants in the *Ramalina siliquosa* complex showed different ecological patterns they must be treated as separate taxa. However, Sheard (1978a, b) used chemistry, morphology and ecology in a multivariate numerical analysis of this complex, concluding that there were only two species, and that the chemotypes within the two species were probably the result of environmental truncation of biosynthetic pathways.

To clarify the significance of secondary chemistry in this complex Mattsson & Karnefelt (1986) examined the bands formed by electrophoretic focussing of extracts from 27 collections with a range of secondary chemistries . They showed that thalli with different chemistries can have the same band patterns, and that thalli with a one chemistry may have different protein bands. This demonstrates that even if a population is defined in terms of uniformity in secondary chemistry it is not necessarily genetically uniform, indicating that secondary chemistry, if genetically determined, may be selected for and inherited independently of other characters. These data strongly support the view that genetic polymorphy occurs within lichen populations, and are in accord with the taxonomic findings of Sheard (1978a).

From Fig. 3 it can be seen that only three enzymes need to be postulated to derive the precursors of all the secondary components used in the taxonomy of the *Ramalina siliquosa* group from those of hypoprotocetraric acid. Thus only three genes are necessary to account for the chemical differences use to delimit five of the six species in the group: in the nil-acid strain it is assumed that secondary metabolism is blocked at an earlier stage, which could involve only one enzyme.

Defending the many-species concept of the *Ramalina siliquosa* complex against the two-species concept, Culberson (1986: 126) wrote: "This two species morphological hypothesis would have us believe that in local populations the multiple chemotypes composing these two 'species' interbreed amongst themselves but the different chemotypes among the subsequent progeny are genetically programmed to select specific microhabitats, to show certain morphological tendencies, and to have particular geographic distributions . . . This conceptualization of the species has no parallel in other systems and is biologically unconvincing". Such a conceptualization, if reworded in terms of selection of strains by the habitat not of habitats by strains, is in fact a well-

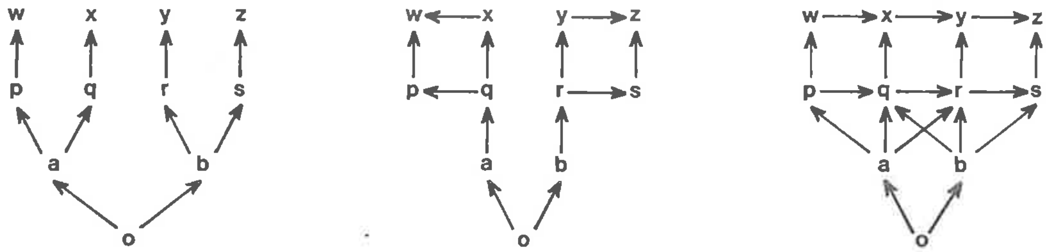

Figure 4. A range of possible biosynthetic trees and grids resulting from differing degrees of specificity in the enzymes involved in producing the end products w,x,y and z from the precursor o via intermediates a,b,p,q,r and s.

known phenomenon, first discussed by Anderson (1948) with respect to *Tradescantia* hybrids. In a classic paper it was shown that hybrid individuals with characteristics which are recombinations of parental character sets would only survive in habitats which had an appropriate mix of characteristics. Thus, if chemistry is genetically determined, hybrids between chemically different lichens with different ecological capacities would survive differentially in different environments. Since only four enzymes and thus only four genes need to be invoked to explain the entire difference, the argument for the six species view is not strong.

A species is a biologically cohesive group of individuals, usually embracing substantial genetic variation, and with significant discontinuity from other such groups. There is no reason to treat chemical variation in lichens as an exception to this understanding. The rank of species, therefore, should not be used to document every variant found in a lichen population.

CONCLUSION

Chemical variation is an aspect of phenotypic variation and is subject to environmental and temporal variation as are morphological characters. It is not necessary that there be any genetic differences involved in the production of different ratios of the same secondary chemicals, nor in the production of minor variants on a basic molecular structure. As with morphology, a continuous scale of significance in chemical differences exists, which can be interpreted only after the construction of biosynthetic pathways. These pathways will take the form of various 'trees' or 'grids' (Fig. 4). β-Orcinol derivatives form metabolic grid (Fig. 2), whereas para-depsides and β-orcinol depsidones represent different branches of a tree (Fig. 3).

'Acid-deficient' strains could be the result of the absence of a single enzyme early in the pathway, the result of repression of synthesis, or the result of a chromosomal deletion, a common phenomenon in the fungi. In this case decisions should be made on the basis of the information that is positive, and the 'acid-deficient' material allocated to taxa on the basis of other characters, not segregated into a taxon of its own.

Birch (1973) observed that "No automatically applicable procedures exist to assess the significance of biosynthetic pathways in connection with plant evolution" and stressed that it is the pathway, not the end product which must be considered when taxonomic decisions are made. If single end products are considered, an illusion of discontinuity is created upon which a taxonomy may then be constructed. Whether a substantial genetic discontinuity is present or not can only be decided in the context of many data, from which a multidimensional matrix can be established (at least notionally), and in which discontinuities involving several attributes are apparent.

The custom of assuming that additional undetected differences are present if chemically different organisms are from widely separated locations or occupy apparently different habitats is not scientifically justified. If a chemical difference is insufficient in itself to justify taxonomic status for a group of organisms, the argument that they occur on different continents or in different habitats does not increase the known level of difference, and ought not change the taxonomic decision. Such geographic and ecological differences may alert a taxonomist to the need to look closely for differences which may have been missed. Attention may well be paid to electrophoretic studies of proteins, to polypeptide sequences in enzymes (Kilias, 1987), and such little used characters as size of conidia, and carbohydrate products. However, since secondary metabolites may play a significant ecological role (Lawrey, 1986; Wicklow, 1988), there is no reason to assume any additional difference is necessary to explain a distribution. Therefore, proposals for using geography and ecology as taxonomic characters in association with chemistry (Hawksworth, 1976; Egan, 1986) must be rejected.

Although there is no hard and fast rule concerning chemical variation and species delimitation, some rules of thumb are proposed.

1. Closely related end products of a biosynthetic pathway have little or no value in differentiating taxonomic units as too few enzymes are necessary to convert from any one form into any other.
2. The presence of different biosynthetic pathways (e.g. para-depsides, meta-depsides, depsidones, triterpenes, aliphatic acids, chromones, xanthones, and dibenzofurans) which diverge from the primary metabolic pathways, or which involve different enzyme complexes in their formation justifies the recognition of varieties, unless correlated with morphological or proven physiological differences, or unless additional biosynthetic pathway differences are involved, in which case species status is justified.
3. Wide spatial separation or occupation of a different habitat suggests that genetic difference is likely, but if no evidence of substantial genetic difference can be demonstrated, geography and ecology ought not be invoked to justify species that would not otherwise be accepted.
4. Taxa must be separated from one another by a discontinuity. Care must be taken that a variable species which can be represented as a matrix of randomly scattered points in a taxonomic hyperspace is not broken up into a number of taxa each differing in trivial aspects from the next.

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Lichenologist **19**(4): 401–408 (1987)

SAGENIDIOPSIS, A NEW GENUS OF BYSSOID LICHENIZED FUNGI

R. W. ROGERS* and J. HAFELLNER‡

Abstract: The genus *Sagenidiopsis* gen. nov. of uncertain family in the order Opegraphales is erected for a byssoid lichen which occurs in the cool temperate rainforests of the Macpherson Range of eastern Australia, *S. merrotsii* sp. nov. The genus is characterized by its byssoid thallus and bitunicate asci which have no amyloid structures apparent in the tholus. A byssoid thallus is without taxonomic significance at the family level, but is an ecological key character.

Introduction

Fertile material of a byssoid lichen was collected from the cool temperate rainforest of the Macpherson Range in south-east Queensland and north-east New South Wales, Australia. The material could not be included in any known genus of lichenized fungi and a new genus is therefore described to accommodate it here.

Description

Sagenidiopsis R. W. Rogers & Hafellner gen. nov.

Fungi lichenisati. Thallus crustaceus, byssoideus, ecorticatus, in strato superiore algas generis *Trentepohlia* continens. Ascomata primum globulosa demum discoidea, rotundata, marginata, marginibus hyphis libris obtectis. Excipulum proprium et pars inferior hypothecii fuscum, prosochymaticum. Asci fissitunicati, octospori, stipitati, K/IKI+gelatina ascorum caerulescens sed neque stratum amyloideum endoasci distinguentum est, necque structura annularis amyloidea in apicis visibile. Paraphysoides septatae, ramosae anastomosantesque, apicibus elongatis ex epihymenio exstantibus. Ascosporae hyalinae, transversaliter septatae, pariete tenui, non halonatae, septis non incrassatis.

Species holotypica adhuc unica: *Sagenidiopsis merrotsii* R. W. Rogers & Hafellner.

Lichenized fungi. *Thallus* of loosely woven hyphae forming extensive rather thick and spongy crusts; ecorticate; differentiated into an upper layer of hyphae including well-developed algal filaments, and a lower layer without algae; fungal haustoria penetrate the algal cells. *Phycobiont Trentepohlia*-like.

Ascomata initially globular and closed, but later opening and developing a circular disc, somewhat stipitate; margin covered in free hyphae, like those of the thallus, concealing the proper exciple; proper exciple composed of dark red-brown prosenchyma; lower part of the hypothecium dark. *Paraphysoids* septate and anastomosing, projecting above the hymenial jelly to form a supra-hymenial layer of thickened hyphae with slightly pigmented walls. *Asci* fissitunicate, long-stiped, exoascus and endoascus both thick, with a small

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*Botany Department, University of Queensland, St Lucia, Queensland 4067, Australia.
‡Institut für Botanik, Karl-Franzens Universität, Holteigasse 6, A-8010 Graz, Austria.

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ocular chamber, encased in K/I + blue hymenial jelly, all other wall layers K/I −, no ring structures apparent under the light microscope, 8-spored. *Ascospores* hyaline at all stages, thin walled, no perispore visible with a light microscope, transversely septate; septa apparently of simple construction and of uniform thickness.

Anamorph not found.

Sagenidiopsis merrotsii R. W. Rogers & Hafellner sp. nov.

(Figs 1–2)

Thallus byssaceus, vivus aurantiacus, in herbario cinereo-viridis aut viridiflavus; hyphae crystallis instructae, in parte superiore hyalinae et partim filamenta algarum cinctae, in parte inferiore fuscae. Ascomata stipitata, ad 1 mm in diametro lata, primum globosa demum apothecia valde similia, rotundata, disco ochraceo-brunneo, margine albido byssoideo prominenti; in sectio transversali excipulum proprium fuscum hyphis libris hyalinis obtectis visibile. Hypothecium in parte inferiore fuscum, in parte superiore hyalinum. Hymenium hyalinum 100–120 µm altum. Epihymenium fuscidulum. Asci typo generis, fissitunicati, 50–60 × 12–15 µm, stipitati. Paraphysoides ramosae et anastomosantes, *c.* 1·5 µm crassae, apicibus elongatis fuscidulis et ad 3 µm incrassatis. Ascosporae postremo triseptatae, fere bacilliformes, 24–29 µm longae, 2·5–3·5 µm latae. Thallus acidium protocetraricum, acid virensicum et substancia ignobilis continens.

Typus: Australia, New South Wales, Border Ranges National Park, north-east of Wiangaree, Brindle Creek, 28°23′S, 153°04′E, alt. *c.* 850 m, on bark of tree in *Nothofagus moorei* forest, 30 August 1986, *P. Merrotsy, R. Rogers & J. Hafellner* (*Merrotsy* 277) (MEL—holotypus; isotypi per ‘ Vězda, *Lichenes selecti exsiccati* ’ distribendi).

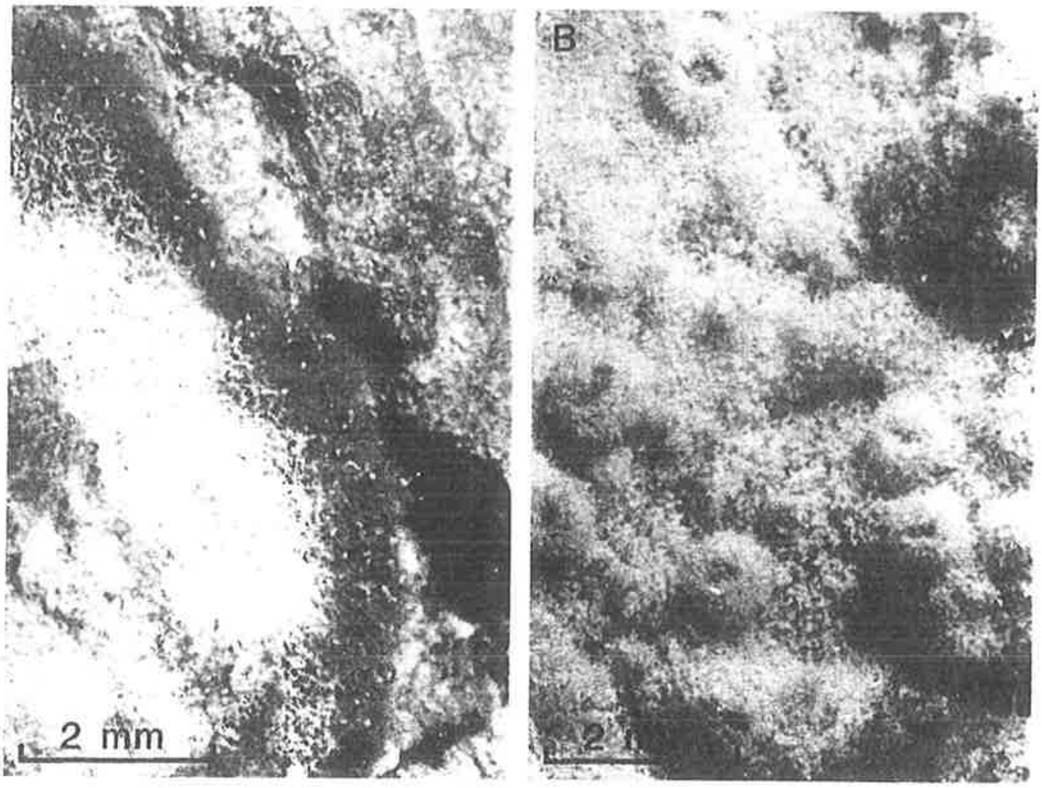

FIG. 1. A, Thallus of *S. merrotsii* showing the dark hypothallus; B, apothecia of *S. merrotsii*.

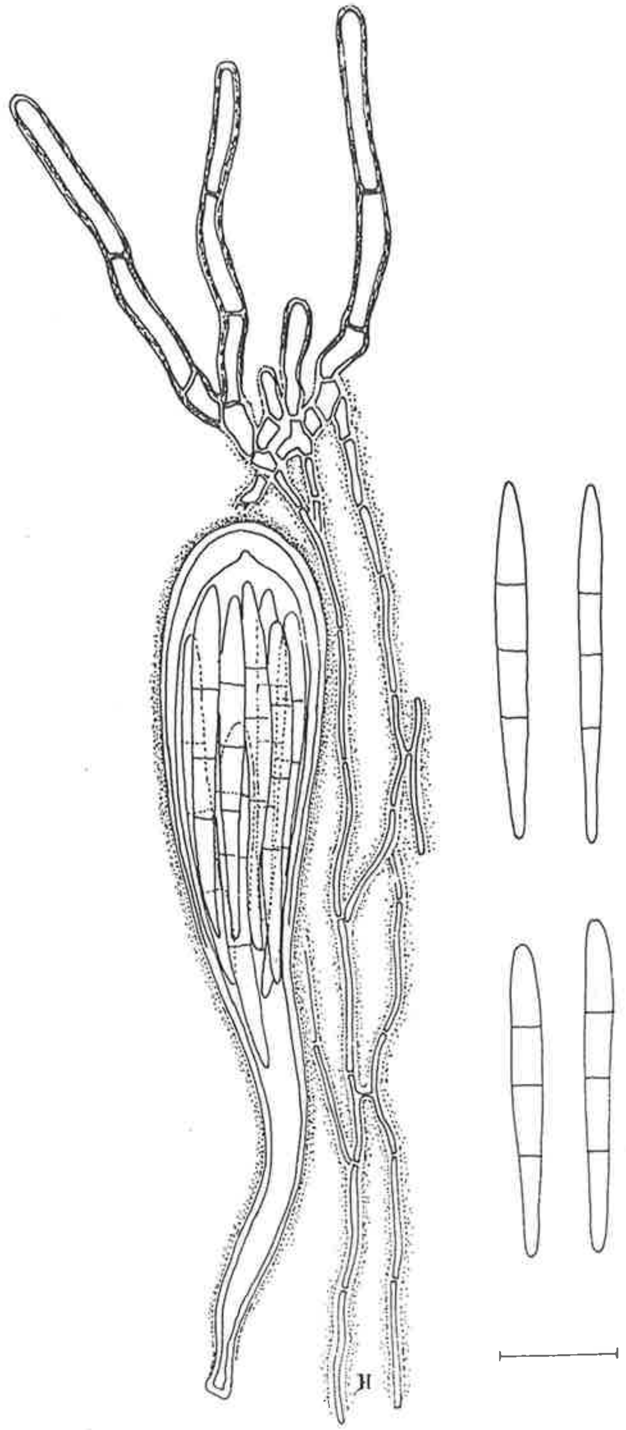

FIG. 2. Hymenial structures of *Sagenidiopsis merrotsii*, showing the ascus, paraphysoids, and ascospores. K/I + blue structures are stippled: scale = 10 µm.

Thallus byssoid, orange when collected fading to greyish-green or greyish-yellow when dry, the margin with a distinct white band overlying a layer of dark reddish-brown hyphae. *Hyphae* in the upper part of the thallus hyaline, 2·0–2·5 µm thick, wall <1 µm thick; in the lower part of the thallus purple-brown, 3–4 µm thick, wall about 1 µm thick, encrusted with crystals.

Ascomata up to 1 mm broad, initially spherical, but opening to expose a more or less flat disc; proper exciple dark red-brown, K+dark olive, but concealed in a layer of hyaline hyphae like those of the thallus causing the ascocarp to appear white; disc dark, with layer of protruding hyphae causing it to appear slightly white pruinose; hymenium hyaline, 100–120 µm high; upper part of the hypothecium hyaline, lower part coloured like the exciple; epihymenium 30–45 µm high. *Asci* as for the genus, 50–60 × 12–15 µm. *Paraphysoids* as for the genus, 1·5 µm thick, swelling to 3 µm in the supra-hymenial layer. *Ascospores* as for the genus, 1-septate in early stages, ultimately 3-septate; almost bacilliform, 24–29 × 2·5–3·5 µm, length:breadth ratio 9–10; wall thickness <1 µm.

Chemistry: Protocetraric acid (major constituent) with traces of virensic acid and an unidentified substance (Rf33 in Solvent C).

Ecology: on overhung rock faces and tree trunks in montane forest, especially in the vicinity of *Nothofagus moorei*.

Other specimens examined: **Australia:** Queensland: Great Dividing Range, Gambubal State Forest, Con's Plain (Bald Mountain) east of Emu Vale, 1100–1200 m, 28°14'S, 152°25'E, 7 September 1986, *J. Hafellner* (GZU); Lamington National Park, near Silver Falls, *c.* 7 km from O'Rielly's Guest House, 850 m, 28°16'S, 153°09'E, in subtropical rainforest, on the base of *Argyrodendron actinophyllum*, 21 November 1984, *P. Merrotsy* 536 (BRIU); *ibid.* on a near vertical rock face, 28 January 1986, *R. Rogers* 8002 & *P. Merrotsy* (BRIU); *ibid.* on the base of the trunk of a rainforest tree, 28 January 1986, *R. Rogers* 8003 & *P. Merrotsy* (BRIU); *ibid.* on a near vertical rock face, 28 January 1986, *R. Rogers* 8005 & *P. Merrotsy* (BRIU); *ibid.* on base of old *Argyrodendron actinophyllum*, 28 January 1986, *R. Rogers* 8008 & *P. Merrotsy* (BRIU).

This species is named in honour of Mr Peter Merrotsy who first drew attention to it, and who has made significant lichen collections in the Macpherson Range.

Discussion

The genus *Sagenidiopsis* is clearly distinct at family level from the other byssoid lichens. It has affinities with the Opegraphales, but the delimitation of families within that order is unsatisfactory, the families Lecanactidaceae and Opegraphaceae (*sensu* Henssen & Jahns 1974) having no clear separation while each is quite heterogeneous. *Sagenidiopsis* is not closely related to any family of lichenized fungi we know: Table 1 summarizes information concerning morphologically or taxonomically close genera and families derived from the literature and from examination of the specimens cited. It is premature at this stage to propose a new family for this genus. The taxonomy of the Opegraphales is poorly understood, and other species in the genera examined, or other genera in the order which have not been examined, could have a similar ascus structure.

The structure of the ascus is consistent with the order Opegraphales, having a thick walled endo- and exo-ascus and is functionally fissitunicate. The ascus

TABLE 1. *Comparison of* Sagenidiopsis *and some families and genera to which byssoid lichens have been referred, or which are taxonomically close*

	Fissi-tunicate ascus	Endoascus		Spore with thick septa	Chemistry					Byssoid thallus
		I+ inner	I+ ring		pro	atr	lep	sch	lec	
Sagenidiopsis	+	−	−	−	+	−	−	−	−	+
Byssocaulon	?	?	?	?	−	−	−	−	+	+
Opegraphaceae (incl. Lecanactidaceae)										
Lecanactis	+	+	+	−/+	−	+	−	+	+	−
Opegrapha	+	+	−/+	−/+	−	−	−	−	+	−
Sagenidium	+	+	+	+	−	−	+	+	+	+
Schismatomma	+	+	+	+	−	+	+	−	+	−
Phragmopelthecaceae										
Mazosia	+	+	+	+	−	−	−	−	−	−
Roccellaceae										
Combea	+	+	+	+	−	−	−	−	−	−
Roccella	+	+	+	−	+	−	+	−	+	−
Roccellinastraceae										
Roccellinastrum	−	−	+	−	+	+	−	−	−	+
Stictidaceae										
Conotremopsis	−	−	−	−	?	?	?	?	?	+

Key to columns: Endoascus I+ inner = inner layer of the endoascus staining KOH/I+ blue; endoascus I+ ring = a KOH/I+ ring structure apparent in the tip of the endoascus; pro = protocetraric acid; atr = atranorin; lep = lepraric acid; sch = schizopeltic acid; lec = lecanoric acid. Products which occur in genera other than *Sagenidiopsis, Sagenidium* and *Byssocaulon* are not all listed. Where alternate character states are indicated the first stated is based on the type species of the genus (Eriksson 1981). The family Opegraphaceae is used in the sense of Eriksson & Hawksworth (1985).

Information on the ascus and spore structure of *Sagenidium* is from Henssen *et al.* (1979); on *Roccellinastrum* from Henssen *et al.* (1982) and Hafellner (1984); on the type species of *Lecanactis, Opegrapha* and *Roccella,* from Eriksson (1981). Chemistry of *Sagenidium* is from Henssen *et al.* (1979), and for *Roccellinastrum* from Henssen *et al.* (1982). Except for *Sagenidiopsis,* other chemical data are from Culberson (1969), Culberson & Culberson (1970), or Culberson *et al.* (1977).

All other morphological information was obtained by direct observation on the following collections: *Combea mollusca* (Ach.) Nyl. (**Namibia:** Luderitzbucht, an Holzbalken der Brucke am Diaz Point, 3 October 1984, *H. Schindler,* GZU).——*Conotremopsis weberiana* Vězda (**Australia:** Tasmania, Lake St Clair National Park, on saplings near shore of Lake St Clair at beginning of trail to Mt Hugel, 24 February 1968, *W. A. Weber L-49678 & D. McVean,* GZU).——*Lecanactis inalbescens* Stirton (**Australia:** Queensland, Dan Dan Scrub on Futter Creek, 24·5 km south-west of Calliope, 24°12′S, 151°04′E, dry rainforest on creek banks, 150 m, 3 September 1985, *R. W. Rogers,* BRIU).——*Mazosia melanophthalma* (Müll. Arg.) R. Sant. (**Australia:** Queensland, Mt Glorious, near Brisbane, on a leaf of a small rainforest shrub, 2 August 1980, *R. W. Rogers* 2223, BRIU).——*Opegrapha astraea* Tuck. (**U.S.A.:** Louisiana, East Feliciana parish, Idlewild Experimental Farm about 3 miles south-east of Clinton, 30°48′N, 90°45′W, on *Quercus michauxii,* 16 March 1979, *S. Tucker* 18444, BRIU).——*O. longissima* Müll. Arg. (**U.S.A:** Louisiana, East Baton Rouge Parish, Burden Research Plantation, Essen Lane, Baton Rouge, 30°24′30″N, 91°06′45″W, on *Nyssa sylvatica,* 28 October 1974, *S. C. Shirley* 13248, BRIU).——*O. subrimulosa* Nyl. (**U.S.A.:** Hawaii, Hawaii Volcanoes National Park, Kipuka Ki, along Mauna Loa Strip Road, 4000 ft alt., on trunk of huge *Acacia koa,* 4 April 1983, *W. A. Weber & A. Bujakiewicz* [Lich. Exs. Colo. no. 628], BRIU).—*Roccella belangeriana* Awasthi. (**Australia:** Northern Territory, Nhulumby area—small island with mangroves in Melville Bay on *Rhizophora stylosa,* September 1981, *M. Boot,* BRIU).——*Sagenidium molle* Stirton (**Australia:** Tasmania, Lake Skinner Track, on *Nothofagus cunninghamii* in rain forest, 700 m, 4 April 1980, *G. Kantvilas* 103/80, BRIU).——*Schismatomma pericleum* (Ach.) Branth. & Rostr. (**U.S.A.:** Louisiana, St Tammay Parish, Fontainbleau State Park, north-east of Lake Pontchartrain, 30°20′N, 90°03′W, 2 October 1982, *S. C. Tucker* 18444, BRIU).

of *Sagenidiopsis*, however, differs from that of the other Opegraphalean asci examined (Table 1) in that it shows neither a more or less distinctive K/I+ blue ring structure in the tholus, nor a K/I+ blue inner layer in the endoascus.

The spores of *Sagenidiopsis* show no thickening in the transverse septa when viewed under the light microscope. While this character has proved taxonomically useful in other lichenized fungi, too little is known of the Opegraphales for it to assist in placing *Sagenidiopsis* at the present.

Chemistry is of little assistance in determining the place of *Sagenidiopsis*, as protocetraric acid together with virensic acid and the unidentified substance present in *S. merrotsii* are part of a chemical syndrome widespread in the lichenized fungi (J. A. Elix pers. comm.). Amongst the Opegraphales, however, protocetraric acid is apparently recorded only from *Roccella gallopagoensis* Follm. and *Enterographa sorediata* Coppins & P. James.

In similar environments in or near the *Nothofagus* forests of the Southern Hemisphere there are at least five genera of byssoid lichens (*Byssocaulon, Conotremopsis, Roccellinastrum, Sagenidium* and *Sagenidiopsis*) all in different families (Eriksson & Hawksworth 1985). Some species of *Chiodecton* in these forests (e.g. *Chiodecton congestulum* Nyl.) are also somewhat byssoid. Even in such forests where related genera are expected on phytogeographic grounds (Schuster 1979, Kantvilas *et al.* 1985) a byssoid thallus morphology has no taxonomic value at family or higher level.

Sagenidiopsis is found on rock and tree trunks in misty and humid forest on surfaces which are not normally wetted by flows of water or direct rainfall: it is clear that *Sagenidium molle* and *Conotremopsis weberi* occupy similar habitats in Tasmania (Kantvilas *et al.* 1985). *Chrysothrix pavonii* (syn. *C. noli-tangere*, see Laundon 1981) and *Roccellinastrum spongioidium* are both found on the spines of cacti in the very humid fog oases of Chile (Follman & Redón 1972) in which rainfall is rare. *Byssocaulon niveum* is also a species of fog oases in Chile (Follmann & Redón 1972). A similar thallus structure is found around the world in a number of lichen families and genera which tend to occur in areas of high humidity on surfaces which are protected from direct contact with liquid water. These include Crocyniaceae (*Crocynia*; Hue 1924, Hafellner 1984); Gyalectaceae (*Coenogonium*; Uyenco 1963), sterile lichens (*Cystocoleus, Lepraria,* and *Racodium*; Duncan 1970, Wirth 1980) and the hyphomycete *Blarneya* (Hawksworth *et al.* 1980).

It has been suggested by Kershaw (1985: 38) that the rate of water vapour uptake into a lichen thallus from the air is positively correlated with the surface area:weight ratio. If it is assumed that the surface area of a byssoid lichen is that of the exposed fungal hyphae rather than of the outline of the thallus the surface area:weight ratio is enormous, suggesting an adaptation for absorption of water from the air. As such thalli occur in a range of families which contain a preponderance of species with more normal thallus structure, lack of an upper cortex and development of a thallus consisting of a very loose network of hyphae must, in this case, be interpreted as an ecological specialization which has arisen by convergent evolution in a number of different lichen families.

A number of other byssoid genera including, *Sagenidium* (Henssen *et al.* 1979) and *Roccellinastrum* (Henssen *et al.* 1982) are also reported to have thalline hyphae densely encrusted with lichen acids. James & Coppins (1979) noticed that sorediate lichens with *Trentepohlia* as phycobiont and large amounts of secondary lichen products tended to be found in sheltered habitats rarely if ever wetted by rain. A loosely woven thallus, dense encrustation with secondary products and *Trentepohlia* as phycobiont are apparently what Grubb (1985) recognized as 'key characters', allowing the lichen to live in a very specialized habitat.

It is now clear that Henssen *et al.* (1979) were justified in not following Follmann (1975, 1979), who treated *Sagenidium* and *Byssocaulon* as synonyms, without considerably more information.

We are grateful to the University of Queensland for a travelling fellowship which permitted Dr J. Hafellner to participate in this study; to Dr G. Kantvilas for provision of a specimen of *Sagenidium molle;* and to Dr J. A. Elix who kindly carried out chemical analyses.

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Maronina — a new genus of lichenised Ascomycetes (Lecanorales, Lecanoraceae) with multispored asci

J. HAFELLNER & R.W. ROGERS

Abstract: The genus *Maronina* is described as new. It comprises at the moment two species, the type species *Maronina australiensis* Haf. & Rogers and the Southamerican *Maronina multifera* (Nyl.) Haf. & Rogers. *Maronina* is clearly distinguished from *Maronea* by ascus and spore characters and is much more closely related to *Protoparmelia* than to *Maronea*.

Zusammenfassung: Die Gattung *Maronina* wird neu beschrieben. Sie umfaßt zur Zeit zwei Arten, die Typusart *Maronina australiensis* Haf. & Rogers sowie die südamerikanische *Maronina multifera* (Nyl.) Haf. & Rogers. *Maronina* unterscheidet sich im Ascus- und Sporenbau klar von *Maronea* und ist viel näher mit *Protoparmelia* verwandt als mit jener.

INTRODUCTION

MASSALONGO (1856) described the genus *Maronea* for the single species *Maronea berica* Massal. which is a later synonym of *Maronea constans* (Nyl.) Hepp. It was assumed to be related on the one hand to *Lecanora* because of the external appearance and the lecanorine margin of the ascomata, and on the other to *Acarospora*, *Sarcogyne* and *Biatorella* because of the multispored asci.

MAGNUSSON (1934) monographed the genus and accepted 13 species. He stated that the genus was quite homogenous both in external appearance and in anatomy of the ascocarps.

Until recently *Maronea* was still assumed to belong to the Acarosporaceae (POELT 1974, POELT & VEZDA 1981, HALE 1983) but since then it has been demonstrated that the type species *Maro-*

nea constans is clearly related to *Fuscidea* (HAFELLNER 1984) and the placement of *Maronea* s.str. in the Fuscideaceae is now generally accepted (ERIKSSON & HAWKSWORTH 1988).
During revisional work on crustose lichens from Australian mangroves we came over an obviously undescribed species which - according to traditional concepts - should be a species of *Maronea*. However, we soon recognized important differences in ascus construction between this Australian species and *Maronea constans* which also occurs in Australia (FILSON 1986). Because of the lack of an appropriate genus a new one is described here. Searching for further species belonging to this new genus, we established that at least one of the well known *Maronea*-species, *Maronea multifera* (Nyl.)Vainio, fits the new generic description well.

Maronina Haf. & Rogers gen. nov.

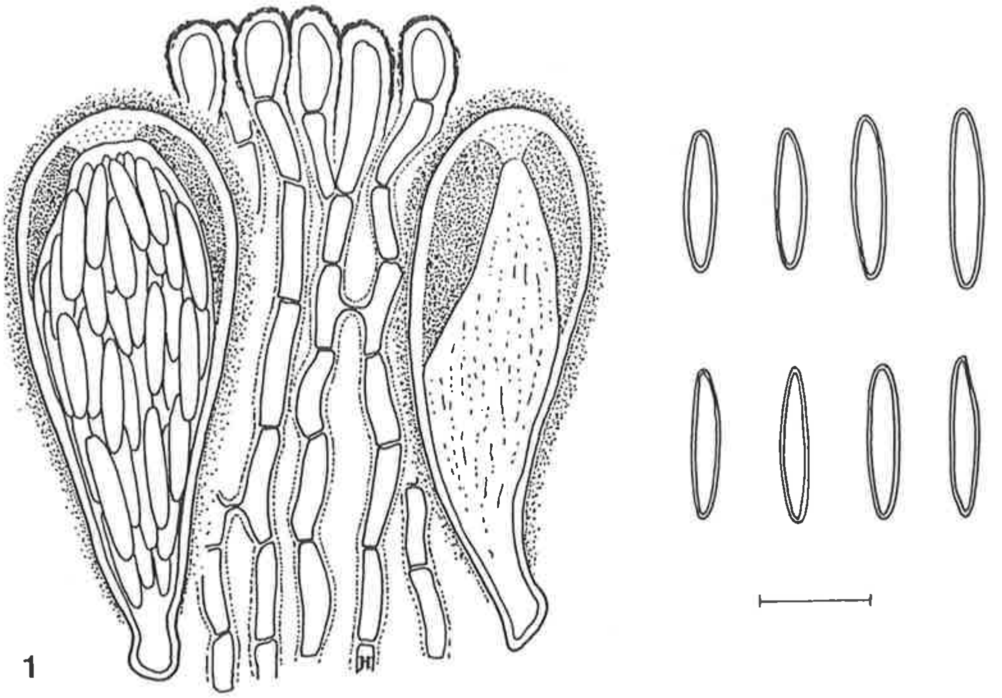
Ascomycetes lichenisati. Genus ad Lecanorales, Lecanoraceae s. ampl. pertinet. Thallus custaceus algas chlorococcales continens. Apothecia marginata, excipulo thallino cincta, aliquot ad *Protoparmeliam badiam* revocantes. Asci typo designato, varietas typi generis *Lecanora*, tholis amyloideis et gelatina amyloidea circumdati, multispori. Paraphyses septatae, ramosae et parce anastomosantes, apicibus pigmentosis. Ascosporae hyalinae, unicellulares, fere bacilliformes, non halonatae. Pycnosporae bacilliformes, rectae.

Holotypus: *Maronina australiensis* Haf. & Rogers

Lichenised ascomycetes belonging to the Lecanorales, Lecanoraceae s. ampl. Thallus crustose, containing coccoid green algae, covered by thin upper cortex or an indistinct cortical layer. Apothecia similar to *Protoparmelia badia*, with a thalline margin and brown to blackish-brown discs.Hypothecium hyaline to brown. Asci a variation of the *Lecanora*-type as in *Protoparmelia badia*, "masse axiale" rather broad but not very distinct, surrounded by amyloid gelatine, multispored. Dehiscence rostrate. Paraphyses with some branches and anastomoses, embedded in a gelatine, not easily separated with pressure. Paraphysal tips brown. Ascospores hyaline, narrow elliptic to bacilliform, one-celled, in light microscope without a visible perispore. Pycnospores bacilliform, straight.

Fig. 1: *Maronina australiensis*: asci (in Lugol's solution), paraphyses and ascospores, scale = 10 µm (Holotypus)

Fig. 2: *Maronina australiensis*: known distribution



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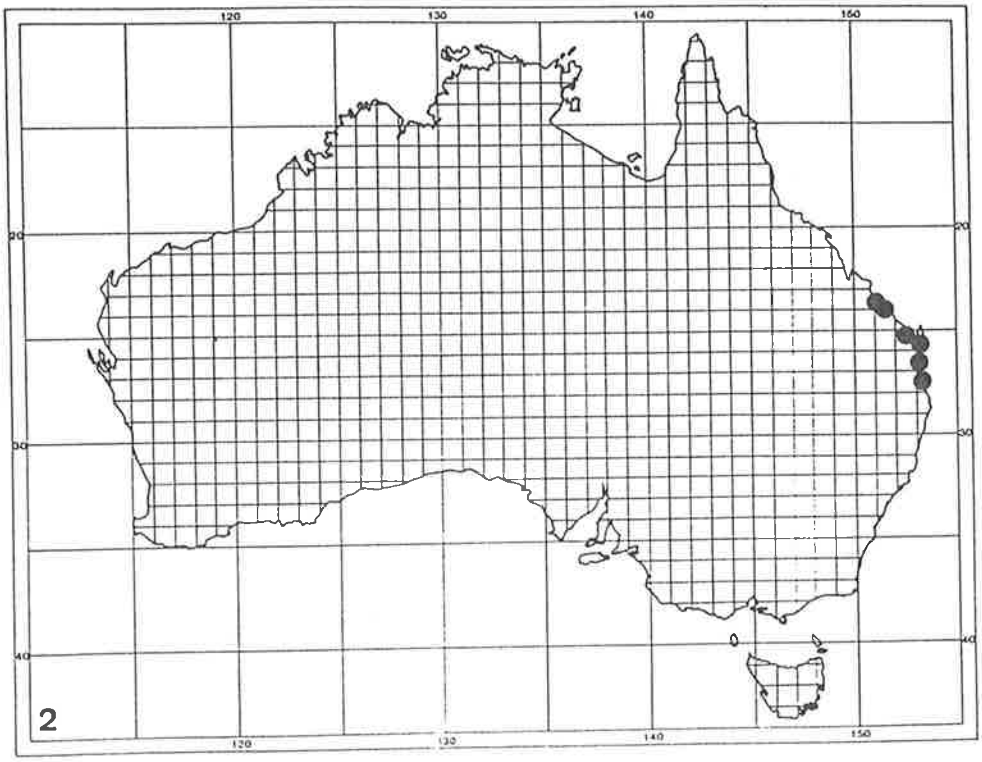

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Maronina is a tropical to subtropical genus and it seems to be much more common in the southern hemisphere with approximate limits of distribution from 30° S to 20° N. *Maronina*-species are mostly corticolous, but we have seen some lignicolous and saxicolous specimens of species which shall be treated elsewhere.

The genus is most closely related to *Protoparmelia* and *Maronina* may be regarded as a multispored derivative with tropical to subtropical distribution. This is consistent with the suggestion of NYLANDER (1863) who argued that *Lecanora multifera* (now *Maronina multifera*) may belong to the *Lecanora badia*-group (now *Protoparmelia*). Species of *Protoparmelia* are widely distributed on the world and live mostly on acid rocks, which is true also for species of the closely related genus *Miriquidica* (HERTEL & RAMBOLD 1987).

KEY TO THE DESCRIBED *MARONINA*-SPECIES

1 Ascospores 9-12 x 2-3 µm, apothecia up to 2 mm in diam.; known distribution: subtropical eastern Australia *Maronina australiensis*

1* Ascospores 6-8 x 2,5-3 µm, apothecia up to 1,2 mm in diam.; known distribution: South America *Maronina multifera*

Maronina australiensis Haf. & Rogers spec. nov.

Thallus albidus ad cinereobrunneus, crustaceus, fissuratus ad areolatus. Apothecia discis fuscis ad rufofuscis, planis ad aliquot convexis, marginibus cinereoalbidis ad cinereobrunneis, nitidis, saepe crenulatis, ad 2 mm in diametro. Excipulum tenuiter corticatum et epipsamma obtectum, interior algas aggregatas continens. Hypothecium hyalinum. Hymenium hyalinum, 45 ad 55 µm altum, non inspersum. Epihymenium leviter fusce pigmentosum.

Asci typo generis, 35-45 x 14-18 µm magni, ca. 60-100 sporas continentes. Gelatina et tholi ascorum jodo caerulescentes.

Paraphyses septatae, ramosae, ad 3 µm crassae, apicibus fusce pigmentosis aliquot incrassatis.

Ascosporae hyalinae, unicellulares, plusminusque bacilliformes, 9-12 (-14) µm longae et 2-3 µm crassae.

Pycnidia in thallo immersa, rotunda, non divisa. Cellulae conidiogenae 10-12 x 2-3 µm magnae. Pycnosporae bacilliformes, plerumque ex cellulis conidiogenis terminales formatae, 7-10 x 1-1,5 µm magnae.

Thallus in medulla substancia ignota ex affinitate acidi caperatici continens.

Habitat in cortice arborum in sylvis Mangrove dictis in Queenslandia.

Typus: Australia, Queensland, Tandora about 25 km ENE of Maryborough, sea level; 25°27'S/152°52'E; mangroves, on *Rhizophora stylosa*, 23. Aug. 1986, leg. J. Hafellner no. 17823 & R.W. Rogers (GZU-Holotypus, G, M, BM, MEL, UPS, US, Kalb, Hafellner - Isotypi).

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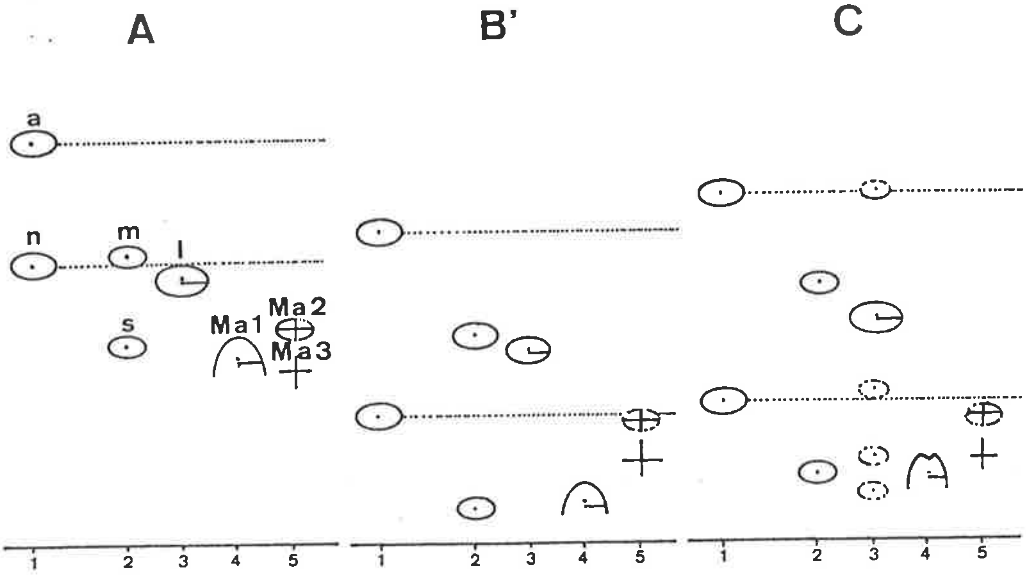

Fig. 3: Schematic chromatograms in standard solvent systems of (1) control containing a and n, (2) *Miriquidica garovaglii* (Haf. 13460 in GZU), (3) *Protoparmelia badia* (Haf. 11274 in GZU), (4) *Maronina australiensis* (Holotypus) and (5) *Maronina multifera* (Brazil, Sao Paulo, 18 km N of Botokatu, leg. Kalb & Plöbst); a-atranorin, n-norstictic, m-miriquidic, l-lobaric, s-stictic, Ma 1, 2, 3 - unknown substances in *Maronina*-species

Thallus whitish to greyish-brownish, crustose, fissured to areolate.

Apothecia with brown to reddish-brown discs, plane to convex, with whitish-grey to greyish-brown, shining, often crenulate margins, up to 2 mm in diam. In transverse section in the uppermost part a thin cortical layer covered by an epipsamma is visible which causes the shininess of the thalline margin (fig. 10, 11). Hypothecium hyaline. Hymenium hyaline, 45-55 µm high. Epihymenium brown (fig. 9).

Asci as drawn in fig. 1, 35-45 x 14-18 µm, containing 60 to 100 ascospores. Ascal gelatine and the tholi of the asci turning blue in Lugol's iodine (fig. 1, 7, 8).

Paraphyses septate, branched, up to 3 µm thick, the somewhat thickened tips covered by brown amorphous pigment (Pigmenthauben-Typ according to KILIAS 1981) (fig. 1, 8).

Ascospores hyaline, one-celled, more or less bacilliform, 9-12 (-14) x 2-3 µm large (fig. 1).

Pycnidia immersed in the thallus, spherical, not divided. Conidiogenous cells solitary or in very short chains, most of the pycnospores formed by terminal conidiogenous cells, but rarely intercalary. Pycnospores bacilliform, not curved, 7-10 x 1-1,5 µm large.

Thallus containing in the medulla an unknown substance related to caperatic acid (anal. J. ELIX, in litt.). Medulla reacting K+ brownish (fig. 3).

The species seems to be restricted to mangroves in the subtropics of eastern Australia, where it is occasionally found on rough bark of *Rhizophora stylosa* and *Ceriops tagal*. At the type locality all the thalli have been collected on the upper side of thick, more or less horizontal branches of *Rhizophora stylosa* in the lower canopy.

Known distribution: on the coast of southern Queensland (Australia) (fig. 2).

Further specimens seen: Australia, Queensland: Gladstone, between town and power house, on bark of *Ceriops*, 10 June 1975, leg. Rogers 744b (BRIU). S of Gladstone, South Trees Inlet, on mangroves at sea level, 4 March 1980, leg. Stevens (BRIU). Turkey, S of Gladstone, on bark of *Ceriops* on beach ridge, leg. Stevens 1254 (BRIU). 1770-Round Hill Head S of Gladstone, on bark of *Rhizophora* at sea level, 16 June 1975, leg. Stevens 1116 (BRIU). Noosa, Weyba Creek, on old *Rhizophora* at sea level, 18 Dec. 1975, leg. Stevens 2387 (BRIU). Noosa River NE of Tewantin about 70 km SE of Gympie, 26°23'S/153°02'E, on *Rhizophora stylosa* at sea level, 27 July 1986, leg. Hafellner 19202 & Stevens (Hafellner). Moreton Bay, Bribie Island, 6 km N of the bridge, on *Rhizophora* in a *Ceriops* glade, 31 Jan. 1976, leg. Stevens 1555 (BRIU). Moreton Bay, Coochie Mudlo Island, 27°35'S/153°20'E, on bark of *Rhizophora* in mangroves, 8 Oct. 1981, leg. Rogers 2373, 2373a, 2373b (all in BRIU).

Fig. 4-8: *Maronina australiensis* (Holotypus). 4-6: apothecium in cross section (scale = 100 µm), 4: mounted in water, 5: in Lugol's solution, 6: in lactic acid/cotton blue, 7-8: hymenium, lactic acid/cotton blue (scale = 20 µm)

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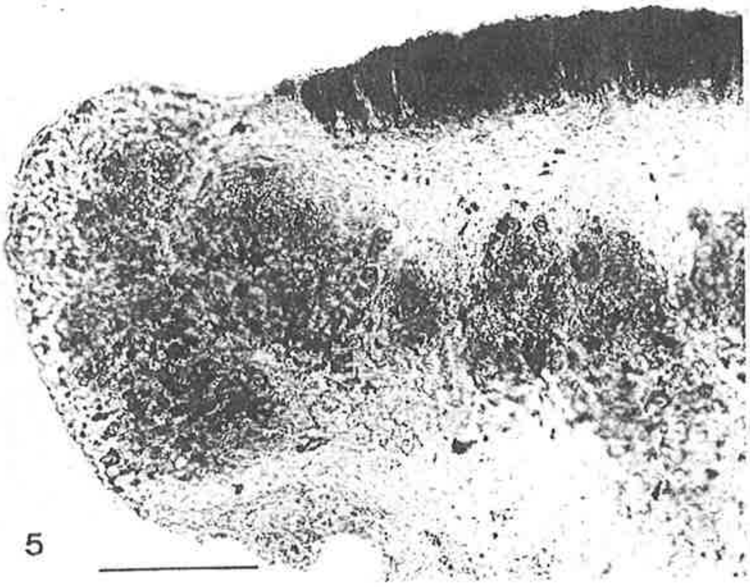

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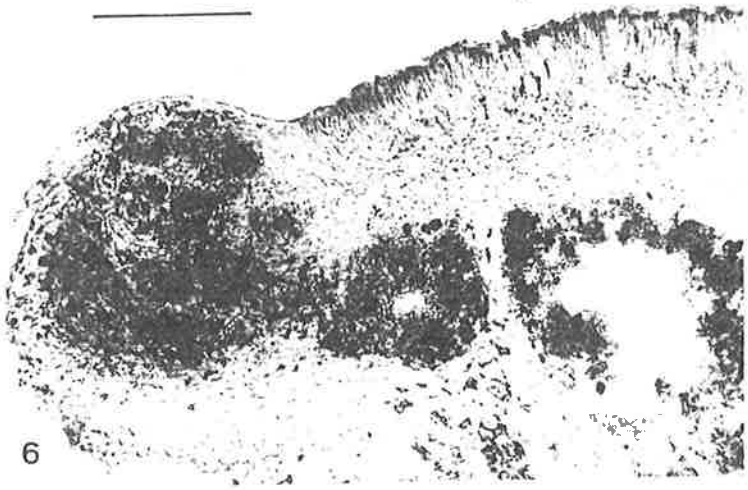

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FURTHER SPECIES

Maronina multifera (Nyl.)Haf. & Rogers comb. nov.

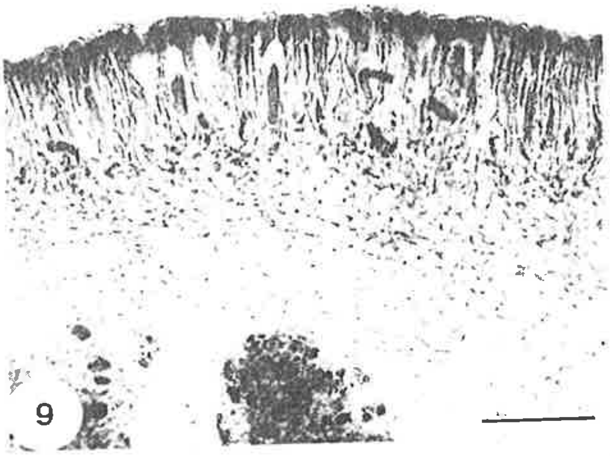
Bas.: *Lecanora multifera* Nylander in Acta Soc. Sci. Fenn. 7: 445 (1863) et in Ann. Sci. Nat., Bot., ser. 4, 19: 319 (1863).
Syn.: *Maronea multifera* (Nyl.) Vainio, Acta Soc. Fauna Flora Fenn. 7: 100 (1890).
Typus: Nova Granata, leg. Lindig 2676 (H-Nyl 25974 - Lectotypus, H-Nyl 25975 - Isotypus) Vidimus!
Exs.: Vainio, Lich. Brasil. exs. 1117 (as *Maronea multifera*)
Kalb, Lich. Neotropici 103b (as *Maronea multifera*)

This species can be easily distinguished from *Maronina australiensis* by the size of the ascospores, which are only up to 8 µm long in *M. multifera* as well as thallus chemistry. In the thallus of *Maronina multifera* two unknown fatty acids have been found (fig. 3).

Known distribution: *Maronina multifera* is not known outside of South America. There it is reported from Columbia (type locality), Brazil and Uruguay (Magnusson 1934).

Further specimens seen: Brazil: Minas Gerais, Serra do Espinhaco, Serra do Caraca, Umgebung des Klosters Caraca (Hauptsammelgebiet von Vainio), 8. Juli 1978, leg. Kalb & Plöbst (Kalb). Minas Gerais, Berghänge oberhalb von Tiradentes bei Sao Joao del Rei, in feuchtem, dunklem Primärwald, 900 m, 6. Juli 1978, leg. Kalb & Plöbst (Kalb). Sao Paulo, Fazenda 13. de maio, 18 km N von Botokatu und 14 km E von Sao Manuel, in einem Cerradao, 550 m, 9. Nov. 1979, leg. Kalb & Plöbst (Kalb). Sao Paulo, Bezirk Ahembi, Fazenda Barrero Rico, Cerrado-Insel in einem Primärregenwald, 450 m, 10. Nov. 1979, leg. Kalb & Plöbst (Kalb). Sao Paulo, bei der Stadt Olimpia, etwa 45 km ENE von Sao José do Rio Preto, an einem Laubbaum am Rand eines Cerradao, 500 m, 14. Sept. 1979, leg.. Kalb & Plöbst = Kalb, Lich. Neotropici 103b (GZU).

Fig. 9-14: *Maronina australiensis* (Holotypus). 9: hymenium, lactic acid/cotton blue (scale = 50 µm), 11, 12: uppermost part of excipulum showing brown hyphal tips covered by a thin epipsamma, causing the shininess of the margin, water (scale = 20 µm), 12: apothecium in cross section, polarized light/water (scale = 100 µm), 13: outermost part of exciple, water (scale = 20 µm), 14: outermost part of exciple, lactic acid/cotton blue (scale = 20 µm).



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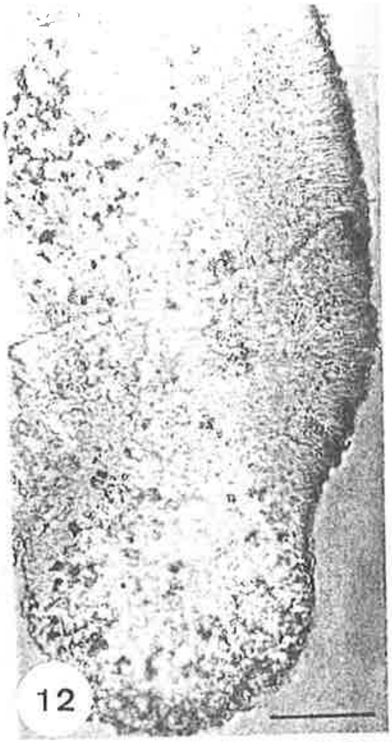

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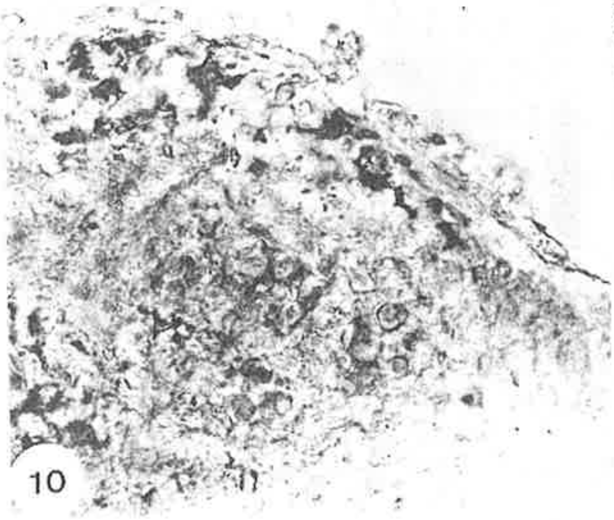

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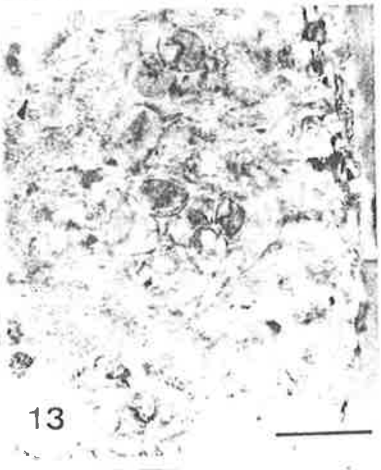

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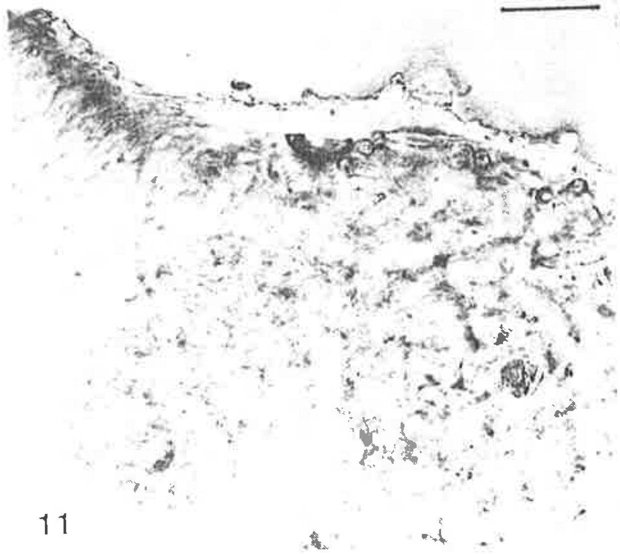

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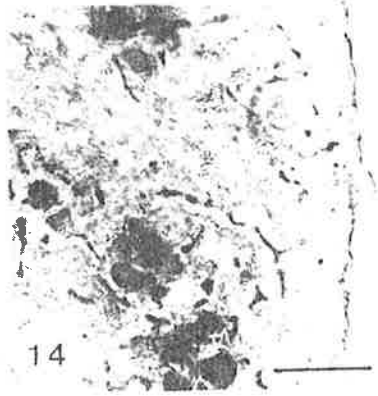

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Dr. J. Hafellner, Institut für Botanik, Karl-Franzens-Universität
Holteigasse 6, A-8010 Graz, Austria

Dr. R.W. Rogers, Department of Botany, University of Queensland, St. Lucia, Queensland, Australia 4067

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Aust. Syst. Bot., 1988, 1, 181-3

Verrucaria cribbii (Verrucariaceae, Lichenised Ascomycetes), a New Marine Lichen from a Coral Cay

R. W. Rogers

Botany Department, University of Queensland, St Lucia, Qld 4067.

Abstract

Verrucaria cribbii R. W. Rogers was collected from crevices and under boulders of the beach rock on Heron Island, a tropical coral cay. It is characterised by small ascospores, a continuous thallus and emergent hemispherical ascocarps with a thick black involucre around the ostiole.

Introduction

Marine lichens are prominent in the eulittoral and supralittoral fringe of rocky coasts in cool temperate areas, and have played an important role in the definition of littoral zones in many places (Lewis 1961). In southern Australia the genera *Verrucaria* and *Lichina* form a distinctive zone on the rocky shores of South Australia and Victoria (Womersley 1981). Searches of rocky shores in northern New South Wales and southern Queensland have failed to find any truly littoral lichens and, in Queensland, lichens are uncommon on any but the most protected maritime rocks. An examination of lichen floristic studies from other tropical and subtropical regions, e.g. Hawaii (Magnusson 1956), the Carribean (Wainio 1915) and Java (Zahlbruckner 1943), failed to reveal records of marine lichens in these areas. However, Cribb (1966, 1973) reported the presence of *Verrucaria* on intertidal rocks of Heron Island (lat. 23°26′S., long. 151°55′E.) on the east coast of Queensland, Australia.

Heron Island is a coral cay, 830 m long and 300 m wide, which has a band of beach rock varying from 3 to 20 m wide on much of its northern and southern shores. This rock is composed mainly of algal and coral skeletal debris with lesser amounts of molluscan, bryozoan and foraminiferan materials (Flood 1984). It is upon the soft calcareous beach rock that a species of *Verrucaria* was found which differed from all others known to occur in littoral zones around the world.

Verrucaria cribbii R. W. Rogers, sp. nov.

Thallus crustaceus, continuus, viridis vel ater, cortex 5–7 μm crassus. Perithecia solitaria, ex parte immersa; involucrellum hemisphaericus, niger, carbonaceus, 200 μm diametro; ostiolum centrale, angustus; paries perithecialis plectenchymatus, atrobrunneus, 20 μm crassus; periphyses 0·7–1·0 μm crassus; haud ramosae, usque ad 20 μm longus; ascus 8 sporae, ascosporae hyalinae, paries tenuis, 7–10 × 5–6 μm.

Habitat ad petris calcaris littoralis, Australia tropica.

Holotype: Australia, Queensland, Heron Island, in a crevice of the beach rock on the southern side of the island. *R. W. Rogers 8851* (MEL).

Thallus crustose, continuous, green to black, cortex 5–7 μm thick. *Perithecia* solitary, partly immersed; involucre hemispherical, glossy black, carbonised, 200 μm diameter; ostiole central, very narrow; perithecial wall plectenchymatous, dark brown, *c.* 20 μm thick. *Periphyses* 0·7–1·0 μm thick, unbranched, up to 20 μm long. *Asci* 8-spored, thick-walled. *Ascospores* hyaline, thin-walled, fusiform, 7–10 × 5–6 μm.

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Ecology: on calcareous rock in the intertidal zone of a tropical coral cay.

This species is named in honour of Dr Alan Bridson Cribb, who first reported marine lichens on Heron Island and who has made important contributions to our knowledge of marine fungi and algae.

Discussion

Verrucaria is a very large genus, with some hundreds of species described that have not been monographed in recent times. However, only a small proportion of the described species is marine, and these have been considered by Fletcher (1975) and Santesson (1939).

While distribution data must be treated with some caution when making taxonomic judgments, it appears that the described species of *Verrucaria* that occur in marine habitats are species of the arctic or antarctic to cool temperate regions (Santesson 1939). Since no *Verrucaria* has been reported from intertidal rocks in tropical or subtropical regions, and since *Verrucaria* is generally a genus of cool regions, it is highly probable this is a distinct species.

There are, however, good morphological grounds for recognising *Verrucaria cribbii* as a new species. *V. cribbii* is part of the microspora group (Santesson 1939), a useful but artificial cluster of species with small spores. However, *V. cribbii* is easily separated from other species in the microspora group by its smooth continuous (not cracked or areolate) thallus, and emergent (only the base is immersed) black hemispherical (not depressed at the apex) perithecia and a very well developed black involucre.

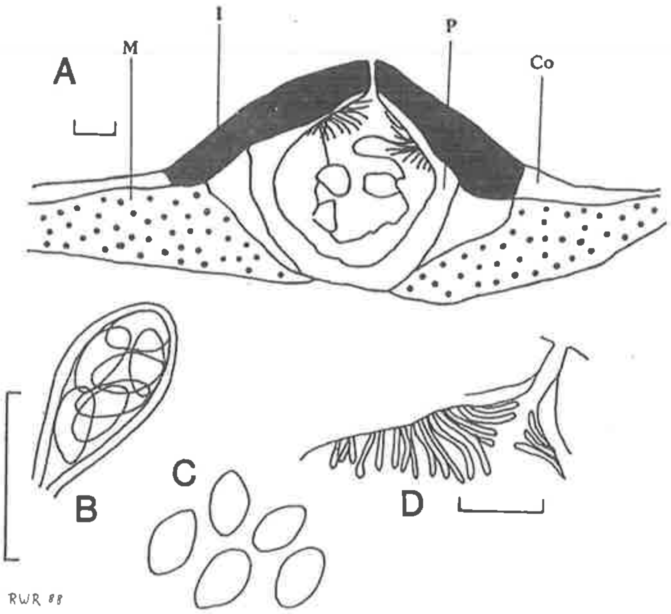

Fig. 1. Anatomy of *Verrucaria cribbii*. *A*, vertical section through a perithecium (*I*, involucre; *P*, perithecium wall; *Co*, cortex; *M*, medulla with algae). *B*, mature, thick-walled ascus containing ascospores. *C*, ascospores. *D*, periphyses lining the ostiolar region of the perithecium. Scales: 20 μm.

The distribution of *V. cribbii* on Heron Island is most peculiar as it is almost totally restricted to crevices in the beach rock. It occurs on both upper and lower surfaces of horizontal cracks, and deep into vertical cracks, as well as on the underside of coral boulders lying on the exposed beach rock. In exposed areas the thallus is thick (60 μm), glossy and black, looking like a deposit of pitch which has oozed out of the crevices. The thick exposed thalli form scattered patches *c.* 1–3 cm across but thalli in the shade are often continuous over areas in excess of 10 cm diameter. Deep within crevices and under boulders the thallus is thinner, distinctly green and not at all glossy.

V. cribbii is only rarely exposed to direct sunlight and usually grows in areas with only very low levels of diffuse light. Its distribution range on the beach rock is circumscribed by tides of 2·3–2·6 m, and it is found in cracks and crevices throughout this area. Tides in excess of 2·3 m occur on about 310 days per year, and in excess of 2·6 m on 250 days per year.

This cryptic occurrence of *V. cribbii* is a contrast to that of other *Verrucaria* species, which form conspicuous bands on rocks in the intertidal zone of Britain (James *et al.* 1977), southern Australia and New Zealand (Womersley 1981). Zonation diagrams by Lewis (1961) and Womersley (1981) show that on calm shores *Verrucaria* is normally restricted to the region between low and high tides. The beach on Heron Island is protected by extensive coral development extending at least 400 m out from the beach rock, resulting in a shallow, warm and usually calm lagoon. Therefore, restriction of *Verrucaria* to the intertidal zone is as expected. Restriction to deep crevices and cracks is probably explained by the high levels of solar radiation and hence high surface and air temperatures experienced in the tropics, which would rapidly dry out a thallus exposed to the full sun and, unless it was well drained, leave it caked in salt. A thallus that remained wet in the full sun would undoubtedly suffer severe stress, as lichens, although resistant to heat when dry, are extremely susceptible to heat damage when wet (Kappen 1973).

An organism growing on the beach rock that may be confused with *V. cribbii* is the crustose brown alga *Ralfsia expansa* J. Agardh. *R. expansa*, however, forms distinct plaques (often 30–50 mm diameter) and grows in more exposed locations on the beach rock lower in the intertidal zone. The minute perithecia of *Arthopyrenia sublitoralis* (Leighton) Arnold, previously reported from Australia and Indonesia by Santesson (1939), were found on fragments of beach rock examined in the laboratory.

Acknowledgments

I am grateful to the Great Barrier Reef Marine Park Authority for permission to collect on Heron Island, and to the staff of the University of Queensland, Heron Island Research Station for field assistance.

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Handbook of the Flora and Fauna of South Australia, issued by the Handbooks Committee on behalf of the South Australian Government and published by favour of the Honourable the Premier (D. O. Tonkin, M.P.)

LICHENS OF SOUTH AUSTRALIA

by

REX B. FILSON
National Herbarium of Victoria

and

RODERICK W. ROGERS
Botany Department, University of Queensland

Wholly set up and printed in Australia by
D. J. WOOLMAN, Government Printer, South Australia
1st November, 1979

HANDBOOKS COMMITTEE

FOREWORD

What Matthew Flinders achieved for yachtsmen and mariners by charting the unknown coastal waters of this continent, so Mr. Filson and Dr. Rogers have succeeded in providing for botanists, zoologists, geologists and soil scientists a clear chart to guide them through the wide range of variation that is found in one of the most distinctive difficult and neglected groups of plants, the lichens.

This is the first regional lichen flora compiled in Australia this century. It is a pioneer landmark that justifies the years of effort spent in careful field collection, mounting and incorporation of specimens into the herbarium, purchase of expensive non-Australian taxonomic literature and the comparative morphological and biochemical studies. All of these are pre-requisites to the production of sound taxonomic work which forms the infra-structure to the production of regional floras.

The cumulative cost of all this lichenological research is estimated to be no less than two hundred and fifty to three hundred thousand dollars. However, the benefits of sound and careful herbarium taxonomy are also cumulative. The publication of the handbook will provide a useful excursion companion in South Australia and each of the adjoining States.

The book will benefit teachers, students and field workers who can now increase their awareness of the lichens around them and, like their careful collecting predecessors of note in South Australia, bring any new material that comes to hand back to the herbaria for further study and thereby help in the advancement of knowledge of all Australian lichens.

Armed with this new knowledge it is to be hoped that lichens will become better understood in their ecological role in the ecosystem.

The authors bring a worldwide experience and perspective to bear on the taxa described herein and both have worked in the British Museum, where the world's largest collections of lichens are curated.

The taxonomic value of the descriptions is enhanced considerably for future readers by including herbarium reference numbers to the actual voucher specimens examined in the course of this work.

(Dr.) D. M. Churchill
Director and Government
Botanist of Victoria

Code for Collectors

LICHENS ARE VULNERABLE

Lichens are extremely slow-growing organisms and are very dependent on their habitat. The recovery of a lichen colony after sampling may take many years.

Rare species could easily be lost by over-collecting and indeed this is already happening in other countries.

The use of lichens in dyeing must be discouraged as the colours produced can be obtained from other plant material. Already scenic areas in Australia are being denuded of their lichen flora by the thoughtlessness of home dyeing enthusiasts. These areas will never recover.

Small specimens are ample for most research purposes and collectors in Australia, as elsewhere, must never forget the need to preserve their heritage unimpaired.

Whether for serious research, for exchange, or general interest, indiscriminate or wasteful collecting is unethical, immoral, and altogether to be deplored.

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INTRODUCTION

The study of lichens has lagged far behind the other fields of botany. The reasons for this are diverse. They include—fear of a group that is notoriously difficult taxonomically, with species descriptions and keys unavailable, being published in overseas journals, often in foreign languages, and the purely pragmatic objection that the phanerogamic flora is still poorly known and its study must take precedence.

Within South Australia the phanerogams are relatively well known, thanks to the efforts of J. M. Black (1922-29) and Hj. Eichler (1965). The lichen flora is relatively small and the botanical library at the National Herbarium, Melbourne (MEL) has provided most of the literature relevant to this study.

Perhaps the most limiting factor in production of a lichen flora is the very lack of such a flora; for most naturalists will not collect a plant which they know they will not be able to name. If collections do not exist, taxonomists do not have a basis on which to produce a flora. In an effort to break this circle, the present work has been compiled. It is a first approximation presented in the hope that with this information available, collectors will be able to collect intelligently and so provide the material for a second, much improved edition.

Because information on the distribution of lichens in South Australia is so incomplete and the state of lichen taxonomy so fluid, individual collections have been cited under *Specimens examined.* Citing specimens in this manner identifies the precise localities on which the Handbook record is based, indicates broadly where the species is likely to occur, and provides opportunity for further checking to determine the sense in which the name has been applied, thereby facilitating revision.

All species known to occur in South Australia have been included as well as genera and species which, though not recorded, are likely to occur in the State.

Species descriptions have been based for the most part on material gathered by the authors, which is housed in the collections mentioned in the chapter on Collections in South Australia.

Early in the compilation of the manuscript it became apparent that information concerning the crustose lichens was sparse and their taxonomy confused (Weber 1962) and, except for the soil surface species, could be treated only at the generic level.

This work thus aims to provide the information needed to name the crustose lichens of South Australia to generic level and the fruticose and foliose lichens to specific level. The flora is synoptic: it summarises our present knowledge, but no new taxa are described herein; it is not the result of critical revisions, but rather points to groups in which such studies are needed; it points to areas in which further collections must be made.

The new combination *Peltula australiensis* (Müll.Arg.) R. B. Filson is made on page 142. Nine species, *Hypogymnia pulchrilobata* (Bitt.) Elix, *Parmelia* sp. *nov.* 1, *P.* sp. *nov.* 2, *P.* sp. *nov.* 3, *P.* sp. *nov.* 4, *P.* sp. *nov.* 5, *P.* sp. *nov.* 6, *P.* sp. *nov.* 7, are being described elsewhere. Three species, *Endocarpon* sp., *Leptogium* sp. and *Usnea* sp. are in groups which are not being revised at present, so that it will be some time before firm descriptions will be available for them.

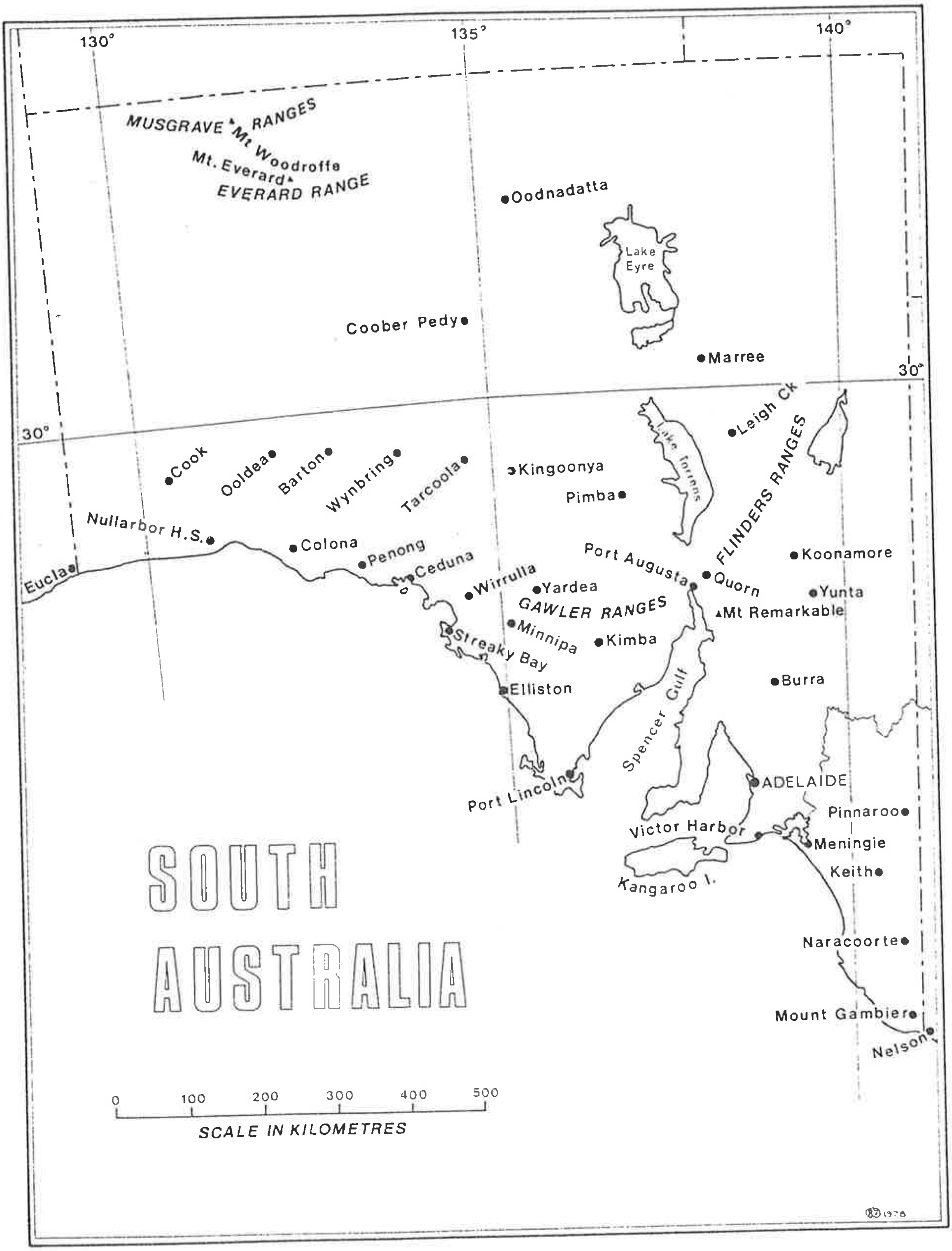

Fig. 1. Map of South Australia showing principal localities mentioned in the text.

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STRUCTURE OF LICHENS

Lichens are classified as *cryptogams*, which are lower plants including the algae, fungi and bryophytes. Technically they are placed with the fungi though the layman often confuses them with the mosses. The fundamental part of lichen is called the *thallus*, which is in fact composed of two of the above cryptogamic groups; a fungus (the *mycobiont*) and an alga (the *phycobiont*). These two components grow together in an association loosely referred to as *symbiosis* or more correctly, controlled parasitism. Lichen symbiosis differs from all other kinds in that the thallus bears no resemblance to either the fungus or the alga growing in the free state, though the final shape is, in the majority of cases, determined by the fungal partner. This composite organism behaves as a single independent plant, the alga manufacturing sugars by photosynthesis and the fungus living off these foodstuffs and providing the alga with shelter, moisture and nutrients.

Lichens may be grouped into three main thallus types, *crustose* (Plate 9B and 9C), *fruticose* (Plate 2C and 16B) and *foliose* (Plate 10 and 14A).

Crustose lichens are tightly appressed to the substrate. They are composed of an *upper cortex*, an *algal layer* and a *medulla* (Fig. 2A). Sometimes they are completely immersed in the rock (*endolithic*) or bark (*endophloeadal*). Some crustose species develop from a basal *hypothallus* which is a thin film of non-lichenised *hyphae* and when present can be observed in the cracks between the *areolae* and at the margins of the thallus. Within this group is a sub-type, the *squamulose* (Plate 6A). This thallus is intermediate between the crustose and foliose and is composed of numerous small lobes or squamules which seldom grow to more than a few millimetres long.

Fruticose lichens are pendulous or erect and rising from the substrate. They may be entirely unattached or may arise from a disk or *holdfast* (Fig. 2C). The main branches may be cylindrical (*terete*) or more or less flattened and can be hollow or solid with or without a central cord-like strand (*axis*).

Foliose lichens vary considerably in thallus shape and size but basically they are typified by the development of more or less horizontally-spreading leaf-like *lobes*. The thalli are usually *dorsiventral* and usually consist of several well defined layers: the upper cortex, algal layer, medulla and lower cortex (Fig. 2B). Foliose lichens have two different growth forms: the typical form is lobed and leaf-like and attached to the substrate by *rhizines*, *tomentum*, or part of the lower cortex; and the *umbilicate* form which usually has a *peltate* thallus and is attached to the substrate by a single central holdfast (*umbilicus*).

All the three thallus types may be *gelatinous*. These lichens have no well defined layers in the thallus other than an upper and lower cortex. The medullary layer consists of loosely woven hyphae and scattered algal colonies. These genera are jelly-like and swollen when wet and rather shapeless when dry.

THALLINE STRUCTURES

Certain lichens have various modifications of the thallus which are important when studying the taxonomy of the group.

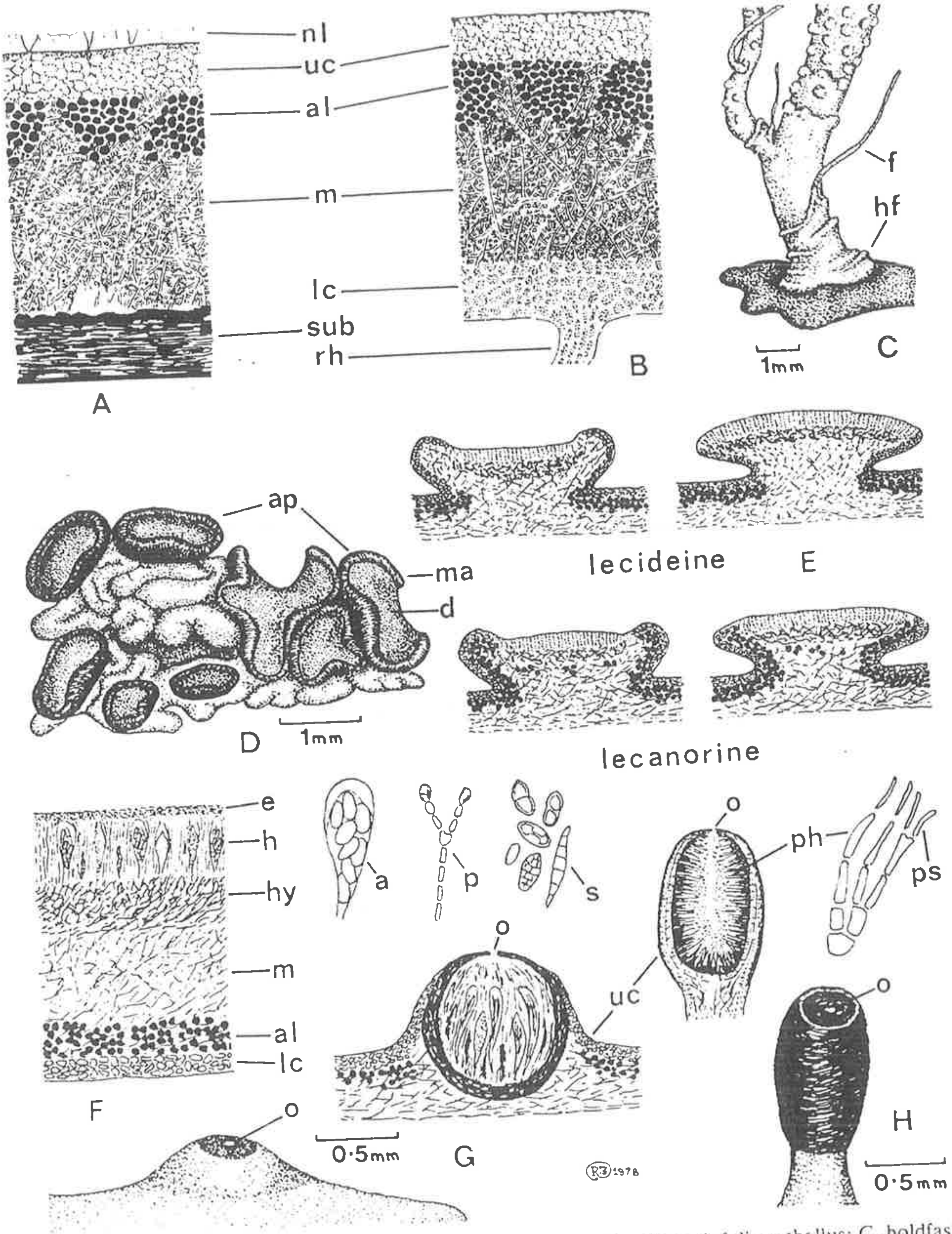

Fig. 2.—A, cross-section through crustose thallus; B, cross-section through foliose thallus; C, holdfast of fruticose thallus; D, apothecia on crustose thallus; E, cross-sections through lecideine and lecanorine apothecia; F, enlargement of cross-section through apothecia showing ascus, paraphyses and ascospores separated from hymenium; G, perithecium in thalline wart and cross-section; H, terminal pycnidium and cross-section showing pycnidiospore bearing hyphae. *a*, ascus; *al*, algal layer; *ap*, apothecia; *d*, disk; *e*, epithecium; *f*, fibril; *h*, hymenium; *hy*, hypothecium; *hf*, holdfast; *m*, medulla; *ma*, margin; *nl*, necrotic layer; *lc*, lower cortex; *o*, ostiole; *p*, paraphysis; *ph*, pycnidiospore-bearing hyphae; *ps*, pycnidiospore; *rh*, rhizine; *s*, ascospore; *sub*, substrate; *uc*, upper cortex.

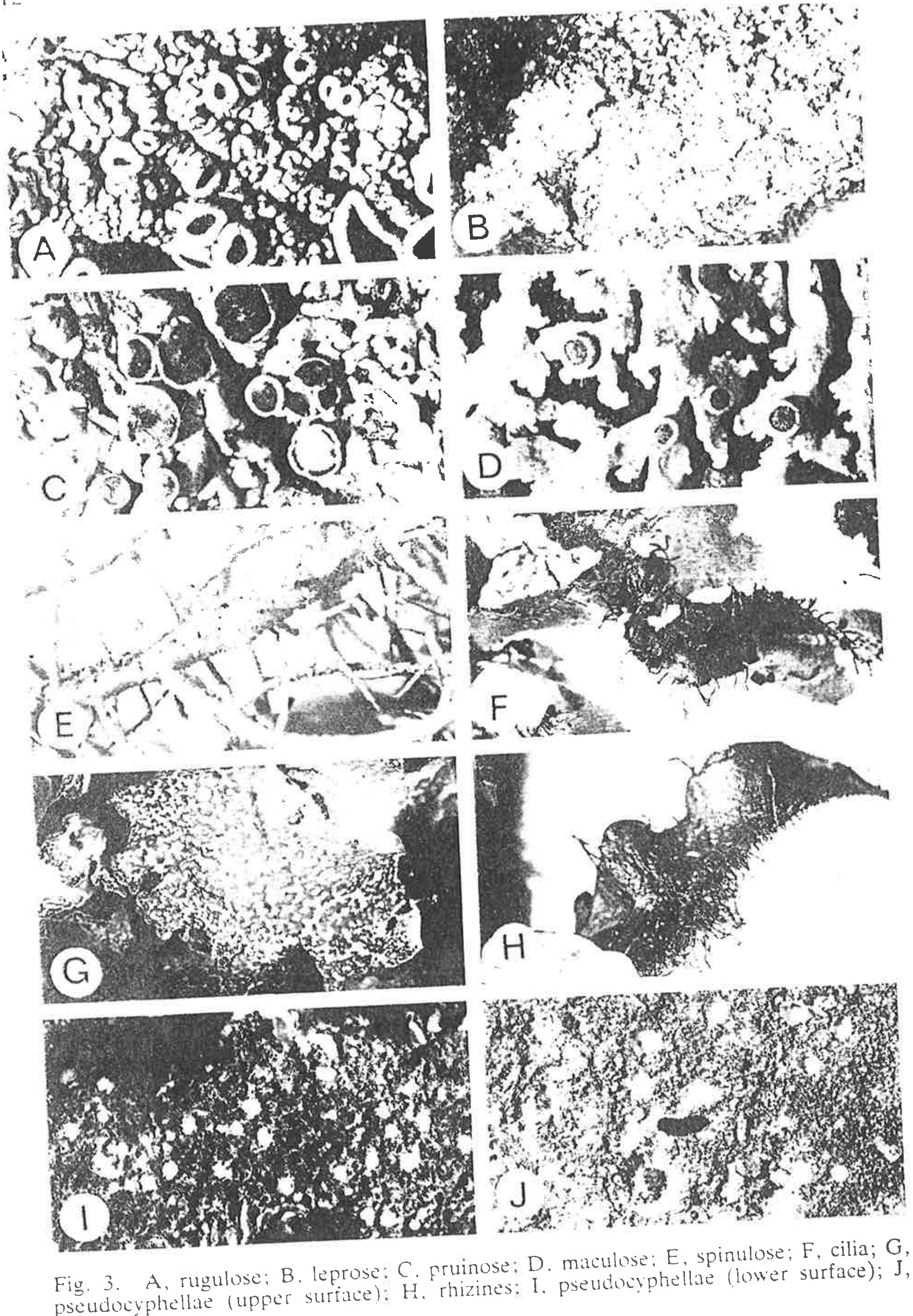

Fig. 3. A, rugulose; B, leprose; C, pruinose; D, maculose; E, spinulose; F, cilia; G, pseudocyphellae (upper surface); H, rhizines; I, pseudocyphellae (lower surface); J, cyphellae.

The upper surface of the thallus lobe may be smooth, wrinkled, *rugulose* (Fig. 3A), cracked, or reticulate. It may be *maculose* (Fig. 3D), where irregular patches in the algal layer gives the surface a white-spotted appearance. In some species this condition leads on to reticulate cracking, and in some leads on to the formation of *pseudocyphellae* (Fig. 3G) which are effigurate cracks through the upper cortex. Sometimes the lobes, especially at the ends, become *pruinose* (Fig. 3C). The lobes may be adorned with one of the accessory reproductive structures.

Soralia (Fig. 4D) are areas of the thallus where the upper cortex has broken down and is replaced by a powdery or granular mass of *soredia* (Fig. 4E). They originate in the *gonidial* layer from a crack or pore in the upper cortex. In crustose lichens the soralia may remain as small round patches or the entire thallus may completely dissolve into a sorediose mass. This condition is called *leprose*. In the fruticose and foliose thalli the soralia are often characteristic of species and have important taxonomic value. Therefore the development and position of the soralia is important. Some of the more commoner types of soralia are:—

Laminal soralia (Fig. 4G) occur in patches on the upper surfaces of the thallus lobes only. Sometimes on the older portions of the thallus the lobes are completely covered with soredia.

Marginal soralia (Fig. 4E) can be divided into three forms: the first where the soralia develop all along the margins of the lobes, the second where the soralia are confined to the underside of the lobe and then the lobe rolls upward exposing a lip-shaped *(labriform)* patch of soredia (Fig. 4F), and the third *capitate* (Fig. 4H) which is confined to the ends of the lobes which often stand erect and appear to be capped by a mass of soredia.

Pustular soredia (Fig. 4I) originate in small globose, inflated swellings on the thallus lobe. These swellings often open by an irregular tear in the cortex and then the margins of the swelling dissolve into soredia.

Each grain of soredia consists of a few algal cells enmeshed in a weft of fungal filaments; they are never corticate. The size of the grain may be important in diagnosis, fine flour-like grains are called *farinose* whilst those a little coarser are *granular*.

Isidia (Fig. 4A & B) differ from soralia in being corticate. They are coralloid outgrowths from the upper cortex and can occur over the whole surface of the lobe or be confined only to the margins. They may be sparse, scattered, or the whole central part of the thallus may become an isidiose mass. Isidia may be simple, cylindrical, globose, inflated, club-shaped or branched *(coralloid)* terete or flattened. Sometimes the apex splits and sometimes, though rarely, it becomes sorediose.

Lobules (Fig. 4C) resemble isidia except that they are dorsiventral. They usually occur on the margins of foliose and fruticose species; only in a few species do they occur on the surface of the lamina.

The margins of foliose lichens may be *ciliate* (Fig. 3F). These fine hair-like structures can be simple, branched or bulbate. If they occur on the upper surface

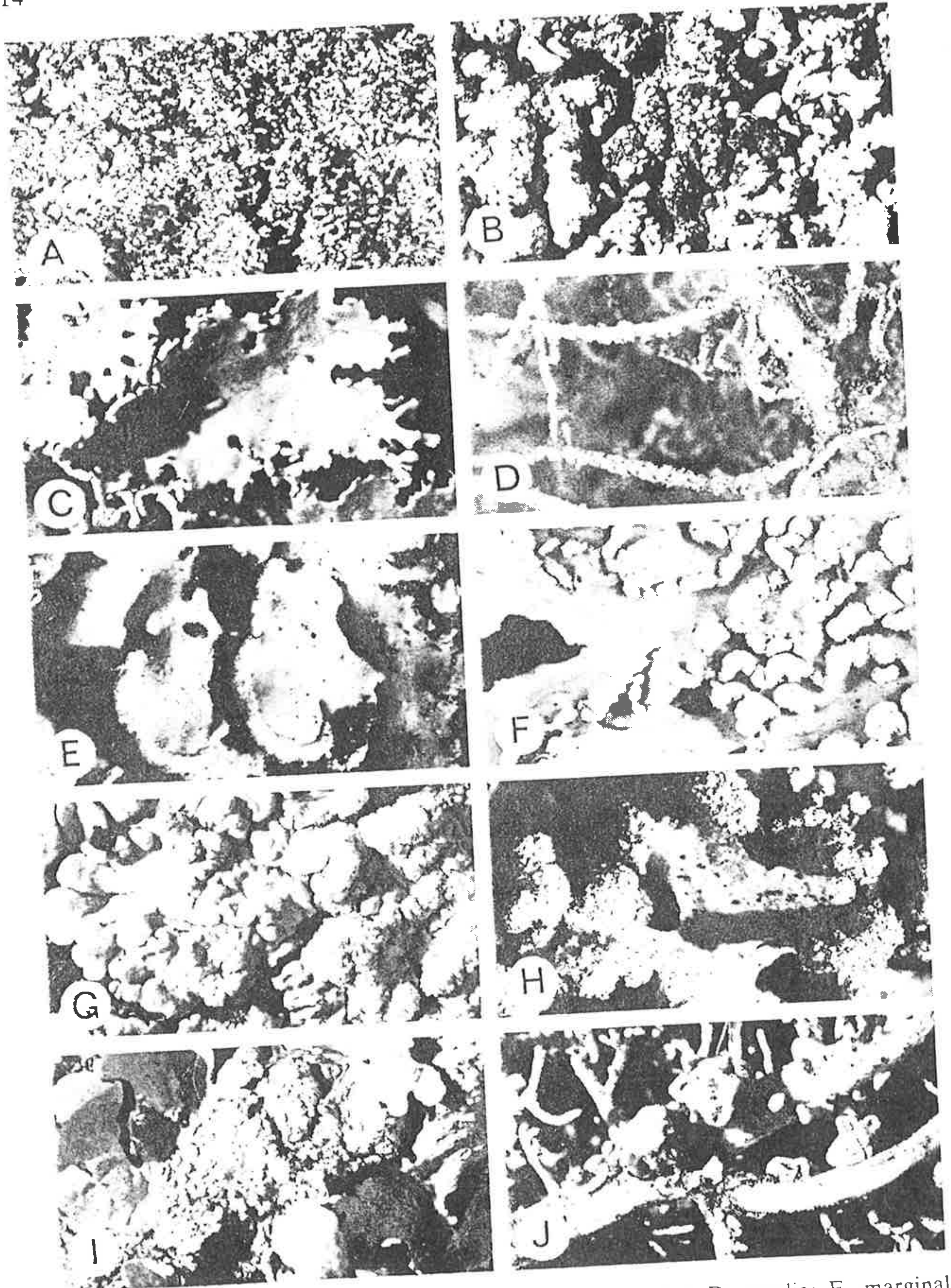

Fig. 4. A, cylindrical isidia; B, inflated isidia; C, lobules; D, soralia; E, marginal soredia; F, labriform soredia; G, laminal soredia; H, capitate soredia; I, pustulate soredia; J, cephalodia.

or on a fruticose thallus they are often referred to as *spinules* (Fig. 3E). *Papillae* are small wart-like outgrowths found on some fruticose thalli.

The lower surface of the thallus lobe may be ecorticate, corticate, bare or *rhizinate* (Fig. 3H). Rhizines are bundles of dark hair-like hyphae by which many of the foliose lichens are attached to the substrate; they may be simple, dichotomously or squarrosely branched or *fasciculate*. The lower surface of some species may be covered with fine hairs or pubescence which is referred to as *tomentum*. Small round or angular holes with a distinct marginal ring of cells through the lower cortex, exposing the medulla, are called *cyphellae* (Fig. 3J) whereas *pseudocyphellae* (Fig. 3I) are merely holes or elongated breaks in the cortex with intruding medullary filaments.

Small warted or cerebriform protuberences on some lichens are *cephalodia* (Fig. 4J). These structures occur when a lichen with an exclusive green algal phycobiont has trapped a blue-green alga. The importance of this structure lies in the fact that the blue-green alga is able to fix atmospheric nitrogen and has been shown to pass this to the mycobiont in the main part of the thallus (Jahns 1973:49).

REPRODUCTIVE STRUCTURES

Lichens mostly reproduce by asexual or vegetative means. This is more often achieved by *fragmentation* though many species produce highly specialised reproductive bodies; *soredia, isidia* and *lobules*. However, a great number of lichens do not have any obvious means of vegetative reproduction.

The fruiting bodies on a lichen thallus represent only the fungal component, and the spores which are produced are therefore only of the mycobiont. The most common fruiting body is the conspicuous saucer-shaped structure *(apothecium)* on the surface of the thallus. Apothecia may be immersed, *adnate* or *stipitate; laminal, marginal* or on the upper or the lower side of the lobe ends. The apothecium contains a number of tissues, the colour, thickness and type of which are diagnostic in identification of species (Fig. 2F). The *epithecium* is the upper part of the *hymenium* and is composed of the tips of the *paraphyses*. It is often coloured and forms the apothecial disk. The disk is variously coloured and sometimes covered by a powdery deposit called *pruina*. The *hymenium* is a layer of *asci* and sterile filaments *(paraphyses)* which originate in the dense layer of tissue called the *hypothecium*. The asci are small sacks containing the *ascospores*. The ascospores vary in shape, size structure and colour. Although the majority of asci contain 8 spores, some contain as few as one or as many as 300. The outer edge of the hypothecium forms a margin known as the *exciple*, or proper margin, around the edge of the apothecium. If this is the only margin present around the apothecium then it is said to be *lecideine* (Fig. 2E). If the exciple is surrounded by a secondary (outer) margin of thalline material containing algae, the apothecium is said to be *lecanorine* (Fig. 2E). The proper margin may in some instances be completely hidden by the *thalline margin*. Below the hypothecium is the *medulla* and enclosing the whole *ascocarp* is the lower cortex.

In some lichens the asci disintegrate at maturity leaving the spores and paraphyses free in a capitate mass. This is known as a *mazaedium*.

Some genera bear globular or pear-shaped receptacles, up to 1 mm in diameter, immersed in the thallus. These are called *perithecia* (Fig. 2G). The spores are contained in asci in a similar manner to the apothecia but instead of being discharged through the epithecium they are discharged through a narrow opening at the top. The same tissues are present in both types of fruiting body.

Pycnidia (Fig. 2H) are small globose or flask-shaped structures which occur in most lichen genera. They are mostly immersed in the thallus but in some genera they are sessile or stipitate. They can easily be confused with perithecia but the *pycnidiospores* bud off from simple or branched hyphae instead of being enclosed in an ascus. *Pycnidiospores* (Fig. 2H) have been variously called pycnospores, conidiospores, microconidia, or spermatia. Some authors suggest that they are asexual reproductive bodies capable of germination; others that they have a sexual function as they have been observed adhering to the trichogynes of ascogenous filaments (Letrouit-Galinou 1973: 62). If this latter observation is true these spores are spermatia and the pycnidia from which they emerge must be called spermogonia. Until this matter is clarified we prefer to use the terms pycnidia and pycnidiospores.

CHEMISTRY

No study of lichen taxonomy can be complete without some knowledge of the simple reagent tests discovered by Nylander (1863). Species which are easily confused without careful study are quickly separated by a simple test. Lichens produce unique chemical substances which are deposited in the form of crystals in the medullary hyphae. Each species usually has a constant chemical make-up so that when the same lichen is collected from a variety of different habitats the chemical tests will be constant. The three basic reagents are: Potassium hydroxide (abbreviated KOH or K), Calcium hypochlorite (abbreviated C), and paraphenylenediamine (abbreviated P). Calcium hypochlorite (common bleaching powder) should be mixed with water before each use as it deteriorates rapidly and will give no reaction when stale. Potassium hydroxide should be mixed as a 10 per cent solution in water and kept in a stoppered bottle. This solution is stable and will keep for several months. As this chemical is caustic it should be handled with extreme care. Paraphenylenediamine comes as dark rusty crystals and is used as a 5 per cent solution in 95 per cent alcohol which should be made up fresh before use. It can be purchased only from a chemical supply company and must also be handled with great care because the spilled solution or powder will ruin clothing and paper. It is most important not to let the chemical come in contact with the skin or to inhale the crystals as it possibly causes blindness and brain damage (J. Santesson 1966:216, Swinscow 1959:120). **Paraphenylenediamine is very dangerous.**

The chemical tests are usually carried out on the medullary tissue. Under a lens or dissecting microscope carefully remove a small section of the upper cortex exposing the white medulla. The reagent is then applied with a fine glass rod and any colour change noted. The tests K, C, and P are straightforward; the KC is observed when K is applied first then followed by a drop of C. Some skill is required in this latter test as sometimes the reaction is only fleeting and the unwary may miss it. With a little practice the chemical tests can be carried out on a very small area of the thallus.

For further determination of the lichen products crystal tests and thin layer chromatograms can be used but these techniques are beyond the scope of this present handbook.

COLLECTIONS IN SOUTH AUSTRALIA

Until recently few lichens had been collected in South Australia. In 1847 Dr. Ferdinand von Mueller emigrated from Germany to South Australia on the advice of Ludwig Preiss. He found employment with a chemist in Adelaide and in his spare time he commenced a study of the local flora. He sent his lichen collections to Dr. Georg E. Hampe in Germany who published their names and descriptions in *Linnaea* (1852). They included the first collections of two species new to science *Biatora byssaceae* Hampe and *Sticta muelleri* Hampe (now *Heterodea muelleri* (Hampe) Nyl.), the last species named in honour of Mueller. Mueller continued his collecting until 1853 when he moved from Adelaide to take up the position of Government Botanist in Melbourne in the Colony of Victoria.

Johann Gottlieb Otto Tepper* was born in 1841 at Neutomischel, Posen, Prussia and migrated with his parents to South Australia in 1847. The Tepper family soon settled on the land in the Lyndoch Valley and it was here that the young Otto grew up. Life on the farm was hard and he improved his education by studying Mathematics, Latin, English and German in his spare time. He started his working life as a shearer and later became partner in a flour mill. When the mill failed he was persuaded by a German pastor to take charge of the parish school. While there he passed the necessary examinations to qualify as a State school teacher, and there followed a teaching career which lasted for nearly 20 years. Tepper moved from school to school in South Australia and in each centre he pursued his interest in natural history and added greatly to his botanical collections.

In 1883 he was appointed Natural History Collector to the Adelaide Museum and later became Museum Entomologist. When J. G. O. Tepper died in 1923 his collections were donated to the Field Naturalists' Section of the Royal Society of South Australia. They later passed to the South Australian Museum and still later to the State Herbarium, Adelaide (AD) with odd duplicates in the National Herbarium, Melbourne (MEL) and the National Herbarium, Sydney (NSW).

Johann Friedrich Carl Wilhelmi was a professional seed collector, in about 1852, who sent specimens from Eyre Peninsula, Port Lincoln and Mount Gambier to Mueller in Melbourne (MEL).

Richard Helms was naturalist and botanical collector with Sir Thomas Elder's Expedition to Central and Western Australia in 1891-92. The expedition, under the command of David Lindsay, set out from Warrina Railway Siding in South Australia and headed northwestward to the Everard Ranges, then turned westward into Western Australia. Helms's specimens were also sent to Mueller in Melbourne (MEL).

Mueller forwarded portions of these collections to Professor Jean Müller (Müll. Arg.) at the University of Geneva, Switzerland, who published on his determinations (Müll. Arg. 1892, 1893). Twelve collections by Helms were

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*see Krahenbuehl 1969

reported as new to science including *Endocarpon helmsianum* Müll. Arg. named in honour of its collector. These collections are housed in the herbaria in Geneva (G), Melbourne (MEL) and Adelaide (AD).

Professor T. G. B. Osborn arrived in Adelaide as first Professor of Botany in 1912, and encouraged botanical exploration, making some lichen collections himself and despatching large numbers to Scandanavia for determination. It was probably from this parcel that Magnusson (1940) described *Pseudocyphellaria australiensis* Magn. This species was described from material collected at Encounter Bay by Professor J. B. Cleland, Professor of Medical Pathology in the University of Adelaide. Professor (later Sir John) Cleland was Chairman of the Handbooks Committee from 1921 to 1969.

Dr. Colin Barnard, of the C.S.I.R.O. Division of Plant Industry, collected lichens from the Koonamore Vegetation Reserve, north of Yunta, in 1927. These collections were sent to the Kew Herbarium in England (K) and specimens reputed to be duplicates were retained in the Adelaide University Herbarium (ADU). All of the lichen collections from the Kew Herbarium were later transferred to the British Museum (Natural History), London (BM). The collections in Adelaide were examined again in 1966 and the names were found to be so confused that it is difficult to accept thay they are in fact duplicates of those at Kew. Miss C. M. Eardley, Lecturer in Botany at the University of Adelaide for many years made collections in the Koonamore Reserve in 1946. Dr. J. H. Willis, Assistant Government Botanist at the National Herbarium of Victoria until 1972, was the botanist with the Russell Grimwade Expedition of 1947. He collected lichens on the western coastal strip of the State (Willis 1953). Mr. D. Kemsley made collections in the Nullarbor region in 1952 and Mr. T. R. N. Lothian in the arid north west of the State in 1954.

Mr. B. Copley collected near Bute in 1960 and Dr. E. Shaw near Iron Knob in the same year. Miss D. Hunt made extensive collections between Naracoorte and Penola in 1962. Mrs. V. Cruikshank collected widely in the Mount Lofty and Flinders Ranges in the years 1964-68. In 1965 Mr. G. Hazel collected a number of specimens from near Kapunda, and Mr. A. C. Beauglehole collected widely across the state from Meningie to the Nullarbor Plain. Mr. D. N. Krahenbuehl collected samples from the Gawler Ranges in 1968. Mr. R. D. Seppelt collected a few specimens from the Millicent area, and more from the Mount Lofty Ranges in 1970. A number of other persons have collected a very small number of specimens and are not mentioned here. Virtually all of the collections mentioned are housed in the herbaria in Adelaide (AD) or Melbourne (MEL).

In the 1960's Mr. L. D. Williams (L.D.W.) collected some 70 numbers mostly of foliose and fruticose species from locations ranging widely over the state, and his private collections have proved very valuable in extending the ranges of some species, and as the only collections known for others.

Mr. N. N. Donner is actively engaged in the collection and curation of the lichens in the State Herbarium of South Australia. He has travelled throughout South Australia in his efforts to obtain comprehensive collections of the State's lichen flora.

Of the present authors, Dr. R. W. Rogers collected extensively in the years 1965-1970. These specimens are housed mostly in his personal herbarium (R.W.R.) with some duplicates held in Adelaide (AD) and Melbourne (MEL). Rogers's collections are dominated by specimens from arid areas and the Mount Lofty Ranges. He has studied the crustose species of the arid zone (Rogers 1971, 1972a, 1972b, 1974).

Mr. R. B. Filson collected extensively throughout the State in the years 1967-77. His collections range from the South-East, Eyre Peninsula, Nullarbor Plain, along the East-West Railway Line, Flinders Ranges, Stuart Highway, Everard and Musgrave Ranges. The main set from these collections is housed in Melbourne (MEL) with some duplicates in other institutions.

LICHEN ECOLOGY

The taxonomic study of lichens is assisted by ecological investigations which can help to amplify visible distinctions between species and to suggest underlying physiological differences. Ecological information can be very helpful in suggesting new areas where a species might be found and in deciding whether different collections of similar material represent one or more than one taxon.

Ecological studies are an avenue of research open to amateurs. Investigations on the distribution of a single species, and the factors controlling the distribution (autecology) are easily carried out. Studies on the groupings of species colonising certain surfaces and the factors controlling the groupings (synecology) are more involved, but very rewarding.

In order to live, a lichen has a few simple requirements, the fulfilment of which present some problems. The thallus must be exposed to sufficient light, moisture and minerals to allow the algal cells buried within it to photosynthesise and produce food. If the thallus is growing in strong sunlight, it is likely to dry out rapidly as the lichen thallus has no special adaptations for water conservation. It is apparently only by change of shape, or increase in cortex thickness, that lichens adapt to varying water availability. Thus fruticose lichens, with a large exposed surface area, are quite rare in desert regions, whereas crustose lichens, and lichens which have their thalli immersed within the rock or soil, are more common. Lichens, however, have special physiological properties which allow them to overcome this problem. Whereas flowering plants die if they dry out, lichens can survive complete desiccation. Specimens of the South Australian desert lichen, *Chondropsis semiviridis*, kept air dry for nine months recovered fairly normal photosynthetic activity within 30 minutes of being rewetted.

Another hazard facing organisms growing in full sunlight is heat. Temperatures as high as 65°C have been recorded on rocks and soil in the mid-summer sun. Although flowering plants can tap reserves of water beneath the surface of the soil, the lichen thallus cannot. It has been found that if the lichen thallus is air-dried it is not damaged by high substrate temperatures, but if it is wet before it is exposed to high substrate temperatures then it is quite sensitive. This may be the reason why lichens are rare in the areas of arid northern Australia which have a hot, humid summer. The South Australian deserts are rich in lichens, presumably because of the usually very dry summers and cool, sometimes moist winters.

Resistance to cold is not a hazard that must be faced by most South Australian lichens. However some lichens are very cold-resistant and records show that they have recovered after exposure to temperatures below −150°C.

Lichens can quite rapidly absorb water from fogs and even from moist air. This is demonstrated in the so-called 'fog oases' in the desert regions along the western coasts of North and South America, and of North and South Africa. The lichen *Ramalina maciformis* from the Negev Region in Israel, one of the driest deserts, survives on the moisture received as dew in the early morning. This moisture soon evaporates in the first few hours after the sun rises. There are places in Chile which have a rich lichen flora on the soil and rocks where no rain has fallen in a hundred years. Also in Chile are areas where the desert cacti are festooned with lichens that are normally associated with rainforests rather than with deserts. This phenomenon is not recorded in Australia, but could possibly occur along the coast of the Great Australian Bight or south of Onslow in Western Australia.

Lichens have evidently evolved very powerful mechanisms for the rapid absorption of mineral nutrients from the environment. This has revealed itself in some unfortunate ways, perhaps the most notable involving the reindeer lichens *(Cladina)* of Lapland. These lichens concentrated the biologically dangerous radio-isotope Strontium 90 (released from aerial atom bomb tests) within the thallus. After the reindeer ate the lichen, they retained the Strontium 90 in their tissue which was in turn absorbed by the Laplanders when they ate the reindeer meat. The ability to absorb and concentrate elements relating to air pollution is discussed in a later section.

LICHENS AND SUBSTRATES

While many lichens grow on a wide range of substrates, some species are very selective in the surfaces they colonise. Some species are apparently restricted to the bark of a single species of tree, some to limestone rocks or granite, whereas others grow on a wide range of trees as well as on rocks. A granite habitat has a particular rich lichen flora. The study of the lichen flora on various types of rocks is in itself an interesting project. In semi-arid and arid areas (which includes the Mallee) there is a well-developed lichen flora on the soil surface. This habitat does not occur in wetter areas as small plants and perennials apparently shade the lichens out.

Lichens are found on the trunks, twigs and leaves of trees. A number of species in South Australia are usually found on thin twigs (especially *Ramalina* species) rather than on thick branches and tree trunks. No leaf-inhabiting lichens have been reported from South Australia, although they are quite common in the rainforests and wet areas of other States.

Dead trees, fallen branches and fence posts are the substrates preferred by a number of lichens, and some species are confined to charred wood. *Thysanothecium hyalinum* is one species commonly found in South Australia on charred logs and stumps.

In addition to the natural surfaces discussed above, lichens seem able to colonise almost any stable surface. Around old garbage dumps in the bush they may be observed growing on old boots, tiles, crockery and glass.

ENVIRONMENTAL MODIFICATION

The lichen thallus can be subjected to a range of extreme conditions and is considerably influenced by changes in the microclimate. These microclimes may be separated from each other by only a few centimetres, for example the upper and lower surfaces of a rock ledge, or the part of a tree trunk down which water runs and the part from which the water is diverted. Because of difference in exposure to the sun the north and south faces of a tree trunk provide very different habitats for lichens. The upper surfaces of species of *Teloschistes* growing in strong sunlight are mostly deep orange in colour, whereas those in the shade tend to be a pale yellow. The colour of crustose lichens may also vary, not only with insolation, but with the chemical nature of the surface on which they grow. Young individuals of many species tend to look different from bleached and worn older populations. Near the extremes of species tolerance individuals tend to be rather stunted and distorted.

An interesting environmental modification is demonstrated by the crustose species, *Aspicilia calcarea*, which grows on limestone pebbles and soils in the arid regions. Under some conditions it ceases to form the normal flat areolate thallus, the areoles then elongate vertically, producing rope-like structures which become more or less recumbent and spreading; in fact a fruticose modification of a crustose thallus. The collector and taxonomist must be aware of the plasticity of lichens and exercise caution in the interpretation of the likely influence of environmental variation on lichen thalli.

LICHENS AND CITIES

Overseas studies have shown that lichens are sensitive to conditions found in some cities. The sensitivity is normally attributed to air pollution, especially pollution by sulphur dioxide. It appears that sulphur dioxide changes the acidity of rainfall to such an extent that highly toxic sulphite ions are produced which oxidise the chlorophyll in the lichen. The ability of lichens to concentrate nutrients from very dilute sources is also a hazard in the city. Lichens are indiscriminate in what they absorb and have been shown to accumulate large, and often fatal, amounts of toxic substances such as fluorides emitted by aluminium smelters, brick-works, fertiliser factories and cement works.

Generally, lichens growing on tree trunks have the least buffered substrate and as they suffer from acidification most easily, they are the lichens most sensitive to air pollution. Those growing on tiles, rocks, soil, cement, and asbestos cement sheeting are progressively better buffered against acidification of water supplies, and are therefore less sensitive to pollution. As a general rule fruticose lichens are more sensitive than others and the crustose species are the most resistant. However, not all lichens are disadvantaged by urbanisation and some species seem to thrive on the slightly richer air found there. These lichens are sometimes known as 'nitriphiles' (nitrogen lovers) and include the genera *Candelaria* and *Xanthoria*.

A study of the distribution of lichen species in relation to city development, air movements and sources of pollution, is an ecological project within the range of those who can determine the lichens they choose to study.

THE ROLE OF LICHENS IN THE ECOSYSTEM

Lichens do not occupy a prominent place in most ecosystems but in some special circumstances may be important. Perhaps the best known role of lichens is colonisation of bare rock surfaces. Lichens are amongst the very few

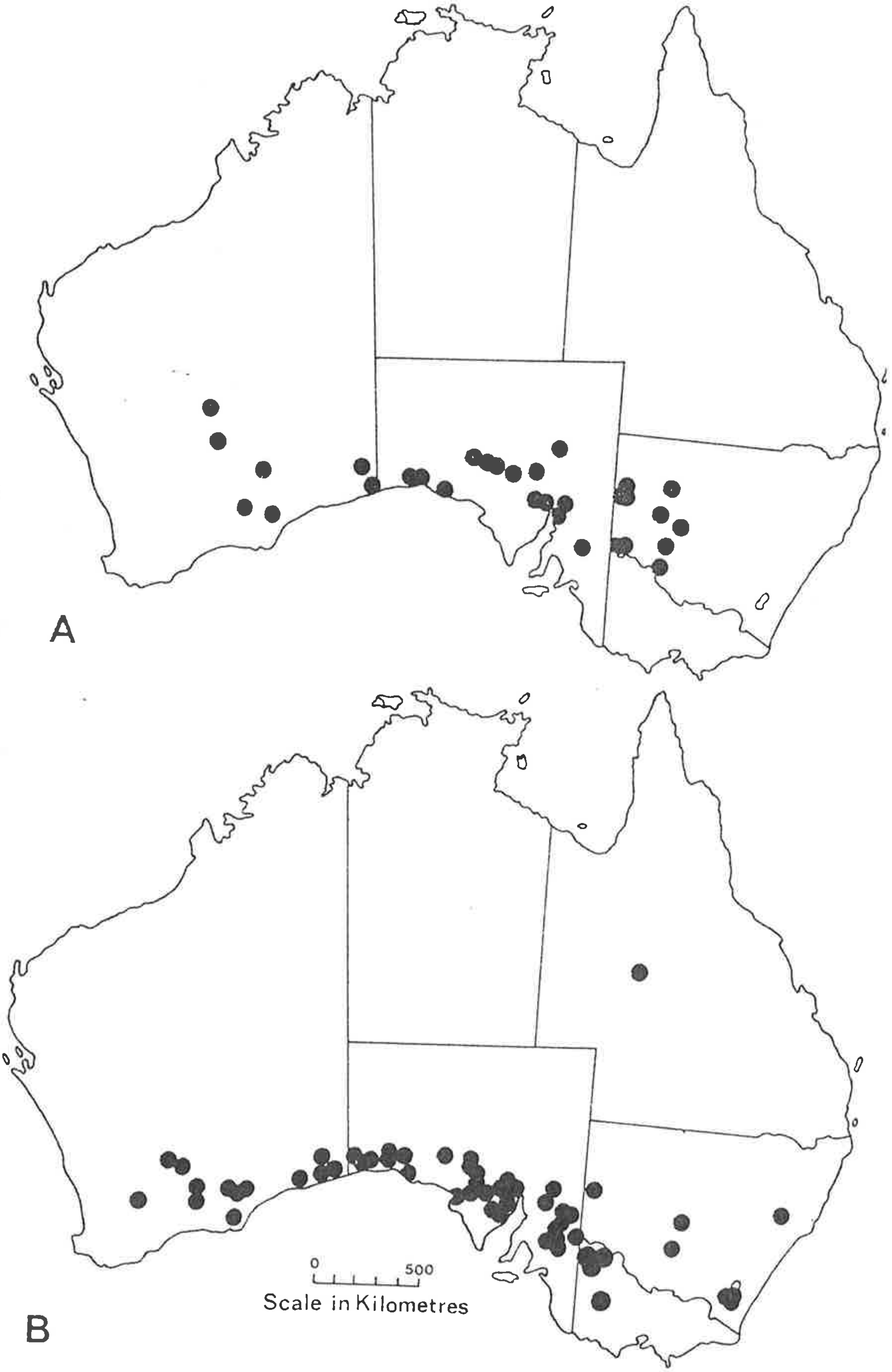

Fig. 5. A, the known distribution in Australia of *Maireana sedifolia*, after Hall et al. 1964, B, the known distribution of *Chondropsis semiviridis*, after Rogers 1971.

organisms that can survive on bare rock. Once established they tend to facilitate soil formation on the rock in two ways: they weather the rock by penetrating its structure physically with rhizines and hyphae, and they chemically erode the rocks with the various acids they produce. In addition to this direct action, the lichen thallus traps wind-blown dust and plant material thus building up a substrate for mosses and small herbs.

In arid areas lichens colonise stable soil surfaces. Once covered with lichens the soil is protected from wind, and to a large extent water erosion, even if the scrub cover dies during drought periods. The carpet of lichens on arid soils

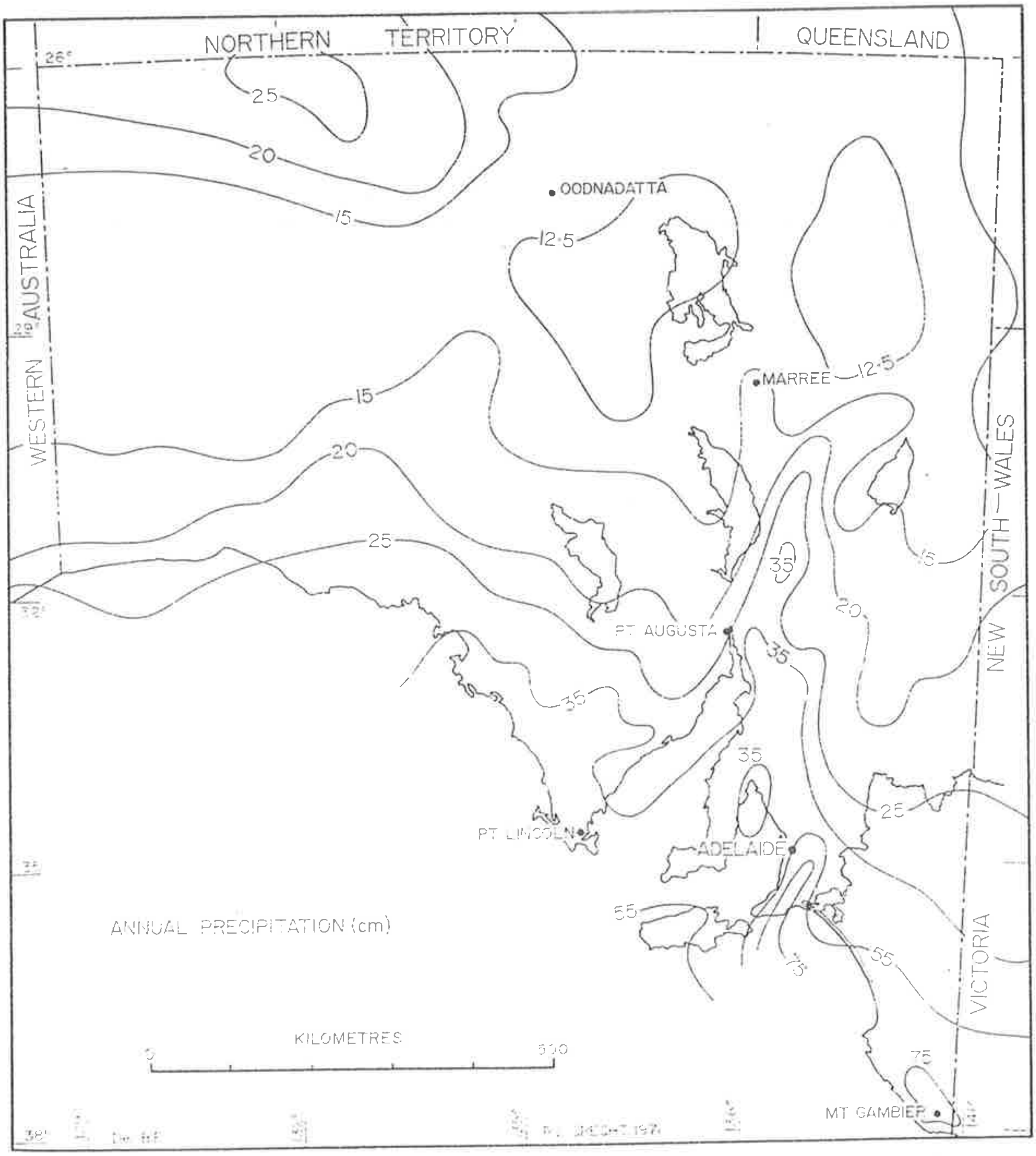

Fig. 6. Rainfall map of South Australia, showing annual isohyets, after Specht 1972.

contains at least one species capable of fixing nitrogen (*Collema coccophorum*) and provides a habitat for numerous other nitrogen-fixing blue-green algae, thus enriching the nitrogen reserves in the soil. This lichen crust is very sensitive to trampling by sheep and once destroyed is slow to recover.

DISTRIBUTION PATTERNS OF LICHENS

As it is expected lichens show distribution patterns which are often basically similar to those of flowering plants. The distribution of *Chondropsis semiviridis* (Fig. 5B) in South Australia for example is very similar to that of the shrub

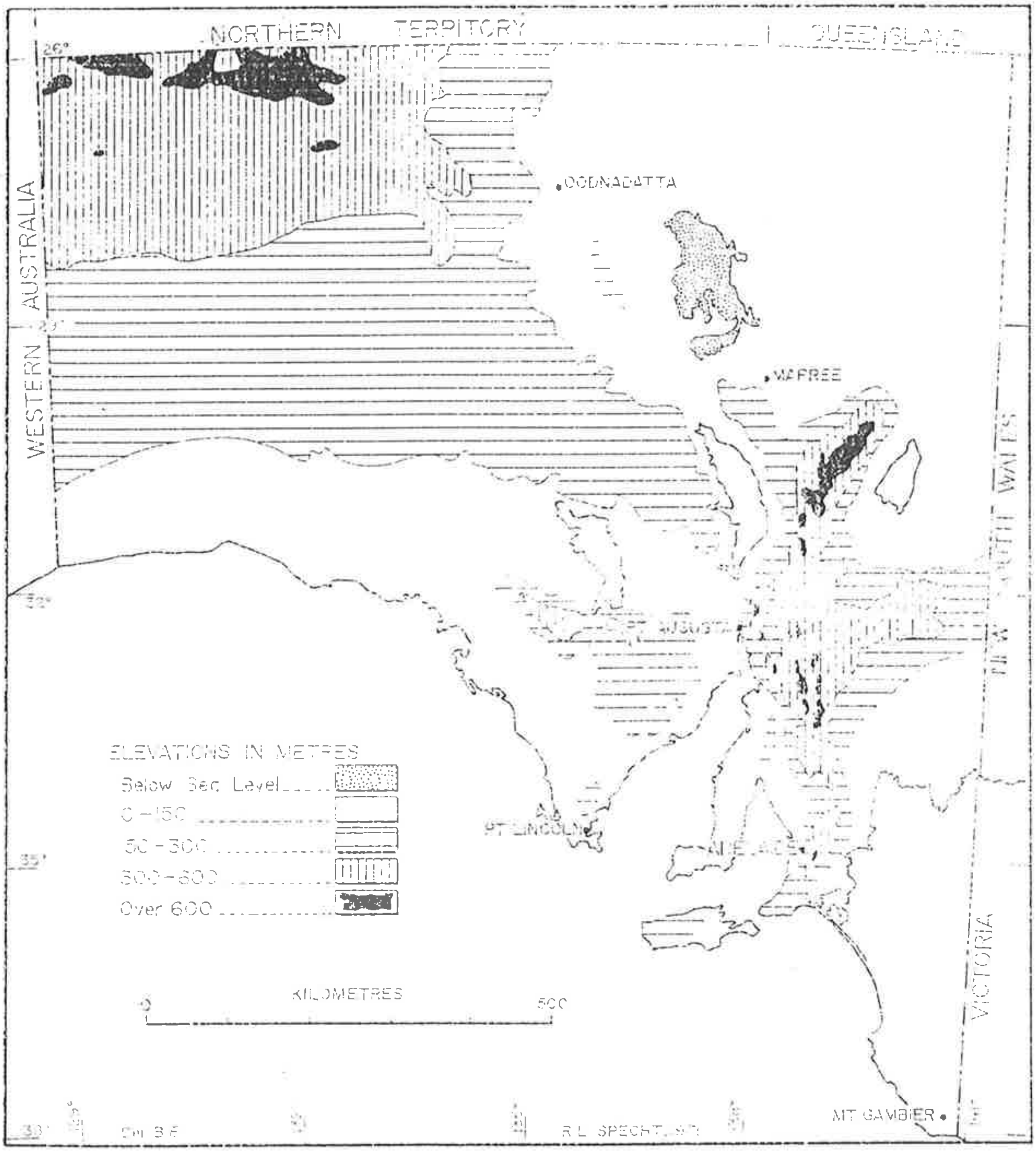

Fig. 7. Relief map of South Australia, after Specht 1972.

Maireana sedifolia (F. Muell.) P. G. Wilson (Fig. 5A), both of which require alkaline soils (which are almost universal in South Australian semi-arid lands) and a rainfall between 150 and 350 mm. *Cladia aggregata* is also a soil surface species, but appears to grow on slightly acid to alkaline soils, or over a layer of decaying plant litter, in areas with a rainfall of more than 250 mm (Fig. 8A) *Cladia schizopora* (Fig. 8B), which appears to be restricted to rotting logs in areas with a rainfall of more than 550 mm is much more limited in its distribution than the two above species.

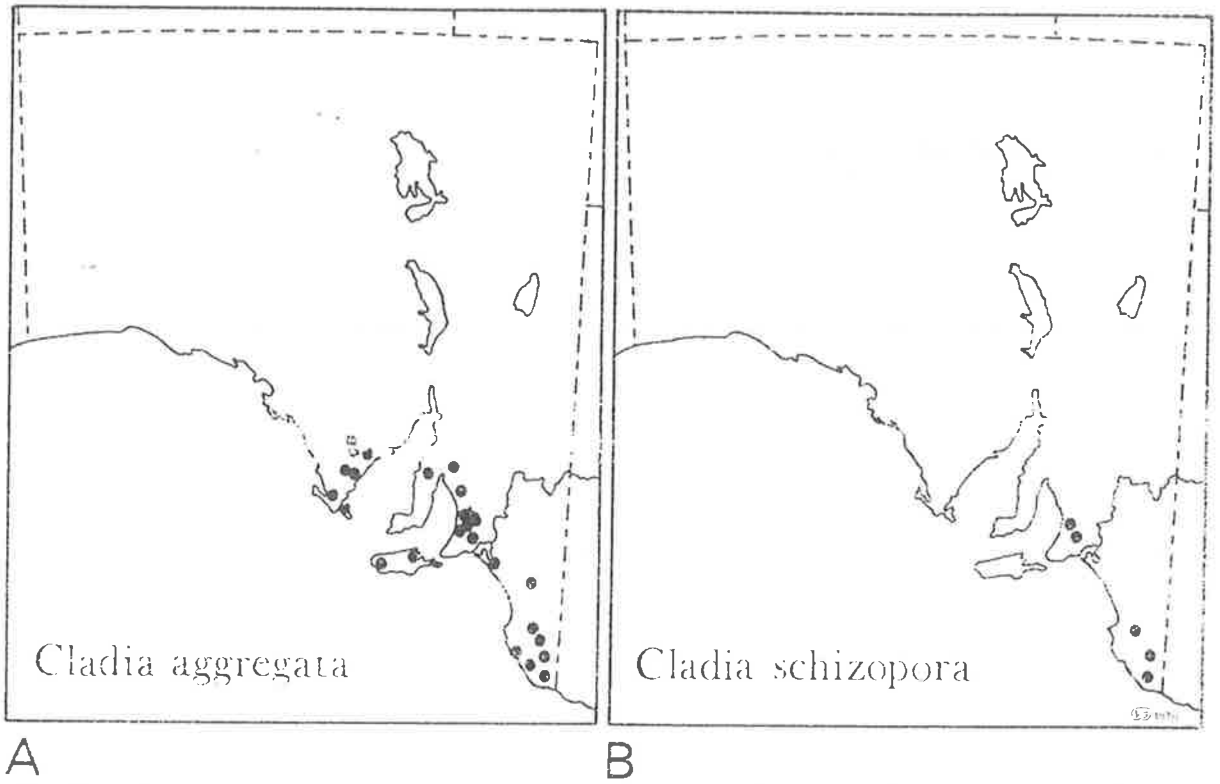

Fig. 8. A, known distribution of *Cladia aggregata* (Sw.) Nyl. in South Australia; B, known distribution of *Cladia schizopora* (Nyl.) Nyl. in South Australia.

Some species are confined to only a few localities, for example the beautiful *Cladia ferdinandii* known in South Australia only from the south of Eyre Peninsula, Kangaroo Island, the Aldinga National Park and near Meningie. Every occurrence is on sandy soil near the coast. Perhaps a thorough search will reveal this species growing on the tip of Yorke Peninsula, and on the sands near Robe or the Coorong. Establishing distribution patterns for lichens and interpreting the ecological factors controlling the distribution is a project that could be easily undertaken by any naturalist.

At present there are few lichen species which have been collected only from South Australia. However, as the lichen flora of the other States is examined in more detail, some of these lichens may be found to occur there. Surprisingly it appears that there is no lichen genus endemic to Australia. We know insufficient about the reproductive and dispersal mechanism of lichens to explain this, but endemism is apparently quite rare.

FURTHER READING

Recently a number of good books have become available on the general biology and ecology of lichens. The most suitable introductory volume is by Dr. Mason E. Hale Jr. of the Smithsonian Institution, Washington, D.C., U.S.A., entitled "The Biology of Lichens". For the more serious student two volumes published by Academic Press "The Lichens", edited by V. Ahmadjian and M. E. Hale, and "Lichen Ecology", edited by M. R. D. Seaward, are very well worthwhile.

HOW TO COLLECT LICHENS

Lichens are very easy to collect and the main tools which are needed are: a heavy hammer and a cold chisel (for forcing off slivers of rock bearing crustose species) and a sheath knife for detaching foliose and fruticose forms.

Always try to collect complete specimens, including the margins of the lichen and the fruiting structures when present. Never try to scrape crustose lichens off the substrate as the resultant crumbs and fragments are useless. With a little practice good complete specimens can be chiseled out from the rock. The rock fragment should be as thin as possible and no larger than 15-20 cm diameter. Foliose lichens should be carefully detached from the rock or wood with the knife blade. If the knife blade is cut into the rock immediately below the holdfast the rock will be found to be softer here and a small fragment of the rock will come away with the lichen complete.

In the field the specimens should be air-dried if possible and rock samples wrapped in tissue and placed in paper bags for transit to the laboratory. Never pack lichens in plastic bags as they quickly discolour and mould.

Once in the laboratory the collections should be first thoroughly air-dried before packing away when they may be sorted and curated at leisure.

Permission must be obtained before collecting in State Forests, Reserves and National Parks.

CURATION OF LICHENS

Specimens which are firmly attached to rock, bark or wood can be glued down with PVC adhesive to standard index card 75 x 125 mm. Lichen crusts on soil should be stabilised first. This is done by diluting the adhesive with water and adding one or two drops of detergent. The soil sample is then placed lichen side down on a piece of blotting paper. The dilute adhesive is fed onto the soil by means of a small dropper, taking care that it does not soak right through and spoil the sample. When the soil is fully charged with adhesive it is allowed to dry before fixing to card in the normal manner.

Fruticose or foliose specimens can be wetted and lightly pressed between blotting paper but special care must be taken that they do not mould on re-drying. Brittle species can also be fixed to card, either with adhesive or paper strips, to prevent fragmentation. The cards are then placed in 16 × 10 cm packets and stored upright in drawers or shoe boxes.

The documentation of specimens is of prime importance. Good samples are useless unless the precise locality of collection, the name of the collector, collector's number and date of collection are provided. Notes on the habitat, substrate and associated species are useful additions to the label. This label should be affixed to the front of the packet or printed onto the paper from which the packet is folded (Fig. 9).

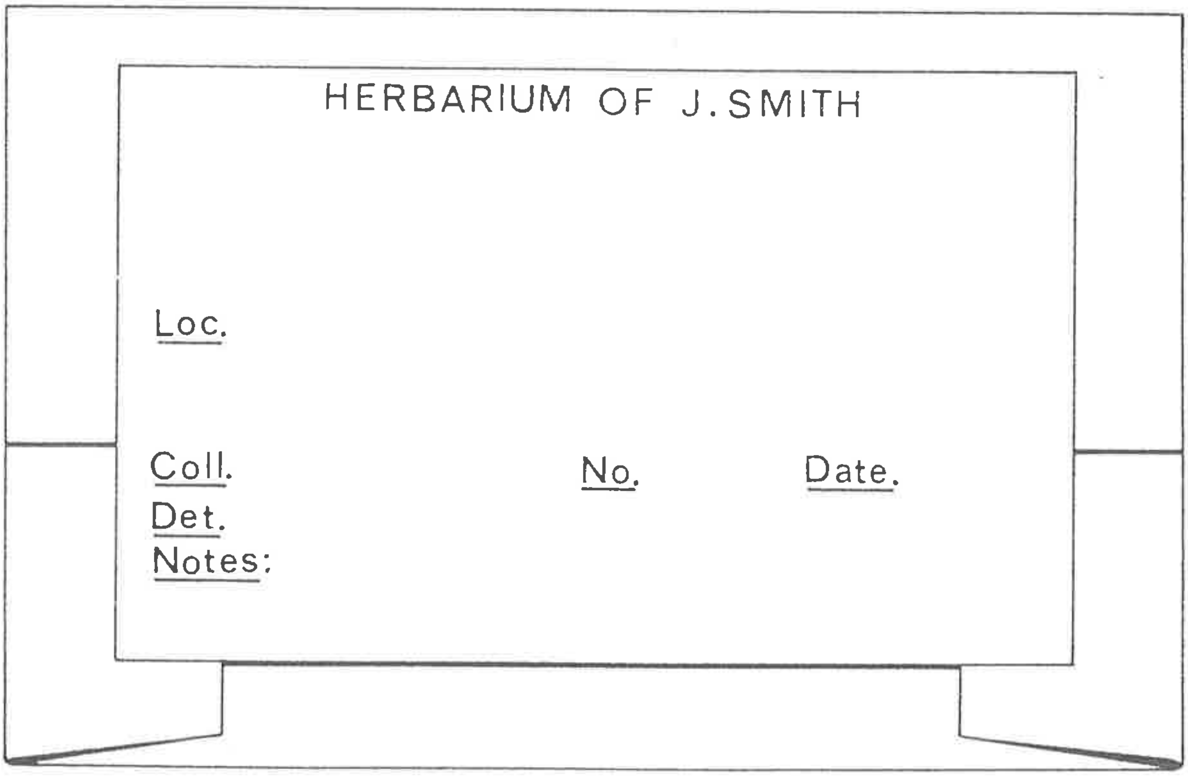

Fig. 9. Folded packet with label.

EXAMINATION OF MATERIAL FOR INDENTIFICATION

To study a lichen properly a small number of essential items are required: a good quality hand lens or dissecting microscope, for examining the morphological characters; a scalpel or one-edged razor blade; a pair of fine forceps; a needle in a handle; the use of a microscope with a magnification at least up to 400x and an eyepiece micrometer: glass slides and coverslips.

The most useful method of examining the fruiting structures of a lichen is to make a squash preparation. First soften the sample with a little water to which a drop or two of detergent has been added. Prick out a small piece from the apothecium, perithecium or pycnidium with a scalpel, corner of a razorblade or the point of a needle. This should be done under a low power dissecting microscope or with a hand lens. Transfer the small fragment to a drop of mounting solution (see below) on a clean glass slide, place a coverslip over it and press down firmly with the corner of a soft rubber or the plastic end of a ball point pen. Just enough pressure should be applied to spread the tissue and not mutilate it or break the coverslip. Examine the preparation two or three times during squashing, first when the tissue breaks so as to note colour and thickness of the epithecium, hymenium, hypothecium, position and kind of exciple. Then apply more pressure and note the size and shape of filaments, paraphyses, and asci. Finally press hard enough to burst the asci and release the spores so that they can be measured free.

For temporary preparations the most suitable mounting solution is water, to which has been added a drop or two of detergent. For more permanent preparations the specimens can be mounted in lactophenol and the cover slips ringed with clear nail varnish. Slides prepared in this manner will last several years.

CLASSIFICATION

Prior to 1866 it was not recognised that lichens were dual organisms, an alga and a fungus. Even as late as 1896 a prominent lichenologist wrote "lichens are a special class different from and contrasting with fungi".

It is now widely accepted that lichen fungi ought to be classified along with other fungi. However, no satisfactory taxonomic system has been developed which integrates lichen fungi with the others. It is therefore necessary to classify lichens into Orders and Families of their own. These Orders can be arranged within Classes and Subclasses recognised amongst the non-lichenised fungi.

ARRANGEMENT OF THE SOUTH AUSTRALIAN LICHENS:

This arrangement is based on Hale (1967) and Poelt (1973).

CLASS **ASCOMYCETIDAE**

Order ARTHONIALES
  ARTHONIACEAE Reichenb.
    Arthonia Ach., *Arthothelium* Mass.

  OPEGRAPHACEAE Stiz. ex Tuck.
    Chiodecton Ach., *Enterographa* Fée, *Opegrapha* Ach.

Order DOTHIDEALES
  PLEOSPORACEAE Wint.
    Arthopyrenia Mass., *Polyblastiopsis* Zahlbr.

Order VERRUCARIALES
  VERRUCARIACEAE Eschw.
    Dermatocarpon Eschw., *Endocarpon* Hedw., *Verrucaria* Schrad.

Order PYRENULALES
  PYRENULACEAE Zahlbr.
    Anthracothecium Hampe ex Mass.

  TRYPETHELIACEAE Eschw.
    Trypethelium Spreng.

Order CALICIALES
  CALICIACEAE Fée
    Calicium Pers., *Chaenotheca* Th. Fr., *Cyphelium* Ach.

Order OSTROPALES
  THELOTREMATACEAE Zahlbr.
    Diploschistes Norm.

Order GRAPHIDALES
  GRAPHIDACEAE Dumort
    Graphina Müll. Arg., *Graphis* Adans., *Phaeographina* Müll. Arg., *Phaeographis* Müll. Arg.

  MELASPILEACEAE W. Wats.
    Melaspilea Nyl.

  GYALECTACEAE Zahlbr.
    Dimerella Trevis.

Order LECANORALES

LICHENACEAE Nyl.
Lichina C. Ag., *Synalissa* Fr., *Porocyphus* Koerb., *Thyrea* Mass.

HEPPIACEAE Zahlbr.
Heppia Naeg., *Peltula* Nyl.

PLACYNTHIACEAE Dahl
Psoroma (Ach.) Michx.

PELTIGERACEAE Dumort
Peltigera Willd.

NEPHROMACEAE Moreau
Nephroma Ach. ex Luyken

LOBARIACEAE Chev.
Pseudocyphellaria Vain.

COLLEMATACEAE Fée
Collema Wigg., *Leptogium* (Ach.) Gray, *Physma* Mass.

COCCOCARPIACEAE Henssen
Coccocarpia Pers.

PANNARIACEAE Tuck.
Erioderma Fée, *Pannaria* Del., *Parmeliella* Müll. Arg.

LECIDEACEAE Chev.
Bacidia de Not., *Bombyliospora* de Not., *Catillaria* Mass. em Th. Fr.
Lecidea Ach. em Th. Fr., *Rhizocarpon* Ram. ex DC., *Toninia* Mass.

LECANORACEAE Fée
Haematomma Mass., *Lecanora* Ach. ex Luyken

ASPICILIACEAE Poelt
Aspicilia Mass.

PARMELIACEAE Eschw.
Chondropsis Nyl., *Hypogymnia* Nyl.. *Menegazzia* Mass., *Parmelia* Ach.

USNEACEAE Eschw.
Usnea P. Browne ex Adans.

RAMALINACEAE C.A. Ag.
Ramalina Ach. ex Luyken

ANZIACEAE Sato
Anzia Stiz.

STEREOCAULACEAE Chev.
Pilophorus Th. Fr.

CLADONIACEAE Reichenb.
Cladonia Hill ex Web. in Wigg., *Gymnoderma* Nyl., *Thysanothecium* Mont. et Berk., *Ramalea* Nyl.

CLATHRINACEAE Duv.
Cladia Nyl.

HETERODEACEAE Filson
Heterodea Nyl.

BAEOMYCETACEAE Fée
Baeomyces Pers., *Icmadophila* Trevis.

SIPHULACEAE Reichenb.
Siphula Fr.

ACAROSPORACEAE Zahlbr.
Acarospora Mass., *Biatorella* de Not., *Maronea* Mass., *Sarcogyne* Flot.

PERTUSARIACEAE Koerb.
Ochrolechia Mass., *Pertusaria* DC.

CANDELARIACEAE Hakulinen
Candelaria Mass., *Candellariella* Müll. Arg.

TELOSCHISTACEAE Zahlbr.
Blastenia Mass., *Caloplaca* Th. Fr., *Fulgensia* Mass. et de Not. *Teloschistes* Norm., *Xanthoria* (Fr.) Th. Fr.

PHYSCIACEAE Zahlbr.
Anaptychia Koerb., *Buellia* de Not., *Diploicia* Mass., *Physcia* (Schreb.) Michx., *Physciopsis* Choisy, *Rinodina* (Ach.) Gray.

TRAPELIACEAE H. Hertel
Trapelia Choisy

NOTES ON THE KEYS AND DESCRIPTIONS

In the following pages keys are provided to the families and genera of lichens which are known to occur, or are likely to occur, in South Australia. To determine the genus to which a specimen belongs, two different approaches are possible. The specimen may be keyed directly to genus using the *Artificial Key to Genera*. This is probably the easiest and quickest way to get a result. This is certainly the best key to use when the material is sterile.

The *Artificial Key to Families* and the *Artificial Key to Genera within Families* require fertile material and often require difficult decisions to be made early in the key. Before attempting to use these keys the student should be familiar with simple squash preparations and the chemical reagent tests.

Following the keys is a systematic treatment of the genera. This treatment includes a description of each genus and an account of what is known of the species which occur in South Australia. Where possible a key to these species is provided together with a short description and a selected list of specimens to give some indication of the distribution.

Anyone using this handbook can expect to discover species or genera hitherto unrecorded in South Australia. Inability to name a specimen from this study is therefore not failure, but a possible new find and may represent an advance in our knowledge of South Australian lichens.

ARTIFICIAL KEY TO FAMILIES

1. Phycobiont blue-green (Cyanophyta, genera includes *Calothrix, Nostoc, Scytonema* and *Gloeocapsa)* 2
1. Phycobiont green (Chlorophyta, genera includes *Chlorella, Chlorosarcina, Coccobotrys, Coccomyxa, Myrmecia, Haematococcus, Pseudochlorella,* and most commonly *Trebouxia)* 10
    2. Thallus gelatinous when wet 3
    2. Thallus not gelatinous when wet 5
3. Thallus a thin film on the substrate .... VERRUCARIACEAE
3. Thallus foliose or fruticose 4
    4. Thallus foliose, apothecium with open disk, phycobiont *Nostoc* .... COLLEMATACEAE
    4. Thallus fruticose, apothecium flask-like or open, phycobiont *Calothrix* or *Gloeocapsa* .... LICHINACEAE
5. Thallus foliose 6
5. Thallus more or less squamulose 8
    6. Apothecia laminal .... COCCOCARPIACEAE
    6. Apothecia on upper or lower tips of the lobes 7
7. Apothecia produced on the upper surface of the thallus lobe .... PELTIGERACEAE
7. Apothecia produced on the lower surface of the thallus lobe .... NEPHROMACEAE
    8. Medulla well developed, asci usually with eight ascospores 9
    8. Medulla absent or poorly developed, asci sometimes with eight but usually with greater than 16 ascospores .... HEPPIACEAE
9. Upper cortex of longitudinal hyphae .... COCCOCARPIACEAE
9. Upper cortex of erect hyphae .... PANNARIACEAE
    10. Fruiting bodies immersed (perithecia) 48
    10. Fruiting bodies discoid or elongate not immersed 11
11. Fruiting bodies elongate (lirellae) sometimes stellately arranged or in lines 45
11. Fruiting bodies discoid (apothecia) 12
    12. Apothecia with a proper exciple only 13
    12. Apothecia with a thalline exciple usually displacing the proper exciple 23

13. Ascospores brown .... PHYSCIACEAE
13. Ascospores hyaline 14
  14. Thallus crustose or squamulose supporting podetia or pseudopodetia. 15
  14. Thallus not crustose or squamulose supporting podetia or pseudopodetia 17
15. Apothecia pink, rarely turning brown, primary thallus crustose .... BAEOMYCETACEAE
15. Apothecia black, brown or red, primary thallus squamulose or rarely servediose 16
  16. Apothecia jet black (in SA) podetia deep green . STEREOCAULACEAE
  16. Apothecia dark brown, pale brown, red .... CLADONIACEAE
17. Thallus of pseudopodetia, pseudopodetia hollow, fenestrate CLATHRINACEAE
17. Thallus not of pseudopodetia 18
  18. Thallus crustose 19
  18. Thallus foliose or fruticose 22
19. Thallus yellow orange or greenish-orange 21
19. Thallus not as above 20
  20. Paraphyses thick, inflated at apices .... LECIDEACEAE
  20. Paraphyses thin, not inflated at apices .... TRAPELIACEAE
21. Thallus yellow, orange or greenish-orange, K+ purple .... TELOSCHISTACEAE
21. Thallus yellow or greenish-yellow, K− .... CANDELARIACEAE
  22. Apothecia yellow or orange, disk K+ purple .... TELOSCHISTACEAE
  22. Apothecia pale brown, K− .... HETERODEACEAE
23. Thallus crustose or squamulose 24
23. Thallus foliose or fruticose 32
  24. Ascospores minute, many per ascus .... ACAROSPORACEAE
  24. Ascospores larger, two to eight per ascus 25
25. Apothecia with well developed thalline and proper exciples 26
25. Apothecia with the thalline exciple dominant, the proper exciple virtually displaced 27
  26. Thallus crustose, thick, terricolous .... THELOTREMACEAE
  26. Thallus crustose, thin, endophloeodal .... GYALECTACEAE
27. Apothecia sunken, disk almost closed by a thick thalline margin .... PERTUSARIACEAE
27. Apothecia immersed, adnate, sessile, disk open, thalline margin thin . . . 28
  28. Ascospores brown .... PHYSCIACEAE
  28. Ascospores hyaline 29
29. Apothecia yellow, orange, the disk K+ purple ..... TELOSCHISTACEAE
29. Apothecia pale to dark brown to black, the disk K− 30
  30. Thallus squamulose .... PLACYNTHIACEAE
  30. Thallus crustose 31
31. Apothecia sessile, rarely immersed, ascospores less than 30 µm long .... LECANORACEAE
31. Apothecia immersed, ascospores large .... ASPICILIACEAE
  32. Thallus foliose 33

32. Thallus fruticose 38
33. Apothecia yellow or orange, the disk K+ purple ... TELOSCHISTACEAE
33. Apothecia yellow, green, grey, brown, disk K− 34
34. Ascospores non-septate 35
34. Ascospores septate 37
35. Lower surface corticate.......................... PARMELIACEAE
35. Lower surface ecorticate....................................... 36
36. Lower surface with a thick layer of tomentum .... ANZIACEAE
36. Lower surface of interwoven hyphae .... PLACYNTHIACEAE
37. Thallus usually small, less than 5 cm diam., grey-green, lower surface sparsely rhizinate, without pores through the lower cortex .... PHYSCIACEAE
37. Thallus usually large, yellow-green to brown, lower surface densely rhizinate sometimes with pores through the lower cortex .... LOBARIACEAE
38. Apothecium with a proper exciple only 39
38. Apothecium with a thalloid exciple 42
39. Thallus crustose or squamulose supporting podetia or pseudopodetia... 40
39. Thallus not crustose or squamulose supporting podetia or pseudopodetia .... CLATHRINACEAE
40. Apothecia pink, rarely turning brown, primary thallus crustose .... BAEOMYCETACEAE
40. Apothecia black, brown or red, primary thallus squamulose or rarely sorediose 41
41. Apothecia jet black (in SA) podetia deep green .... STEREOCAULACEAE
41. Apothecia dark brown, pale brown, red............. CLADONIACEAE
42. Thallus of rather flattened yellow branches K+ purple .... TELOSCHISTACEAE
42. Thallus of flattened or terete grey to grey-green branches K+ yellow or yellow-red, not purple 43
43. Thallus flat, thick, upright, low, terricolous, grey, K+ yellow .... SIPHULACEAE
43. Thallus not as above 44
44. Thallus upright or pendulous, flat or terete with distinct central axis .... USNEACEAE
44. Thallus upright or pendulous, flat or inflated without a central axis .... RAMALINACEAE
45. Ascocarp immersed to sessile, surrounded by thalline tissue, ascospores colourless 3-15 septate .... OPEGRAPHACEAE
45. Ascocarps sparingly or not bordered by thalline tissue 46
46. Ascocarps round to irregularly branched, receptacle rudimentary, ascospores colourless or tinged with brown, 1-8 septate .... ARTHONIACEAE
46. Ascocarps elongate, irregularly branched, receptacle thick, interwoven 47
47. Ascospores 1 septate, pale brown .... MELASPILEACEAE

47. Ascospores several septate to muriform .... GRAPHIDACEAE
48. Perithecia many in stroma, ascospores colourless . TRYPETHELIACEAE
48. Perithecia solitary or grouped in warts 49
49. Ascospores transversely septate .... PLEOSPORACEAE
49. Ascospores simple or muriform 50
50. Ascospores simple .... VERRUCARIACEAE
50. Ascospores muriform 51
51. Thallus crustose .... PYRENULACEAE
51. Thallus squamulose .... VERRUCARIACEAE

ARTIFICIAL KEY TO GENERA WITHIN FAMILIES
(arranged alphabetically)

The number of species at present known from South Australia is shown in parenthesis.

ACAROSPORACEAE

1. Apothecium with a thalloid exciple 2
1. Apothecium with only a proper exciple 3
2. Apothecium immersed, ascospores non-septate .... *Acarospora* (6)
2. Apothecium sessile, ascospores non- or once-septate ..... *Maronea* (1)
3. Exciple hyaline or coloured .... *Biatorella* (0)
3. Exciple dark, carbonaceous .... *Sarcogyne* (0)

ANZIACEAE

1. Thallus yellow to yellow-green, lower surface ecorticate with thick layer of tomentum .... *Anzia* (1)

ARTHONIACEAE

1. Thallus crustose or immersed, disk irregularly round or oblong, ascospores clavate 3-8 septate .... *Arthothelium* (0)
1. Thallus crustose or immersed, disk irregularly round, ascospores obovate to fusiform .... *Arthonia* (0)

ASPICILIACEAE

1. Thallus crustose to effigurate, apothecia immersed, ascospores large, up to eight per ascus .... *Aspicilia* (1)

BAEOMYCETACEAE

1. Primary thallus crustose or sorediose, apothecia borne on pale pink podetia .... *Baeomyces* (0)
1. Primary thallus crustose or granulose, apothecia sessile .. *Icmadophila* (0)

CALICIACEAE

1. Ascocarps stalked 2
1. Ascocarps sessile ascospores brown, 1-septate .... *Cyphelium* (0)
2. Ascospores brown, 1-septate .... *Calicium* (1)
2. Ascospores brown, simple .... *Chaenotheca* (0)

CANDELARIACEAE

1. Thallus lobes flattened, sub-foliose, minutely incised, ascospores hyaline, eight per ascus .... *Candelaria* (1)
1. Thallus completely granular or sometimes minutely sub-squamulose ascospores hyaline, 16 per ascus .... *Candelariella* (3)

CLADONIACEAE

1. Podetia short, simple, seldom forked 2
1. Podetia longer, often branched, simple or cup-shaped...... *Cladonia* (11)
   2. Primary thallus foliose, podetia marginal .... *Gymnoderma* (0)
   2. Primary thallus crustose or granular podetia laminal 3
3. Apothecia lateral, podetia foveolate or striate .... *Thysanothecium* (1)
3. Apothecia terminal, podetia granular and deformed .... *Ramalea* (0)

CLATHRINACEAE

1. Thallus of pseudopodetia with longitudinal cracking or fenestration *Cladia* (4)

COCCOCARPIACEAE

1. Upper cortex composed of longitudinal hyphae .... *Coccocarpia* (1)

COLLEMATACEAE

1. Thallus corticate .... *Leptogium* (2)
1. Thallus ecorticate 2
   2. Ascospores non-septate .... *Physma* (0)
   2. Ascospores septate .... *Collema* (6)

GRAPHIDACEAE

1. Ascospores hyaline 2
1. Ascospores brown 3
   2. Ascospores transversely septate only .... *Graphis* (0)
   2. Ascospores muriform .... *Graphina* (0)
3. Ascospores transversely septate only .... *Phaeographis* (0)
3. Ascospores muriform .... *Phaeographina* (0)

GYALECTACEAE

1. Thallus thin, granulose, or endophloedal, apothecia yellow-orange *Dimerella* (0)

HEPPIACEAE

1. Ascospores eight per ascus .... *Heppia* (1)
1. Ascospores many per ascus .... *Peltula* (4)

HETERODEACEAE

1. Thallus foliose, upper side pale green to greyish-green; lower surface black, black with pale depressions, or pale .... *Heterodea* (2)

LECANORACEAE

1. Ascospores septate . . . . . *Haematomma* (1)
1. Ascospores non-septate . . . . . *Lecanora* (4)

LECIDEACEAE

1. Ascospores non-septate . . . . . *Lecidea* (4)
1. Ascospores variously septate 2
    2. Ascospores transversely septate only 3
    2. Ascospores transversely and longitudinally septate 5
3. Ascospores two- many septate . . . . . *Bacidia* (0)
3. Ascospores once septate 4
    4. Ascospores acicular . . . . . *Toninia* (1)
    4. Ascospores more or less ovoid . . . . . *Catillaria* (?)
5. Ascospores hyaline, apothecia orange-brown . . . . . *Bombyliospora* (1)
5. Ascospores brown, apothecia black . . . . . *Rhizocarpon* (1)

LICHINACEAE

1. Growing in marine environments below high tide level, phycobiont *Calothrix* . . . . . *Lichina* (1)
1. Not growing in marine environments 2
    2. Thallus a mat of thin branched filaments, phycobiont *Stigonema* . . . . . *Ephebe* (1)
    2. Thallus upright not a mat of branched filaments 3
3. Thallus terete, phycobiont *Gloeocapsa* or *Calothrix* 4
3. Thallus broad and flat, phycobiont *Xanthocapsa* . . . . . *Thyrea* (1)
    4. Terricolous in arid areas, phycobiont *Gloeocapsa* . . . . . *Synalissa* (1)
    4. Saxicolous in damp areas on rock outcrops, phycobiont *Calothrix* . . . . . *Porocyphus* (1)

LOBARIACEAE

1. Thallus large, marginal lobes broad, underside densely covered with short rhizines, yellow pseudocyphellae present . . . . . *Pseudocyphellaria* (2)

MELASPILEACEAE

1. Thallus crustose, apothecia rounded or elongate, ascospores brown 1-septate . . . . . *Melaspilea* (0)

NEPHROMACEAE

1. Thallus yellow-green, green or brown, phycobiont blue-green, apothecia on the under side of the lobe ends . . . . . *Nephroma* (0)

OPEGRAPHACEAE

1. Thallus crustose, apothecia immersed in stroma 2
1. Thallus crustose, apothecia not immersed in stroma . . . . . *Opegrapha* (0)
    2. Hypothecium dark . . . . . *Chiodecton* (0)
    2. Hypothecium pale . . . . . *Enterographa* (0)

PANNARIACEAE

1. Thallus squamulose to subfoliose, upper surface smooth 2
1. Thallus subfoliose to foliose, upper surface covered in soft hairy tomentum .... *Erioderma* (0)
    2. Apothecia lecanorine .... *Pannaria* (1)
    2. Apothecia lecideine .... *Parmeliella* (0)

PARMELIACEAE

1. Lower cortex devoid of rhizines 2
1. Lower cortex with rhizines .... *Parmelia* (60)
    2. Thallus solid with thick, tough, small-celled upper cortex rolling into a ball when dry .... *Chondropsis* (1)
    2. Thallus solid or hollow with a thin, larger celled upper cortex, not rolling into a ball when dry 3
3. Upper cortex perforate .... *Menegazzia* (1)
3. Upper cortex imperforate .... *Hypogymnia* (4)

PELTIGERACEAE

1. Thallus deep blue green, phycobiont blue-green, apothecia on upper side of the lobe ends .... *Peltigera* (1)

PERTUSARIACEAE

1. Thallus crustose, apothecia in warts, disk almost completely covered by margin, only small pore visible .... *Pertusaria* (?)
1. Thallus crustose, apothecia sessile or immersed, disk open, margin at first large and heavily inrolled .... *Ochrolechia* (4)

PHYSCIACEAE

1. Thallus crustose 2
1. Thallus foliose 4
    2. Thallus sorediose, non fertile .... *Buellia (Diploicia)* (1)
    2. Thallus non-sorediose, fertile 3
3. Apothecia with a proper exciple only .... *Buellia* (6)
3. Apothecia with a thalline exciple .... *Rinodina* (2)
    4. Upper cortex of hyphae parallel to the surface .... *Anaptychia* (5)
    4. Upper cortex of hyphae vertical to the surface 5
5. Pycnidiospores 10-25 μm long, upper surface K−, closely appressed to the substrate, usually grey-brown .... *Physciopsis* (2)
5. Pycnidiospores 2-3 μm long, upper surface K+, attached to the substrate by longer rhizines, grey-blue or pale grey .... *Physcia* (9)

PLACYNTHIACEAE

1. Thallus squamulose to subfoliose, apothecia large up to 3 mm diam., ascospores hyaline, simple .... *Psoroma* (1)

PLEOSPORACEAE

1. Ascospores transversely septate . . . . *Arthopyrenia* (0)
1. Ascospores muriform . . . . *Polyblastiopsis* (0)

PYRENULACEAE

1. Thallus crustose, ascospores muriform, brown . . . . . . *Anthracothecium* (0)

RAMALINACEAE

1. Thallus fruticose, erect or pendulous, flattened or inflated, without a central axis . . . . *Ramalina* (4)

SIPHULACEAE

1. Thallus terricolous, fruticose, flattened or subterete, thick, attached to the substrate by penetrating rhizines . . . . *Siphula* (1)

STEREOCAULACEAE

1. Thallus granular-crustose, pseudopodetia deep green, non-branched, apothecia terminal, black . . . . *Pilophorus* (1)

TELOSCHISTACEAE

1. Thallus fruticose or subfoliose, upper cortex of hyphae parallel to the surface . . . . *Teloschistes* (4)
1. Thallus foliose, upper cortex pseudoparenchymatous, hyphae vertical to the surface . . . . *Xanthoria* (2)

THELOTREMATACEAE

1. Thallus terricolous or saxicolous, crustose, apothecia sunken into low warts, ascospores brown, muriform . . . . *Diploschistes* (3)

TRAPELIACEAE

1. Thallus crustose fruiting bodies immersed, ascospores simple, hyaline . . . . *Trapelia* (1)

TRYPETHELIACEAE

1. Thallus crustose, fruiting bodies immersed in stromatic warts, ascospores hyaline, transversely septate . . . . *Trypethelium* (0)

USNEACEAE

1. Thallus fruticose, erect or pendulous, terete, simply or compoundly branched with a strong central axis. . . . . *Usnea* (5)

VERRUCARIACEAE

1. Thallus crustose, saxicolous in marine environments . . . . *Verrucaria* (1)
1. Thallus squamulose, terricolous or saxicolous in arid non-marine environments 2
    2. Perithecia immersed, ascospores non-septate, hyaline *Dermatocarpon* (2)
    2. Perithecia immersed, ascospores muriform, brown . . . . *Endocarpon* (4)

ARTIFICIAL KEY TO GENERA

1. Thallus fruticose or foliose 2
1. Thallus squamulose, crustose or leprose 3
  2. Thallus fruticose .... Section I
  2. Thallus foliose .... Secton II
3. Thallus squamulose or crustose .... Section III
3. Thallus leprose .... Section IV

Section I. Fruticose thalli

1. Thallus gelatinous when wet, phycobiont blue-green 2
1. Thallus not gelatinous when wet, phycobiont green 5
  2. In marine splash zone on rocks .... *Lichina*
  2. Not in marine splash zone, on rocks and soil 3
3. Thallus a mat of elongate prostrate to ascending filaments .... *Ephebe*
3. Thallus more or less ascending not filamentous 4
  4. Thallus a cushion of thin, ascending terete branches .... *Porocyphus*
  4. Thallus forming a crust-like plaque of ascending branches as thick as they are tall .... *Synalissa*
5. Primary thallus crustose bearing minute stipes a few millimetres tall, the stipes not photosynthetic, apothecia more or less globular on the stipes . 6
5. Thallus truly fruticose, or primary thallus crustose or squamulose but bearing podetia or pseudopodetia which are photosynthetic 7
  6. Ascospores non-septate .... *Chaenotheca*
  6. Ascospores once-septate .... *Calicium*
7. Thallus less than 1 cm tall, leprose- sorediose, in sheltered parts under rocky overhangs .... *Leprocaulon*
7. Thallus not as above 8
  8. Thallus elongate, thin, cylindrical to more or less terete 9
  8. Thallus thick, more or less irregular 13
9. Thallus hollow upright on earth or amongst litter with few or many perforations through the walls .... *Cladia*
9. Thallus solid, compactly filled with medulla 10
  10. Thallus with a resistant central axis .... *Usnea*
  10. Thallus without a resistant central axis 11
11. Thallus perforated through the outer walls growing upright on earth or amongst litter .... *Cladia*
11. Thallus not perforated, pendulous from trees or rocks or recumbent on calcareous soil 12
  12. Thallus recumbent on soil .... *Aspicilia*
  12. Thallus erect or pendulous on trees .... *Ramalina*
13. Primary thallus granulate-crustose, apothecia on erect pseudopodetia .. 14
13. Primary thallus not granular crustose 17
  14. Apothecia pink or pale to dark brown 15
  14. Apothecia black 16
15. Apothecia terminal pink to pale brown .... *Baeomyces*
15. Apothecia laminal, cream to slate .... *Thysanothecium*
  16. Apothecia aggregated, disk flat .... *Cladia*

16. Apothecia not aggregated, disk hemispheric .... *Gymnoderma*
17. Thallus hollow 18
17. Thallus solid 21
18. Thallus forming cups .... *Cladonia*
18. Thallus not forming cups 19
19. Thallus much inflated and somewhat lacerate, perforations in the walls very irregular .... *Ramalina*
19. Thallus not inflated or lacerate 20
20. Thallus with a regular pattern of perforations through the walls into the central cavity .... *Cladia*
20. Thallus imperforate, slightly irregularly perforate, or perforations appearing only in the axils of the branches .... *Cladonia*
21. Thallus yellow-green to flame-orange, K+ purple .... *Teloschistes*
21. Thallus other than above, K− 22
22. Thallus with basal squamules, on charred tree stumps or hard soil 23
22. Thallus without basal squamules 24
23. Brownish-green to yellow-brown, apothecia terminal .... *Ramalea*
23. Straw-yellow to yellowish-green, apothecia lateral .... *Thysanothecium*
24. On twigs, bark and occasionally on rock .... *Ramalina*
24. On soil 25
25. With extensive underground branching system, thallus mineral-grey, medulla white .... *Siphula*
25. Without extensive underground branching system, thallus greenish-brown, medulla yellow .... *Ramalea*

Section II. Foliose thalli

1. Phycobiont blue-green 2
1. Phycobiont green 15
2. Thallus gelatinous when wet 3
2. Thallus not gelatinous when wet 9
3. Thallus corticate 4
3. Thallus ecorticate 6
4. Cortex distinctly cellular .... *Leptogium*
4. Cortex of interwoven hyphae 5
5. Ascospores non-septate, thick walled .... *Physma*
5. Ascospores septate, thin walled .... *Collema*
6. Phycobiont *Nostoc* 7
6. Phycobiont *Calothrix* or *Xanthocapsa* 8
7. Ascospores non-septate, thick walled .... *Physma*
7. Ascospores septate, thin walled .... *Collema*
8. Phycobiont *Calothrix* .... *Porocyphus*
8. Phycobiont *Xanthocapsa* .... *Thyrea*
9. Lower cortex pseudocyphellate .... *Pseudocyphellaria*
9. Lower cortex not pseudocyphellate 10
10. Lower cortex veined .... *Peltigera*
10. Lower cortex not veined 11
11. Upper surface covered in soft hairy tomentum .... *Erioderma*

11. Upper surface smooth 12
  12. Apothecia lecideine 13
  12. Apothecia lecanorine 14
13. Upper cortex of longitudinal hyphae .... *Coccocarpia*
13. Upper cortex not of longitudinal hyphae .... *Parmeliella*
  14. Ascospores ovoid-elongate, with a thin wall, upper and lower cortices well developed .... *Pannaria*
  14. Ascospores round to ovoid with a thick wall, cortices poorly developed to missing .... *Physma*
15. Lower surface pseudocyphellate or appearing pseudocyphellate 16
15. Lower surface not pseudocyphellate 17
  16. Lower surface a mat of black rhizoids or rhizoids restricted to marginal tufts with a spongy lower surface .... *Heterodea*
  16. Lower surface uniformly rhizinate, rhizines scattered, lower cortex distinctly cellular .... *Pseudocyphellaria*
17. Thallus gold or bright yellow, at least in part 18
17. Thallus neither gold nor bright yellow 20
  18. Thallus K− .... *Candelaria*
  18. Thallus K+ 19
19. Thallus foliose, closely appressed, not beset with fine cilia or spinules .... *Xanthoria*
19. Thallus more or less fruticose, ascending, often beset with fine cilia or spinules .... *Teloschistes*
  20. Thallus with vein-like markings on the lower surface 21
  20. Thallus without vein-like markings on the lower surface 22
21. Apothecia on the upper side of marginal lobes, lower surface ecorticate .... *Peltigera*
21. Apothecia on the lower side of marginal lobes, lower surface corticate .... *Nephroma*
  22. Lower surface with a dense tomentum 23
  22. Lower surface naked or rhizinate 24
23. Thallus brown or grey .... *Psoroma*
23. Thallus green or yellow-green .... *Anzia*
  24. Lower surface naked 25
  24. Lower surface rhizinate 29
25. Thallus hollow 26
25. Thallus solid 27
  26. Lobes perforated through the upper surface .... *Menegazzia*
  26. Lobes not perforated .... *Hypogymnia*
27. Thallus neatly dichotomous, curling into a ball when dry .... *Chondropsis*
27. Thallus irregularly lobed, not curling into a ball when dry 28
  28. Thallus lobes less than 2 mm broad, thallus flat, upper surface brown .... *Physciopsis*
  28. Thallus lobes more than 2 mm broad, thallus inflated, upper surface bluish-grey .... *Hypogymnia*
29. Rhizines restricted to the margins of the lobes 30
29. Rhizines uniformly distributed or absent from the margins 31

30. Margins of the thallus recurving when dry, cilia absent ...... *Heterodea*
30. Margins of the thallus not recurving when dry, ciliate ...... *Anaptychia*
31. Cortex poorly developed ...... *Normandina*
31. Cortex well developed, with apothecia if fertile 32
32. Thallus yellow-green, or with bulbate marginal cilia, or with dichotomous rhizines, or with a broad zone devoid of rhizines at the tips of the lobes ...... *Parmelia*
32. Thallus with none of the above characteristics 33
33. Ascospores unicellular, hyaline, lobes of many species more than 3 mm broad ...... *Parmelia*
33. Ascospores two-celled, brown, lobes less than 3 mm broad 34
34. Lower surface ecorticate ...... *Anaptychia*
34. Lower surface corticate 35
35. Thallus with marginal soralia, K+, P+ ...... *Anaptychia*
35. Thallus with other character combinations ...... *Physcia*

Section III. Crustose or squamulose thalli

1. Fruiting body stipitate, on podetia or pseudopodetia 2
1. Fruiting body immersed, adnate or sessile 13
2. Apothecia on tiny stipes not more than 1 mm tall 3
2. Apothecia on large podetial growths more than 3 mm tall 8
3. Ascospores brown, free in a mazaedium 4
3. Ascospores hyaline, enclosed in an ascus 5
4. Ascospores simple ...... *Chaenotheca*
4. Ascospores septate ...... *Calicium*
5. Ascospores many per ascus 6
5. Ascospores eight per ascus 7
6. Exciple pale, soft ...... *Biatorella*
6. Exciple black, brittle ...... *Sarcogyne*
7. Thallus crustose, apothecia lecanorine, ascospores septate ...... *Icmadophila*
7. Thallus squamulose, apothecia lecideine, ascospores non-septate ...... *Gymnoderma*
8. Apothecia lateral, broad and flat ...... *Thysanothecium*
8. Apothecia terminal, usually convex 9
9. Podetia perforate 10
9. Podetia imperforate 11
10. Podetia perforate only in the axils, apothecia not forming terminal cymes ...... *Cladonia*
10. Podetia extensively perforate, often becoming clathrate, apothecia sometimes forming terminal cymes ...... *Cladia*
11. Brownish-green to yellow-brown ...... *Ramalea*
11. Straw-yellow to yellowish -green 12
12. Primary thallus a fine powdery crust, podetia mostly devoid of algae ...... *Baeomyces*
12. Primary thallus granulose to squamulose, podetia with algal layer ...... *Cladonia*
13. Ascospores more than eight per ascus 14

13. Ascospores one to eight per ascus 19
14. Phycobiont blue-green .... *Peltula*
14. Phycobiont green 15
15. Apothecia immersed .... *Acarospora*
15. Apothecia adnate or sessile 16
16. Apothecia lecanorine 17
16. Apothecia lecideine 18
17. Thallus yellow .... *Candelariella*
17. Thallus grey to green .... *Maronea*
18. Exciple pale, soft .... *Biatorella*
18. Exciple dark, brittle .... *Sarcogyne*
19. Ascospores simple, unilocular 20
19. Ascospores septate or polaribilocular 36
20. Thallus squamulose 21
20. Thallus crustose 27
21. Phycobiont blue-green 22
21. Phycobiont green 23
22. Apothecia lecideine .... *Parmeliella*
22. Apothecia lecanorine .... *Pannaria*
23. Fruiting body an apothecium 24
23. Fruiting body a perithecium 26
24. Apothecia immersed .... *Trapelia*
24. Apothecia sessile to adnate 25
25. Apothecia lecideine .... *Lecidea*
25. Apothecia lecanorine .... *Psoroma*
26. Upper surface corticate, on rocks and soil .... *Dermatocarpon*
26. Upper surface ecorticate, on bark .... *Normandina*
27. Phycobiont blue-green 28
27. Phycobiont green 30
28. Thallus of discrete short, thick, erect, cylindrical lobes 29
28. Thallus granular .... *Pyrenopsidium*
29. Substrate siliceous .... *Porocyphus*
29. Substrate calcareous .... *Synalissa*
30. Fruiting body a perithecium .... *Verrucaria*
30. Fruiting body an apothecium 31
31. Apothecia immersed in the thallus or in warts 32
31. Apothecia adnate to sessile 34
32. Apothecia immersed in thalline warts .... *Pertusaria*
32. Apothecia not in warts 33
33. Paraphyses unbranched .... *Aspicilia*
33. Paraphyses branched and anastomosing .... *Trapelia*
34. Disk of apothecium K+ purple .... *Fulgensia*
34. Disk of apothecium K− or K+ but not K+ purple 35
35. Apothecia lecideine .... *Lecidea*
35. Apothecia lecanorine .... *Lecanora*
36. Fruiting body a perithecium or perithecium-like 37
36. Fruiting body not perithecial 42

37. Ascospores two-celled	*Microthelia*
37. Ascospores many-celled	38
38. Ascospores transversely septate only	39
38. Ascospores transversely and longitudinally septate	40
39. Fruiting bodies immersed in stromatic warts	*Trypethelium*
39. Fruiting bodies not immersed in stromatic warts	*Arthopyrenia*
40. Ascospores hyaline	*Polyblastiopsis*
40. Ascospores brown	41
41. Thallus squamulose	*Endocarpon*
41. Thallus crustose	*Anthracothecium*
42. Fruiting body with a round hymenial layer	43
42. Fruiting body with an elongate, irregular or star-shaped hymenial layer	58
43. Ascospores hyaline	44
43. Ascospores brown	54
44. Apothecia lecanorine	45
44. Apothecia lecideine	47
45. Ascospores with four or more cells	*Haematomma*
45. Ascospores two-celled or polaribilocular	46
46. Ascospores polaribilocular	*Caloplaca*
46. Ascospore walls not thickened	*Icmadophila*
47. Ascospores polaribilocular or two-celled	48
47. Ascospores more than two-celled	52
48. Ascospores polaribilocular	*Blastenia*
48. Ascospore walls not thickened	49
49. Thallus squamulose	*Toninia*
49. Thallus crustose	50
50. Apothecial disk yellow to orange	*Dimerella*
50. Apothecial disk pale to dark not orange	51
51. Apothecia less than 1 mm broad	*Catillaria*
51. Apothecia more than 1 mm broad	*Icmadophila*
52.Ascospores transversely septate only	*Bacidia*
52. Ascospores transversely and longitudinally septate	53
53. Apothecia black, ascospores grey to brown to black	*Rhizocarpon*
53. Apothecia yellow or pale, ascospores hyaline	*Bombyliospora*
54. Ascospores transversely septate only	55
54. Ascospores transversely and longitudinally septate	57
55. Apothecia lecideine	*Buellia*
55. Apothecia lecanorine	56
56. Ascospores free in a mazaedium	*Cyphelium*
56. Ascospores retained in the ascus	*Rinodina*
57. Apothecia immersed in the thallus or lecanorine	*Diploschistes*
57. Apothecia adnate to sessile, lecideine	*Rhizocarpon*
58. Ascospores transversely septate only	59
58. Ascospores transversely and longitudinally septate	65
59. Ascospores brown	60
59. Ascospores hyaline	61

  60. Ascospores two-celled .... *Melaspilea*
  60. Ascospores more than two-celled .... *Phaeographis*
61. Fruiting bodies clustered, immersed in stroma 62
61. Fruiting bodies single, not immersed in stroma 63
  62. Hypothecium dark .... *Chiodecton*
  62. Hypothecium pale .... *Enterographa*
63. Paraphyses unbranched, exciple well developed .... *Graphis*
63. Paraphyses branched and anastomosing, exciple usually poorly developed 64
  64. Ascospores usually two- to four-celled, cells of unequal size ... *Arthonia*
  64. Ascospores usually four or more celled, cells uniform ...... *Opegrapha*
65. Ascospores brown .... *Phaeographis*
65. Ascospores hyaline 66
  66. Paraphyses branched and anastomosing .... *Arthothelium*
  66. Paraphyses unbranched .... *Graphina*

Section IV. Leprose thalli

1. Thallus fruticose, pseudopodetia cartilaginous, leprose-servediose, powdery .... *Leprocaulon*
1. Thallus crustose, pseudopodetia absent, leprose, powdery .... *Lepraria*

1. ACAROSPORA Mass. 1852a:27

Literature: Magnusson 1929, Weber 1968.

Thallus squamulose, scattered or forming a continuous crust, margins often lobed, commonly cellular throughout. *Apothecia* minute, immersed to subimmersed, 1-3 in each squamule, ascospores more than 100 in an ascus, minute, simple, hyaline.

ARTIFICIAL KEY TO SPECIES

1. Thallus yellow, greenish-yellow, yellow and pruinose .... (Section Xanthothallia) 2
1. Thallus brown, reddish-brown to black, grey pruinose .... (Section Phaeothallia) 3
  2. Thallus of scattered areoles or if continuous then margins not lobate .... *A. schleicheri*
  2. Thallus contiguous, margins sublobate .... *A. novae-hollandiae*
3. Growing on rock 4
3. Growing on earth 7
  4. Thallus K+ red on non-calcareous rock .... *A. smaragdula*
  4. Thallus K− 5
5. Growing on non-calcareous rock 6
5. Growing on calcareous rock, thallus C− .... *A. cervina*
  6. Thallus C+ red, growing on non-ferruginous rock .... *A. fuscata*
  6. Thallus C−, growing on ferruginous rock .... *A. sinopica*
7. Thallus K+ red, on non-calcareous earth .... *A. reagens*
7. Thallus K− on calcareous earth .... *A. ferdinandii*

Acarospora cervina (Ach.) Mass. 1852a:28

Lecanora cervina Ach. 1814:188.

Thallus crustose to squamulose, indeterminate, pale brown, greyish-brown to greyish-white, often each areole has a white pruinose margin. *Apothecia* solitary or rarely two per areole; disk up to 1 (−2) mm diam., concave becoming level with the thallus at maturity, dark brown to black, sometimes pruinose; margin indistinct.

Reactions: Thallus K−, C−.

Specimen examined: On cement rendering on wall, Wynbring Rocks, 1·2 km north of Wynbring on East-West Railway Line, *R.B. Filson 11947,* 28.x.1970 (MEL 515439).

This species occurs also in Western Australia.

Acarospora ferdinandii (Müll. Arg.) Hue 1909:160.

Placodium ferdinandii Müll. Arg. 1881:508.

Thallus crustose or squamulose, of scattered areolae forming colonies varying from a few areolae to patches 5-6 cm diam.; areolae pale cream to dark brown in shaded habitats becoming heavily greyish-white pruinose in exposed. *Apothecia* solitary, rarely two per areole, up to 1·5 mm diam., at first punctiform becoming sessile at maturity; disk concave, dull, dark brown becoming jet black, epruinose; margin prominent, concolourous with the disk.

Reactions: Thallus K−, C−.

Figure: Habit, fig. 10A.

Specimens examined: Eyre Highway, 40 km east of Kimba, *R. B. Filson 11734,* 22.x.1970 (MEL 1017958); Mona, 6·4 km southwest of Bute, *R. B. Filson 12009,* 31.x.1970 (MEL 515435).

This species occurs also in Western Australia, Victoria and New South Wales.

Acarospora fuscata (Schrad.) Arn. 1872:279.

Lichen fuscatus Schrad. 1794:83.

Thallus crustose to squamulose, indeterminate, areolate, pale brownish-yellow to dark brown to reddish-brown, sometimes as scattered areoles sometimes continuous; upper surface smooth, somewhat shining. *Apothecia* one to several per areole; disk at first deeply punctiform then concave, reddish-brown to black.

Reactions: Thallus K−, C+ red, KC− red.

This species has not yet been recorded in South Australia, but it grows in the rocky sandstone areas in the Big Desert, Victoria, near to the South Australian border.

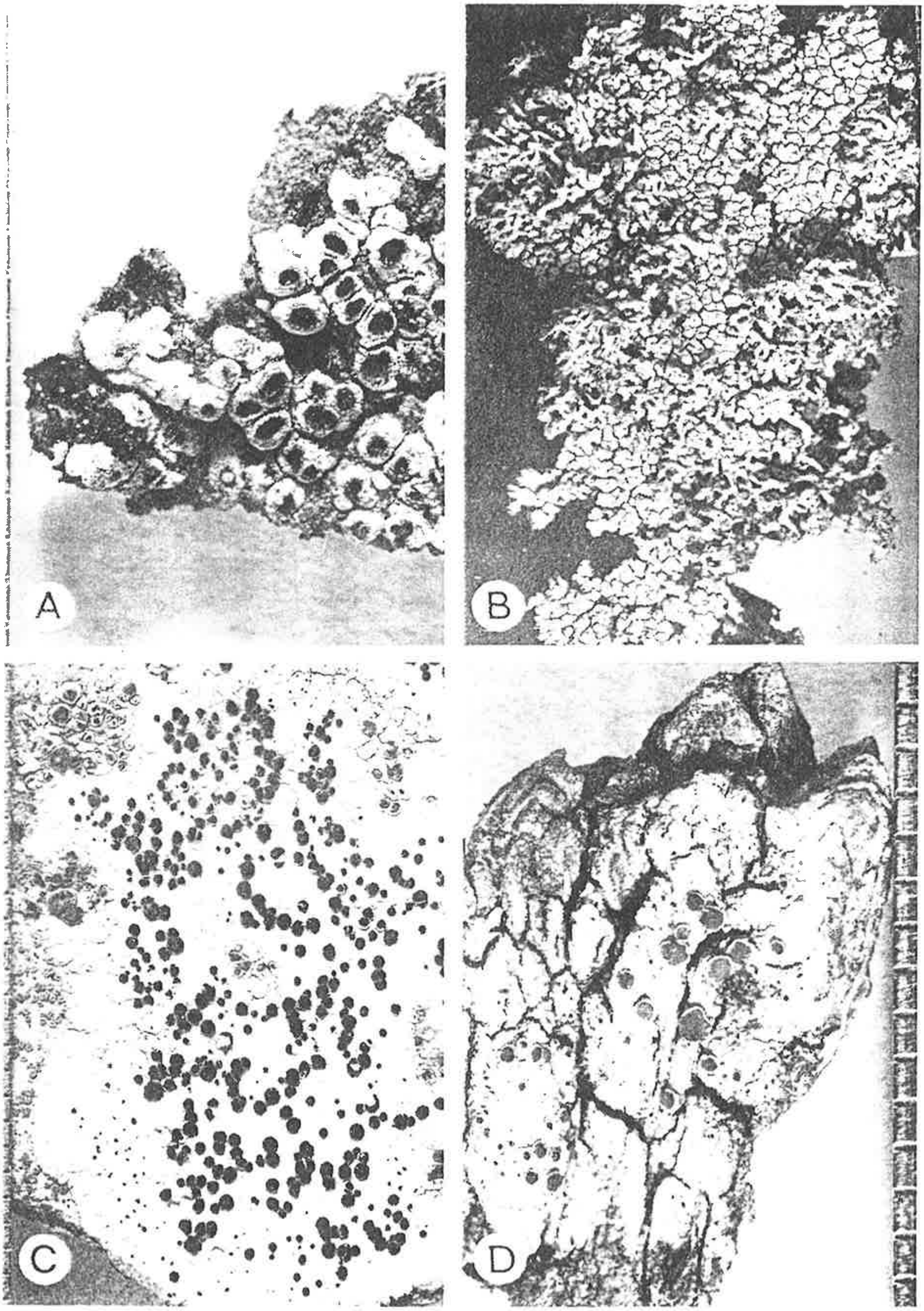

Fig. 10. A, *Acarospora ferdinandii*; B, *Aspicilia calcarea*; C, *Buellia subalbula*; D, *Caloplaca cerina*. Scale in millimetres.

Acarospora novae-hollandiae H. Magn. 1929:89.

Thallus crustose, contiguous, up to 8 cm diam., thin, greenish-yellow in the shade to bright primuline yellow in sunlight, epruinose; margins sublobate. *Apothecia* solitary, punctiform, 0·2-0·3 mm diam.; disk deeply immersed, dark brown to black; margin concolourous with the thallus heavily inrolled.

Reactions: Thallus K−, C−, UV+.

Specimens examined: vicinity of Arckaringa Creek, *R. Helms 66,* 25.v.1891 (MEL 9180); Everard Ranges, 3000 feet (1000 m), *R. Helms 85,* 3.vi.1891 (MEL 9183); Rocky hillside, Olive Grove Station, 14·5 km south of Quorn, *R. B. Filson 11991,* 30.x.1970 (MEL 515442).

The species occurs also in Western Australia, Northern Territory, Victoria and New South Wales.

Acarospora reagens Zahlbr. 1902:162.

Thallus crustose or squamulose of scattered areolae forming small colonies up to 3 cm diam.; areolae pale brownish-cream in shaded habitats becoming heavily greyish-white pruinose in exposed. *Apothecia* one to several per areole up to 1·5 mm diam. immersed in areolae; disk concave to flat, sometimes convex at maturity, dull, black, epruinose; margin indiscernible.

Reactions: K+ red, C−.

A. reagens occurs in Western Australia and Victoria; it has not yet been recorded in South Australia but it is likely to occur on soil in arid regions. It is very similar to *A. ferdinandii* differing in the emarginate apothecium which is never raised above the surface of the areolae and in the K+ reaction of the thallus.

Acarospora schleicheri (Ach.) Mass. 1852a:27.

Urceolaria schleicheri Ach. 1810:322.

Thallus crustose to squamulose, areolae scattered or sometimes contiguous but then the margins never become sublobate, thick, greenish-yellow to primuline yellow sometimes to pale orange. *Apothecia* solitary up to 0·5 (−1·0) mm diam. concave; disk pale reddish-brown to dark brown, concave; margin prominent or absent.

Reactions: K−, C−.

Selected specimens examined: c. 70 km south of Vokes Corner. Vokes Corner is c. 230 km north of Cook on the East-West Railway Line, *N. N. Donner 3974a,* 21.vii.1972 (MEL 1018590, AD); near the Everard Ranges, *R. Helms 25,* 31.v.1891 (MEL 9184); Officer Creek, 30 miles south of Everard Ranges, *D. N. Krahenbuehl 2413,* 5.ix.1968 (MEL 37635); Wynbring Rocks, 1·2 km north of Wynbring on the East-West Railway Line, *R. B. Filson 11942,* 28.x.1970 (MEL 515436); Wilgena Hill, 6·5 km north of Kingoonya-Tarcoola Road, 67·5 km west of Kingoonya, *R. B. Filson 11924,* 26.x.1970 (MEL 515434); vicinity of

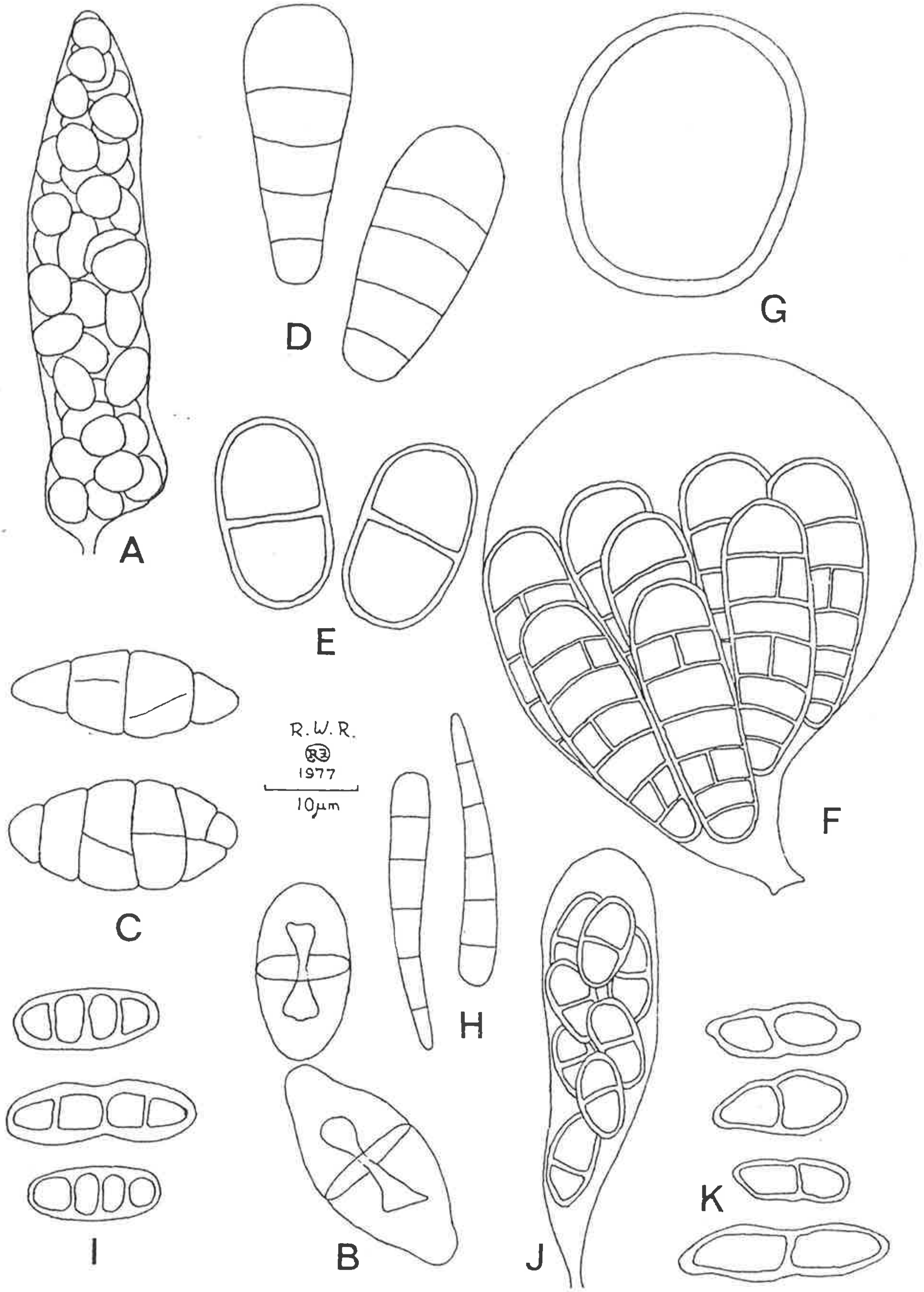

Fig. 11. A, *Acarospora smaragdula*, ascus containing spores; B, *Anaptychia tremulans*, ascospores; C, *Anthracothecium ochraceoflavum*, ascospores; D, *Arthonia* sp., ascospores; E, *Arthopyrenia alba*, ascospores; F, *Arthothelium* sp., ascus containing spores; G, *Aspicilia calcarea*, ascospore; H, *Bacidia fuscorubella*, ascospores; I, *Bombyliospora domingensis* var. *aurantiaca*, ascospores; J, *Buellia subalbula*, ascus containing spores; K, *Buellia parasema*, ascospores.

Arckaringa Creek, *R. Helms 65*, 25.v.1891 (MEL 9184); summit of low ridge above Warren Gorge, *J. Curtis 5*, 23.iv.1967 (MEL 26343).

Acarospora schleicheri is a very common yellow lichen found in almost every inland habitat where it sometimes covers areas many metres in diameter. It may be confused with *A. novae-hollandiae* which is also a yellow species growing in similar habitats; however *A. schleicheri* usually forms a thicker areole which does not have lobate, radiate margins and the areoles are more often scattered. On the other hand the thallus of *A. novae-hollandiae* is more often continuous, with radiate margins and the margins of isolated areole become sublobulate. These two species are difficult to separate when the sample consists of only a few areoles.

Acarospora sinopica (Wahlenb.) Körb. 1859:57.

Endocarpon sinopicum Wahlenb. apud Ach. 1803:30.

Thallus crustose, areolate, forming small patches on substrate, reddish-brown to dark brown to almost black. *Apothecia* abundant, one to several per areole; disk dark brown to black, deeply punctiform, 0·5 mm diam.

Reactions: K−, C−.

Specimen examined: Simpson Desert, K. G. Simpson, ? 1973 (MEL 1020179).

This species occurs also in Western Australia.

Acarospora smaragdula (Wahlenb.) Mass. 1852a:29.

Endocarpon smaragdulum Wahlenb. apud Ach. 1803:29.

Thallus crustose to squamulose, indeterminate, pale brownish-cream to mid-brown, usually scattered on substrate. *Apothecia* several per areole; disk dull, dark brown to black, up to 0·3 mm diam.; margin not prominent.

Reactions: K+ red, C−.

Figure: Ascus containing spores, fig. 11A.

Acarospora smaragdula has been recorded from dry areas in Western Australia; it has not yet been recorded in South Australia but is likely to occur on non-calcareous rock. It differs from the other rock-inhabiting species in the K+ reaction of the thallus.

2. ANAPTYCHIA Körb. 1848:197.

Literature: Kurokawa 1962.

Thallus foliose, prostrate to somewhat ascending at the margins, lobes flat or caniculate, often ciliate, attached to the substrate by rhizines which may be restricted to the margins, differentiated into an upper cortex of parallel hyphae, an algal and medullary layer and a poorly formed lower cortex. *Apothecia* small to large, sessile or pedicillate; disk slightly convex, brown, black or pruinose; margin concolourous with the thallus; ascospores eight in ascus, brown, oblong to ellipsoid, uniseptate.

ARTIFICIAL KEY TO SPECIES

1.	Lower surface corticate	2
1.	Lower surface ecorticate	3
2.	Medulla K+ yellow turning red	*A. pseudospeciosa*
2.	Medulla K+ persistent yellow	*A. tremulans*
3.	Medulla K+ yellow turning red	*A. dendritica*
3.	Medulla K+ persistent yellow	4
4.	Lower surface deep or brownish-yellow	*A. obscurata*
4.	Lower surface white	*A. japonica*

Anaptychia dendritica (Pers.) Vain. 1890a:134.

Borrera dendritica Pers. 1826:207.

Thallus greyish- or greenish-white, forming rosettes which sometimes coalesce, up to 15 cm in diam., attached to the substrate by marginal rhizines, lobes 0·7-2·0 mm broad, smooth, often slightly pruinose near the apices, without soredia or isidia; lower surface ecorticate and arachnoid, purple-black near the centre, but often yellow or ochraceous near the ends of the lobes. *Apothecia* rare, 1·0-4·0 mm diam.

Reactions: Thallus K+ yellow, medulla K+ yellow turning red, C−, P+ yellow.

This species occurs in Victoria, New South Wales and Queensland. It is at present not recorded for South Australia, but is likely to occur in the Mount Lofty Ranges or the South-East.

Anaptychia japonica (Sato) Kurokawa 1962:58.

Anaptychia dendritica var. *japonica* Sato 1936:427.

Thallus greyish-white forming colonies up to 5 cm diam., attached to the substrate by marginal rhizines; lobes 1·0-1·5 mm broad, smooth, sometimes lightly pruinose, the apices ascending with terminal soralia; lower surface white, corticate only at the margins, the rest arachnoid; rhizines marginal, white to black. *Apothecia* rare, 1·0-1·5 mm diam.; ascospores 11-15 x 22-30 μm, with thick walls and complex locules.

Reactions: Thallus K+ yellow, medulla K± yellow, C−, KC−, P± yellow.

Specimen examined: Hindmarsh Falls, *R. W. Rogers 2010,* 7.v.1976 (R.W.R.).

This species occurs over mosses on sheltered ledges at Hindmarsh Falls and is unlikely to be common in South Australia. It is found also in Victoria and on the Bass Strait islands.

Anaptychia obscurata Tuck. in Nyl. 1863b:440.

Thallus greyish- or greenish-white, up to 15 cm diam., attached to the substrate by marginal rhizines; lobes 0·7-2·0 mm broad, smooth, without pruina, forming capitate soralia at the tips of lateral lobes, non-isidiose; lower surface ecorticate and arachnoid, deep yellow to brownish-yellow. *Apothecia* rare 1·0-5·0 mm diam.

Reactions: Thallus K+ yellow, medulla K+ yellow, C−, KC−, P± pale yellow.

This species occurs in Victoria and New South Wales. It is not at present recorded in South Australia, but it is likely to occur in the Mount Lofty Ranges or the South-East.

Anaptychia pseudospeciosa Kurokawa 1959:176.

Thallus greyish-white forming rosettes which sometimes coalesce, up to 5 cm diam., attached to the substrate by laminal rhizines, non-isidiose; lobes 0·7-1·5 mm broad; soralia capitate at the tips of short lateral lobes; lower surface white, corticate, with sparse pale rhizines. *Apothecia* rare, 1·0-3·0 mm diam.

Reactions: Thallus K+ yellow, medulla K+ yellow turning red, C−, KC−, P+ yellow.

This species is common on coastal rocks in Victoria. It is not known in South Australia, but may occur on rocks in wetter areas.

Anaptychia tremulans (Müll. Arg.) Kurokawa 1973:597.

Physcia hypoleuca var. *tremulans* Müll. Arg. 1880:277.

Anaptychia pseudospeciosa var. *tremulans* (Müll. Arg.) Kurokawa 1962:26.

Thallus greyish-white forming rosettes which sometimes coalesce, up to 5 cm diam., attached to the substrate by laminal rhizines, non isidiose; lobes 0·7-1·5 mm broad with capitate soralia at tips of short lateral lobes; lower surface white, ecorticate, with sparse pale rhizines. *Apothecia* rare, 1·0-3·0 mm diam.; ascospores brown, thick walled, simple, 12-14 x 26-32 μm.

Reactions: Thallus K+ yellow, medulla K+ yellow, C−, KC−, P+ yellow.

Figure: Ascospores, fig. 11B.

Specimen examined: Victor Harbor, *R. W. Rogers 1887*, 28.viii.1970 (R.W.R.).

A common coastal species of Victoria, Tasmania, New South Wales and Queensland.

Kurokawa (1962) considered the species one of the commonest lichens in tropical and temperate regions. It is very variable in thallus morphology, and is found on a range of substrates, including both rock and bark. It is likely to be found throughout the wetter parts of the State, probably in association with *Physcia* species, with which it may be confused. *A. tremulans* differs from *A. pseudospeciosa* in the absence of salacinic acid resulting in the K+ yellow medullary reaction.

3. ANTHRACOTHECIUM Hampe apud Mass. 1860:330

Thallus crustose, epi- or endophloic, ecorticate. *Pseudothecia* perithecium-like, more or less immersed in small thalline warts, either singly or in groups; asci clavate with one to eight spores; ascospores brown, muriform; paraphyses unbranched, free.

Figure: Ascospores, fig. 11C.

No specimens referable to this genus have been located in South Australia, but it is likely to grow on bark in the South-East of the State.

4. ANZIA Stiz. 1861:44

Thallus foliose, lobate, upper surface corticate, cellular, of vertical hyphae, algal layer distinct, medulla woolly, composed of more or less parallel longitudinal interwoven hyphae; lower surface composed of a spongy network of anastomosing hyphae. *Apothecia* laminal, concave to crateriform, lecanorine; margin concolourous with the thallus; asci many spored; ascospores hyaline, simple, ellipsoidal or slightly curved.

ARTIFICIAL KEY TO SPECIES

1. Thallus isidiose, usually sterile . . . . *A. wilsonii*
1. Thallus non-isidiose, usually fertile . . . . *A. angustata*

Anzia angustata (Pers.) Müll. Arg. 1889:507.

Parmelia angustata Pers. 1826:195

Thallus yellow-green, up to 5 cm across, lobes 1·0-2·0 mm broad, non-isidiose; lower surface dark and spongy. *Apothecia* common up to 1 cm diam.

Figure: Habit, fig. 12B.

This species is common in Victoria and New South Wales; it is at present not recorded in South Australia, but is likely to occur in the Mount Lofty Ranges or in the South-East.

Anzia wilsonii Räs. 1944:2.

Thallus yellow-green, up to 5 cm across, lobes 1·0-2·0 mm broad, densely papillose-isidiose; lower surface with dark spongy patches. *Apothecia* rare 2·0-3·0 mm diam.

Figure: Habit, fig. 12A.

Specimen examined: Comaum, *K. Alcock 24*, 2.ix.1973 (MEL 1018635).

The species occurs in Victoria, Tasmania, New South Wales and Queensland.

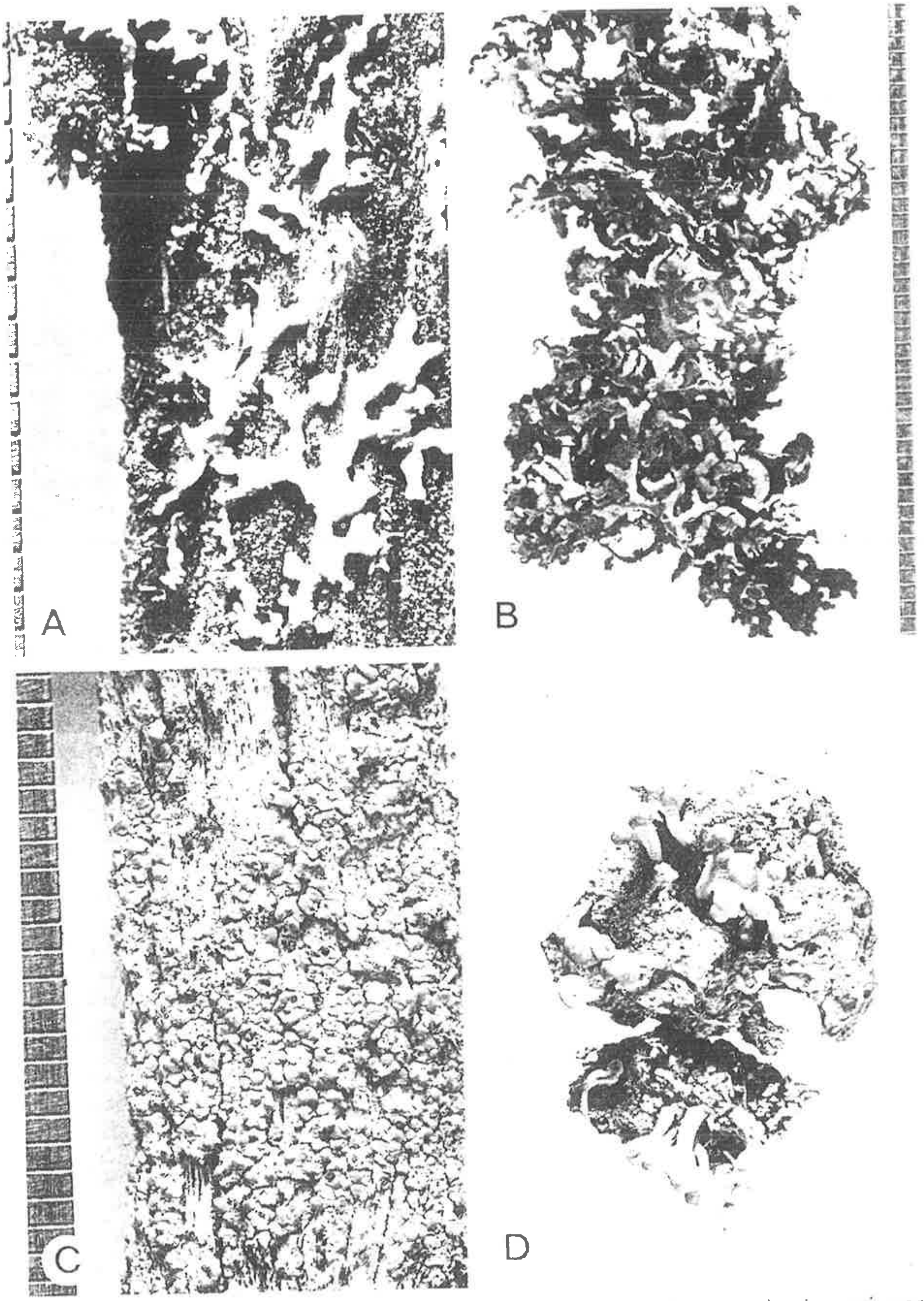

Fig. 12. A. *Anzia wilsonii*; B. *Anzia angustata*; C, *Bombyliospora domingensis* var. *aurantiaca*; D. *Baeomyces fungoides*. Scale in millimetres.

5. ARTHONIA Ach. 1806:3

Thallus crustose, often endophloic, ecorticate. *Pseudothecia* often rather lirella-like, elongate to round or star-shaped, immersed in the thallus, devoid of an exciple; asci almost globose to pyriform or obovoid, often with a heavily thickened apex, eight-spored; ascospores two- to many-celled, the locules often of unequal size, usually hyaline; paraphyses very thin, reticulately branched and interwoven.

Figure: Ascopores, fig 11D.

At present no collections are known of this genus in South Australia but it is likely to occur as inconspicuous white stains on the bark of trees.

6. ARTHOPYRENIA Mass. 1852a:165

Thallus crustose, thin, often endophloic. *Pseudothecia,* perithecium-like more or less immersed in the thallus; asci eight-spored; ascopores hyaline, transversely two- to six-septate, often with protuberences on the ends; paraphyses reticulately branched and anastomosing.

Figure: Ascospores, fig. 11E.

At present there are no known collections from South Australia but it is likely to occur on wood, bark or rock.

7. ARTHOTHELIUM Mass. 1852a:54

Thallus crustose, often endophloic, ecorticate. *Pseudothecia* rather lirella-like, elongate to round or star-shaped, immersed in the thallus, devoid of an exciple; asci almost globose to pyriform or obovoid, often with a heavily thickened apex, eight-spored; ascospores muriform, usually hyaline; paraphyses very thin, reticulately branched and interwoven.

Figure: Ascus containing spores, fig. 11F.

At present there are no collections known from South Australia but species of this genus are likely to be found forming inconspicuous white stains on the bark of trees.

8. ASPICILIA (Stiz.) Mass. 1852a:169

Thallus crustose or subfruticose, more or less areolate, corticate or ecorticate. *Apothecia* immersed in the thallus; asci normally eight-spored; ascospores hyaline, simple, ellipsoidal.

Aspicilia calcarea (L.) Mudd. 1861:161

Lichen calcareus L. 1753:1140

Lecanora calcarea (L.) Sommerf. 1826:102

Thallus rough, chinky to areolate or fruticose, grey to greyish-white. *Apothecia* small 0·5-1·0 mm diam., immersed; disk flat, brown to black often heavily pruinose; margin thin, concolourous with the thallus, smooth becoming crenulate sometimes disappearing; ascospores two to eight in ascus, broadly ellipsoid, 18-30 x 14-27 μm, hyaline.

Figure: Habit, fig. 10B; ascospore, fig 11G.

Specimen examined: Koonamore Vegetation Reserve, *R. W. Rogers 1416*, 28.v.1968 (MEL 1011689).

Aspicilia calcarea is widespread on soil and rocks in arid areas of Victoria and New South Wales. The fruticose form is usually found growing off pebbles onto the soil. This form has pseudocyphellae on the upper surface, is always sterile and has been referred to a separate genus, *Agrestia* Thomson.

9. BACIDIA de Not. 1846:189.

Thallus crustose, granulose, inconspicuous, sometimes disappearing, not differentiated into distinct layers. *Apothecia* usually adnate, but sometimes sessile or immersed, lecideine; disk becoming convex, flesh-coloured to brown or black; margin concolourous with the disk; asci long- or cylindrico-clavate, eight-spored; ascospores hyaline acicular, several septate.

Figure: Ascospores, fig. 11H.

No collections from South Australia have been determined as *Bacidia*, but *B. luteola* (Schrad.) Mudd. was collected on bark at Portland in western Victoria, so it is likely to occur in the South-East.

10. BAEOMYCES Pers. 1794:19

Literature: Thomson 1967.

Thallus crustose, granulose, squamulose or marginally foliose, attached to the substrate by medullary hyphae or rhizines; cortex with one or more paraplechtenchymatous layers, or lacking. *Apothecia* round, finally swollen on more or less a distinct podetia often containing algae, sometimes the base of the podetia partly or entirely overgrown by an algal layer with a cortex similar to that of the thallus; hypothecium and exciple not distinct from the interior of the stipe; asci cylindrical; ascospores eight in ascus, fusiform or ellipsoidal, hyaline, up to four-celled; paraphyses simple or sparingly branched.

ARTIFICIAL KEY TO SPECIES

1. Podetium tall, chalk-pink, bearing a single apothecium ...... *B. fungoides*
1. Podetium low or lacking, flesh-coloured, bearing one to numerous apothecia .... *B. heteromorphus*

Baeomyces fungoides (Sw.) Ach. 1803:320

Lichen fungoides Sw. 1788:146.

Thallus a thin green granular crust, sometimes almost lacking. *Apothecia* solitary terminal on pink chalk-like podetia up to 1·5 cm tall, emarginate, inflated sometimes almost spherical.

Figure: Habit, fig. 12D.

Baeomyces heteromorphus Nyl. 1860:351.

Thallus a thin green to granular crust. *Apothecia* solitary or numerous on short pinkish-brown to flesh-coloured podetia up to 1 cm tall, with a distinct margin; disk plane to hemispheric but not inflated.

Baeomyces is common in Victoria, Tasmania and New South Wales; it has not yet been recorded for South Australia but is likely to occur on roadside cuttings and other bare soil in the damper parts of the State.

11. BIATORELLA Th. Fr. 1861b:299.

Thallus crustose, sometimes lobed at the margins, ecorticate or with a rudimentary upper cortex. *Apothecia* with a pale soft proper exciple, sessile to shortly stipitate; asci broadly clavate, many spored; ascospores hyaline, simple; paraphyses simple.

Material referable to this genus has been collected on soil in Mallee areas. Other species are likely to be found on wood.

12. BLASTENIA Mass. 1852a:101.

Thallus crustose, smooth or powdery to granulose or areolate, devoid of differentiation into layers. *Apothecia* immersed to adnate; disk pale orange to reddish-orange or black, concave to convex; margin concolourous with the disk, sometimes disappearing; asci clavate; ascospores usually eight in the ascus, hyaline, ellipsoid to oblong-ellipsoid, two-celled.

At present this genus is not recorded in South Australia but it is likely to occur on trees or rocks.

13. BOMBYLIOSPORA de Not. apud Mass. 1852a:114.

Thallus crustose, smooth or powdery to granulose or areolate, not differentiating into layers. *Apothecia* immersed or sessile, pale orange to reddish-black; margin concolourous with the disk, sometimes disappearing; asci linear, usually eight-spored; ascospores four- to many-celled.

Bombyliospora domingensis var. **aurantiaca** Zahlbr. in Magnusson and Zahlbr. 1945:32.

Thallus granular crustose of greyish-green squamules. *Apothecia* numerous, bright orange to brick-red.

Figure: Habit, fig. 12C; ascospores fig. 11I.

Specimens examined: Canunda National Park, 9 miles (14 km) west of Millicent, *R. B. Filson 14657*, 17.v.1973 (MEL 1018594); 10 km north of Artimore Ruins, Flinders Ranges, *R. B. Filson 15582*, 11.xi.1975 (MEL 1018595).

It is recorded also from Victoria and the Bass Strait islands.

The name *Caloplaca aurantiaca* (Lightf.) Th. Fr. has been erroneously applied to collections of this taxon in Australia.

14. BUELLIA de Not. 1846:195.

Literature: Magnusson 1955, Sheard 1964.

Thallus crustose to warty or granulose, commonly areolate. *Apothecia* hard, immersed or sessile; disk black, flat to convex; margin concolourous with the disk, disappearing; asci clavate; ascospores eight in the ascus, brown, usually two-celled, ellipsoidal, or oblong-ellipsoidal, often constricted at the septum.

Figure: Buellia subalbula, habit, fig. 10C; ascus containing spores, fig. 11J. *Buellia parasema*, ascospores, fig. 11K.

This genus contains a great number of species; the Australian material being poorly known. Two species are known to occur on the arid soils, *B. epigaea* (Hoffm.) Tuck., which is subfoliose and has a chalky-white upper surface and *B. subcoronata* (Müll. Arg.) Malme, which is squamulose with a cream upper surface.

Two species are common on limestone pebbles, *B. subalbula* (Nyl.) Müll. Arg. which has a thin white powdery thallus with uni-septate spores and *B. alboatra* (Hoffm.) Branth. et Rostr. which has a thicker, white areolate thallus with muriform spores. *B. spuria* (Schaer.) Anzi is common on acidic rocks and *B. parasema* (Schaer.) de Not., together with *Buellia (Diploicia) canescens* (Dicks.) Mass., are common on trees and posts.

15. CALICIUM Pers. 1794:20.

Literature: Tibel 1975.

Thallus endophloic to coarsely granular, bearing stipitate fruiting bodies up to 2 mm tall. *Apothecia* cup-like to lens-shaped, with a flat to convex open disk; asci cylindrical to clavate; ascospores eight in ascus, two-celled, brown to black. With age the asci disintegrate leaving the spores free in the paraphyses.

Figure: Ascospores, fig. 13A.

Calicium glaucellum Ach. 1803:97.

Thallus thin to endophloic. *Apothecia* black, cup-shaped, faintly white-pruinose on lower side; stipe up to 2 mm tall, black; ascospores brown.

Specimen examined: Ewens Ponds, 10 km east of Port MacDonnell, *R. B. Filson 15814,* 8.iii.1977 (MEL 1018555).

Calicium species are difficult to locate in the field. They are lignicolous or corticolous and blend in with the features of the substrate. Several species are known to occur in south-eastern South Australia, however the one described above appears to be the most common. Species of *Calicium* are common also in Victoria and New South Wales.

16. CALOPLACA Th. Fr. 1871:167.

Literature: Wade 1965. Alon and Galun 1970.

Thallus crustose or squamulose, closely appressed to the substrate; upper surface corticate, yellow to orange-red, or white, grey or black. *Apothecia* usually yellow to orange, sessile or immersed; margin usually prominent, concolourous with the thallus; asci eight-spored; ascospores hyaline, polaribilocular.

Figure: Caloplaca fulgens, habit, plate 2A (MEL 1021213). *Caloplaca cerina*, habit, fig. 10D; ascospores, fig. 13B. *Caloplaca ferruginea*, ascospores, fig. 13C. *Caloplaca holocarpa*, ascospores, fig. 13D. *Caloplaca murorum*, ascospores, fig. 13E.

Reactions: Thallus K− or K+ purple, apothecial disk always K+ purple.

This is a large genus and the Australian material is very poorly known. A number of species are recorded from South Australia on soil, rock and bark. On arid soils, *C. cinnabarina* (Ach.) Zahlbr. is widespread but not common. It possibly also occurs on rocks. *C. murorum* (Hoffm.) Th. Fr. is a common species on rock and is easily distinguished by the presence of distinct marginal lobes. *C. holocarpa* has a grey, evanescent thallus and *C. fulgens* a deep orange thallus with immersed apothecia. *C. cerina* (Ehrh. ex Hedw.) Th. Fr. and *C. ferruginea* (Huds.) Th. Fr. both occur on bark, but the former has a distinguishing white or grey thalline margin to the apothecia.

17. CANDELARIA Mass. 1852a:567.

Literature: Almborn 1966.

Thallus foliose, more or less irregularly lobed, usually bright yellow but sometimes greenish-yellow; upper and lower cortex well developed with a thin algal and medullary layer, attached to the substrate by rhizines. *Apothecia* small up to 1 mm diam., sessile; disk flat to convex; margin prominent, concolourous with the thallus; ascospores sixteen to thirty-two in the ascus, hyaline, ellipsoid to ovate, simple or two-celled.

Candelaria concolor (Dicks.) Stein *in* Cohn 1879:84.

Lichen concolor Dicks. 1793:18.

Thallus citrine-yellow forming patches up to 1 cm across, sometimes coalescing into larger, areas, ascending from the substrate; lobes up to 0·4 mm broad, often lacerate, margins usually with granular soredia, which may spread to the upper and lower surfaces; lower surface white or pale brown. *Apothecia* rare, less than 1 mm diam., concave to slightly convex.

Reactions: Thallus K−.

Figure: Ascospores, fig. 13F.

Specimens examined: Roopena Station 60 km north west of Whyalla, *R. W. Rogers 1748,* 10.viii.1969 (R. W. R.); Lincoln Gap Station, 25 km south west of Port Augusta, *R. W. Rogers 75,* 13.i.1966 (R.W.R.); Burra, *R. W. Rogers 1879,* 20.viii.1970 (R.W.R.).

Rare on the bark of trees and shrubs, so far only collected from the arid and sub-arid parts of the State. It is common in Victoria, New South Wales and Queensland.

This species is easily distinguished from *Teloschistes* or *Xanthoria* by the K− reaction of the upper cortex.

18. CANDELARIELLA Müll. Arg. 1894:11.

Literature: Hakulinen 1954.

Thallus crustose, areolate, warty, marginal lobes sometimes radiate. *Apothecia* sessile; disk yellow to golden; margin concolourous with the thallus; ascospores eight in ascus, hyaline, simple or two-celled.

ARTIFICIAL KEY TO SPECIES

1. Thallus growing on bark, ascospores eight in ascus .... *C. antenaria*
1. Thallus growing on rock 2
    2. Ascospores eight in ascus .... *C. spraguei*
    2. Ascospores > eight in ascus .... *C. vitellina*

Candelariella antenaria Räs. 1939:137.

Thallus evanescent. *Apothecia* 0·2-0·7 mm diam., plane to convex; margin entire to crenate; disk deep yellow, opaque; ascospores eight in ascus, simple, 14-20 x 5-6 μm; paraphyses septate with annulate, club-shaped apices.

Reactions: Thallus K−, medulla K−, apothecia K−.

Specimen examined: Koonamore Vegetation Reserve, *R. W. Rogers 1594,* 19.xii.1968 (R.W.R.).

It is often found growing on dead wood amongst *Bombyliospora domingensis* var. *aurantiaca* and is also common in Victoria.

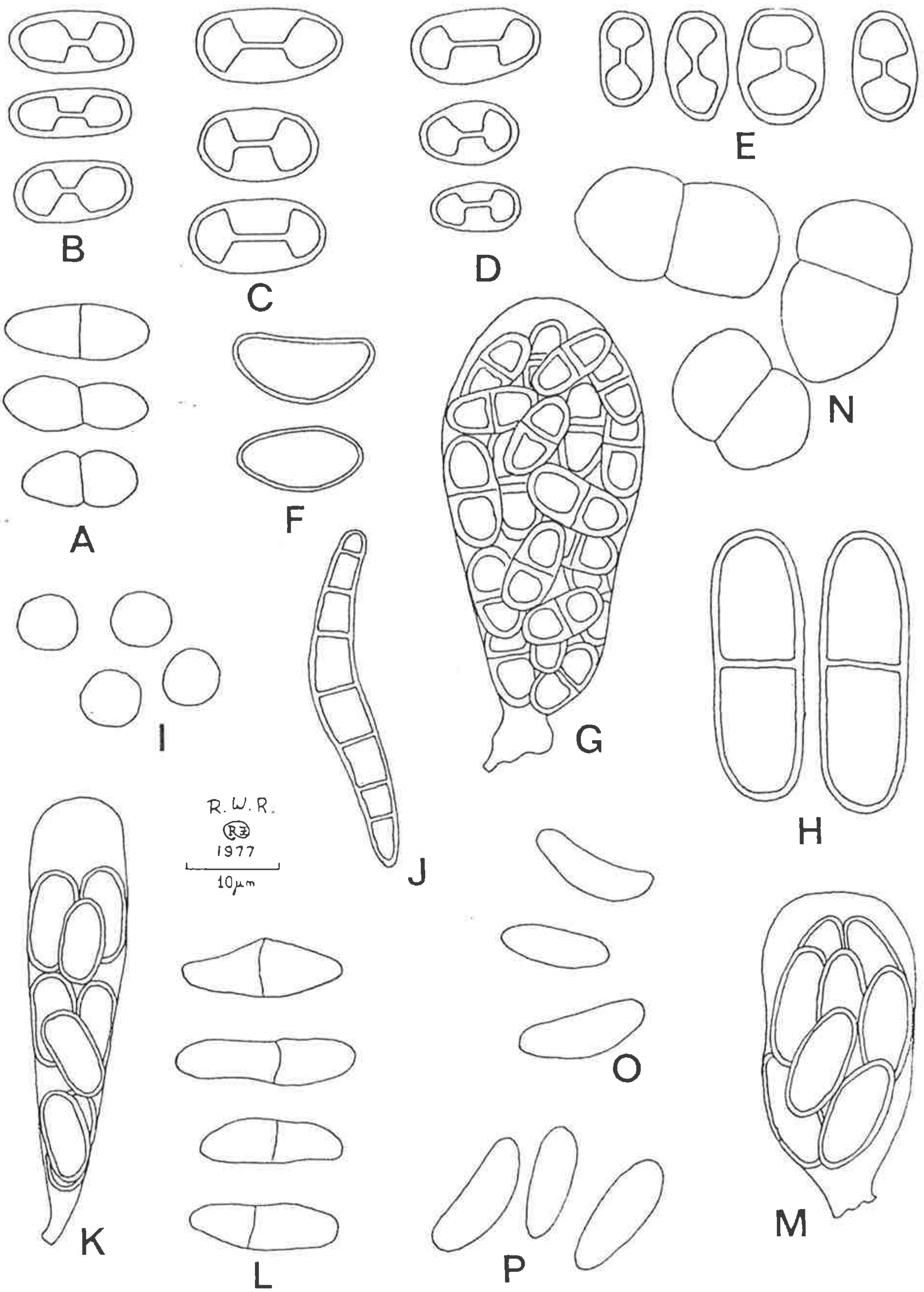

Fig. 13. A, *Calicium albietinum*, ascospores; B, *Caloplaca cerina*, ascospores; C, *Caloplaca ferruginea*, ascospores; D, *Caloplaca holocarpa*, ascospores; E, *Caloplaca murorum*, ascospores; F, *Candelaria concolor*, ascospores; G, *Candelariella vitellina*, ascus containing spores; H, *Catillaria* sp., ascospores; I, *Chaenotheca* sp., ascospores; J, *Chiodecton* sp., ascospores; K, *Chondropsis semiviridis*, ascus containing spores; L, *Collema coccophorum*, ascospores; M, *Coccocarpia pellita*, ascus containing spores; N, *Cyphelium* sp., ascospores; O, *Cladonia verticillata*, ascospores; P, *Cladia aggregata*, ascospores.

Candelariella spraguei (Tuck.) Zahlbr. 1928:802.

Placodium spraguei Tuck. 1882: I, 54.

Thallus saxicolous, of scattered or continuous small lobulate, imbricated areolae, bright yellow to greenish-yellow. *Apothecia* up to 0·75 mm diam., clustered, contorted; disk greenish-yellow, convex; margin concolourous with the thallus, prominent, crenulate; ascospores simple, hyaline 10-15 x 6-7 μm.

Reactions: Thallus K−, medulla K−, apothecia K−.

Specimen examined: Rocky outcrop, 100 metres from the Ernabella road, 6 km west of "Kenmore Park" H.S., Musgrave Ranges, *R. B. Filson 15689,* 26.xi.1975 (MEL 1018603).

Candelariella vitellina (Ehrh.) Müll. Arg. 1894:47.

Lichen vitellinus Ehrh. 1785: 155.

Thallus saxicolous of scattered areolae, golden-yellow to yellow-orange. *Apothecia* up to 0·5 mm diam., clustered; disk yellow-orange, plane to convex; margin persistent, at first entire becoming crenulate, concolourous with the thallus; ascospores up to 32 per ascus, ellipsoid, simple, often appearing two-celled, sometimes slightly curved, 9-10 x 5-6 μm.

Reactions: Thallus K−, medulla K−, apothecia K−.

Figure: Ascus containing spores, Fig. 13G.

Specimen examined: side track, 100 metres north from Port Germein Gorge road, 16 km east of Port Germein, *R. B. Filson 15551a,* 16.xi.1975 (MEL 1018577).

It also occurs in Victoria, New South Wales, Queensland and Western Australia.

19. CATILLARIA (Ach.) Th. Fr. 1874:563.

Lecidea Catillaria* Ach. 1803:33.

Thallus crustose, granulose, warty or areolate, not differentiated into layers. *Apothecia* immersed to adnate or sessile, lecideine; disk yellowish-brown to brown or black; margin concolourous with the disk; ascospores eight in ascus, hyaline, oblong to fusiform two-celled or more rarely simple.

Figure: Ascospores, fig. 13H.

The genus *Catillaria* is poorly understood, and the Australian material in need of taxonomic study. A species of *Catillaria* is common on the bark of trees in the Mount Lofty Ranges, where it forms a very thin white crust with small black apothecia, especially on very smooth surfaces.

20. CHAENOTHECA (Th. Fr.) Th. Fr. 1861b:350.

Calicium β *Chaenotheca* Th. Fr. 1856: 128.

Literature: Tibel 1975.

Thallus crustose, powdery to warty, fruiting bodies stalked; stalks up to 2 mm tall. *Apothecia* more or less globular, always with open disks and proper dark margins; asci cylindrical, disintegrating with age to leave the spores free in the paraphyses; ascospores eight in ascus, globose, simple, dark coloured.

Figure: Ascospores, fig. 13I.

At present this genus is not known from South Australia, but specimens are likely to be found on decaying wood and bark in the wetter parts of the State.

21. CHIODECTON Ach. 1814:108

Thallus adnate to the substrate, ecorticate with pseudothecia immersed in stromatic bodies on the upper surface. *Pseudothecia* simple to elongate or stellate, with a well developed proper exciple; hypothecium dark and carbonaceous; the hypothecia of several disks joining at the base; asci clavate; ascospores eight in ascus, transversely many-septate, hyaline; paraphyses reticulately branched and interwoven.

Figure: Ascospores, fig. 13J.

At present no collections are known to have been made from South Australia but specimens are likely to be found on bark or rock.

22. CHONDROPSIS Nyl. *in* Crombie 1879:397.

Literature: Filson 1967, Rogers 1971.

Chondropsis semiviridis F. Muell. ex Nyl. *in* Cromb. 1879:397.

Parmeliopsis semiviridis F. Muell. ex Nyl. 1869:57.

Parmelia semiviridis (F. Muell. ex. Nyl.) P. Bibby 1955:60.

Thallus foliose, repeatedly dichotomously branched, branches divergent, hardly overlapping; upper cortex prosoplectenchymatous, thick, opaque when dry, transparent when wet, with a distinct algal layer; medulla loosely woven, lower cortex of interwoven hyphae; lower surface devoid of rhizines. Thallus rolls into a ball when dry. *Apothecia* rare, sessile, concave becoming flat; disk light brown to reddish-brown; margin concolourous with the thallus; asci clavate; ascospores eight in ascus, hyaline simple 10 × 5 µm.

Reactions: K−, C−, KC−, P+ yellow becoming orange.

Figure: Habit, fig. 14A; ascus containing spores, fig. 13K.

Selected specimens examined: 26½ miles (42 km) west-south-west of "Koonalda" H.S., Nullarbor Plain, *A.C. Beauglehole 14907*, 26.ix.1965 (MEL 22843); 11 miles (18 km) north-west of "Nullarbor" H.S., *R. B. Filson 9430*, 11.i.1967 (MEL 25373); Eyre Highway 40 km east of Kimba, *R. B. Filson 11731*, 22.x. 1970; Yardea Station, Northern Eyre Peninsula, *R. W. Rogers 1190*, 22.v.1967 (AD 97733155); Iron Knob, *R. W. Rogers 556*, 1.x. 1966 (AD

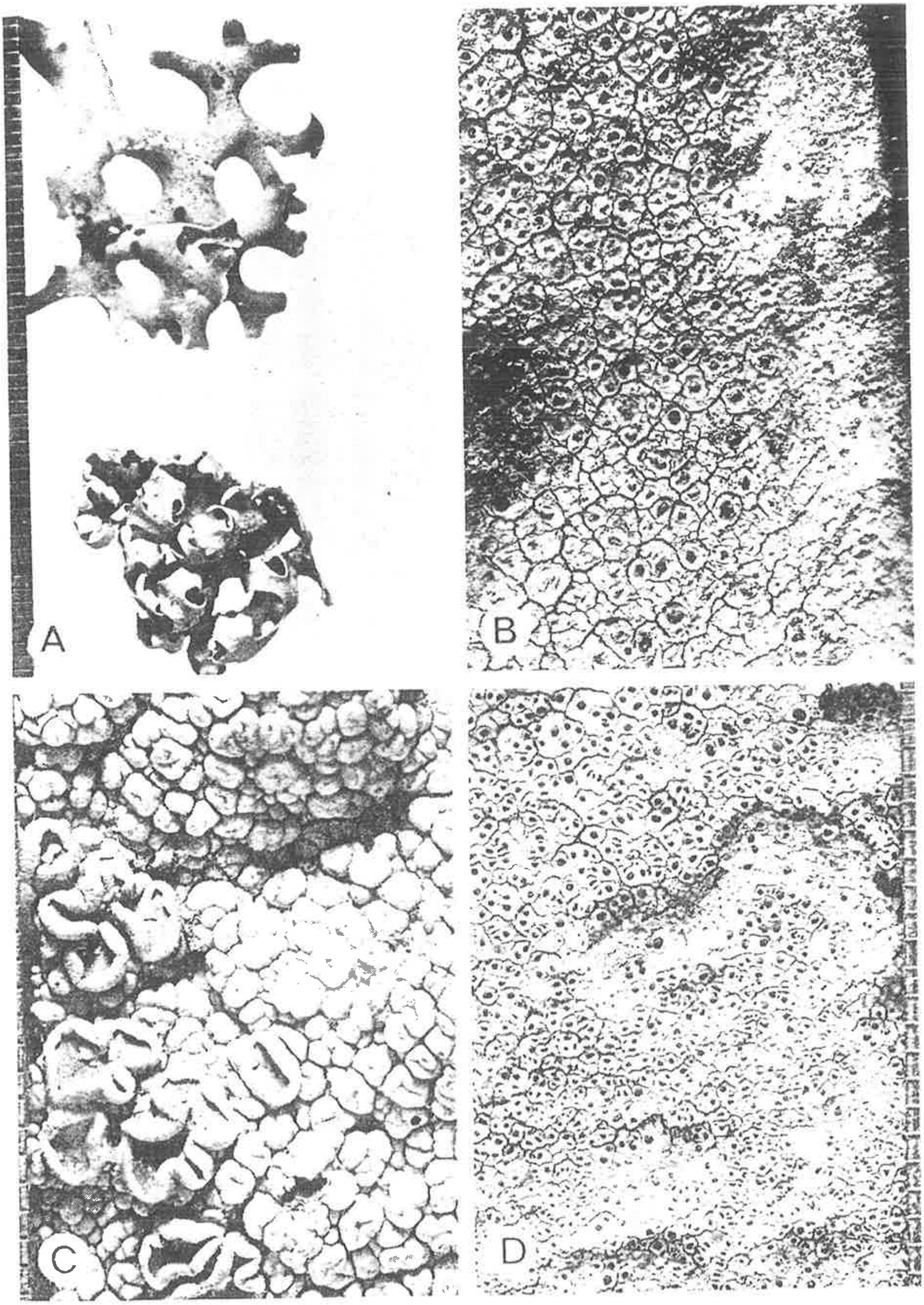

Fig. 14. A, *Chondropsis semiviridis*; B, *Diploschistes gypsaceus*; C, *Diploschistes ocellatus*; D, *Diploschises scruposus*. Scale in millimetres.

97733157); Koonamore Vegetation Reserve, *B. Barrien*, ?1944 (AD); "Quondong" Station, east of Burra, *R.W. Rogers 1135*, 18.v.1967 (AD 97733156); Morgan, *Cleland*, ?1966 (AD).

23. CLADIA Nyl. 1870:167.

Literature: Filson 1970.

Thallus fruticose, composed of pseudopodetia, simple or intricately branched, not arising from primary thallus; pseudopodetia sometimes hollow, sometimes filled with loose or compact medullary tissue, walls clathrate to sparingly perforate. *Apothecia* minute, brown to dark brown to black; ascospores hyaline, simple; pycnidia sessile on tips of pseudopodetia; pycnidiospores bacilliform.

ARTIFICIAL KEY TO SPECIES

1. Thallus hollow 2
1. Thallus not hollow, with tightly packed medulla 4
  2. Fenestrations many, the pseudopodetia becoming hollow clathrate structures .... *C. ferdinandii*
  2. Fenestrations few, pseudopodetia not clathrate 3
3. Thallus tall robust, sterile pseudopodetia>3 mm tall not sorediose. .... *C. aggregata*
3. Thallus short, sterile pseudopodetia<3 mm tall, sorediose, sometimes reduced to a powdery mass.......................... *C. schizopora*
  4. Thallus white to grey, cortex smooth, internal medulla white .... *C. corallaizon*
  4. Thallus yellow to yellow-brown, cortex crystalline, internal medulla white above, brown below .... *C. sullivanii*

Cladia aggregata (Sw.) Nyl. 1870:69

Lichen aggregatus Sw. 1788:147.

Cladonia aggregata (Sw.) Ach. 1795:68.

Thallus fruticose, composed of pseudopodetia, up to 8 cm tall in lush situations and as low as 1 cm in poor; hollow, fragile when dry, walls perforate; perforations round to elliptic, varying in number, in pulvinate clumps or scattered amongst leaf debris, varying in colour from green through shades of cream, brown to almost black; sterile pseudopodetia horny, rigid when dry, extremely variable in size from 0·5-0·8 mm diam., dichotomously or irregularly branched, flexuose, prostrate or ascending; fertile pseudopodetia much thicker and taller and usually more perforate and more branched towards the apex. *Apothecia* terminal on the branches of upright fertile pseudopodetia, lecideine, 0·15-0·3 mm diam; disk slightly concave to flat, dull brownish-black; margin slightly raised; hymenium up to 50 μm tall; asci 48 × 11 μm; ascospores eight in ascus, simple, hyaline 12-15 × 4-5 μm ellipsoidal.

Reactions: Cortex all reactions negative, medulla K−, C−, KC−, P±

Figure: Habit, plate 5A (MEL 1022006) & 5B (MEL 1021219); ascospores, fig. 13P.

Selected specimens examined: Marble Range, Eyre Peninsula, *R. B. Filson 11868,* 24.x.1970 (MEL 1015446); Memory Cove, Cape Catastrophe, *R. B. Filson 11849,* 24.x.1970 (MEL 1015444); Dark Island, 9 miles (14 km) north-east of Keith, *R. L. Specht & P. Rayson,* v.1950 (MEL 25267); Torrens Gorge, *N. N. Donner 1312,* 13.iii.1965 (MEL 9115); Mt. Crawford, 8 km west of Springton, *J. A. Elix 2166,* 18.v.1976 (MEL 1017181); Between the Coorong and the sea, south of Meningie, *A. C. Beauglehole 15099,* 2.x.1965 (MEL 22866); Humbug Scrub, 25 miles (40 km) north-east of Adelaide, *J. D. Curtis,* 9.iv.1967 (MEL 25296); Aldinga Scrub, *R. B. Filson 15723* 5.xii.1975 (MEL 1015493); 14 km south-east Mount Burr Township, *I. B. Wilson 542,* 8.vii.1966 (MEL 27391); Western River, Kangaroo Island, *M. A. Allender,* 5.ix.1974 (MEL 1013771); Eucalypt Forest, 6 km east of Penola, *R. B. Filson 15401,* 12.xi.1975 (MEL 1015411).

This species occurs also in Western Australia, Tasmania, Victoria, New South Wales and Queensland.

Cladia corallaizon R. Filson 1970:324.

Thallus fruticose, composed of pseudopodetia up to 5 cm tall, in pulvinate clumps up to 12 cm diam. or occasionally in scattered clusters 3-4 cm diam., white to grey sometimes stramineous when old; sterile pseudopodetia rigid, horny when dry 2-3 mm diam, dichotomously branched, walls perforate, perforations narrow elliptic, regularly spaced, medulla compact below the algal layer and loosely filling the hollow interior of the pseudopodetia; fertile pseudopodetia similar. Apothecia terminal on the upper branches of the fertile pseudopodetia, lecideine, 0·2-0·7 mm diam.; disk slightly concave to flat becoming strongly convex on maturity, dull reddish-brown to black; margin slightly raised at first, disappearing; hymenium 50-80 μm tall; asci 48 x 12 μm; ascospores eight in ascus, hyaline, ellipsoidal, simple, 15 x 3 μm.

Reactions: K−, C−, KC−, P−.

Figure: Habit, plate 5C (MEL 1021216) & fig. 15 B.

Specimens examined: Monster Mount, 10 km south of Keith, *R. D. Seppelt 2784,* 28.vii.1973 (MEL 1012082).

This species occurs also in Western Australia, Victoria, New South Wales and Queensland.

Cladia ferdinandii (Müll. Arg.) R. Filson 1970:325.

Cladonia ferdinandii Müll. Arg. 1882:293.

Thallus fruticose, composed of pseudopodetia up to 10 cm tall, in pulvinate clumps or patches several metres wide, creamy white to yellowish-white; sterile pseudopodetia rigid, horny when dry, up to 12 mm diam., irregularly branched,

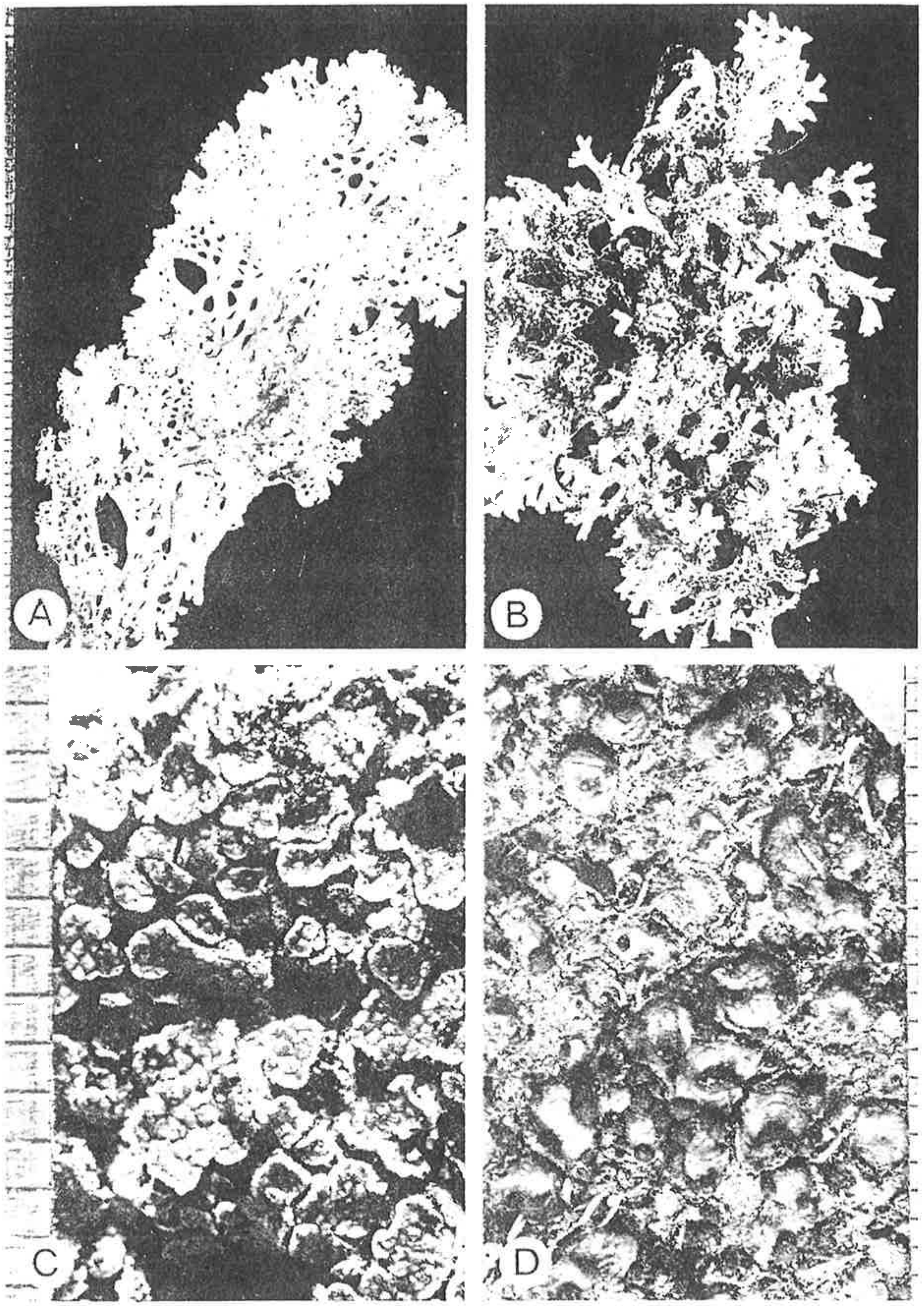

Fig. 15. A, *Cladia ferdinandii*; B, *Cladia corallaizon*; C, *Lecidea crystallifera*; D, *Lecidea globifera*. Scale in millimetres.

walls regularly perforate, perforations large, up to 4 mm diam., irregularly round, medulla loosely woven, the inside of the hollow pseudopodetia completely devoid of medullary tissue; fertile pseudopodetia not seen.

Reactions: K+ pale yellow, C−, KC−, P−.

Figure: Habit, fig. 15A.

Specimens examined: Koppio, 35 km north of Port Lincoln, *J. Tapley*, 17.iv.1965 (MEL 1007501); Aldinga Scrub, Aldinga Beach, *R. B. Filson 15724*, 5.xii.1975 (MEL 1015494); Meningie, *L. D. Williams 723*, 22.iv.1960 (MEL 1007496); Kangaroo Island, *Tate* (MEL 6707).

Endemic in southern regions of Western Australia and South Australia.

Cladia schizopora (Nyl.) Nyl. 1870:69.

Cladonia schizopora Nyl. 1860:217.

Thallus fruticose, composed of pseudopodetia up to 1·5 cm tall, forming continuous patches on bark and fallen trees; sterile pseudopodetia up to 2 mm high, sorediose on the tips or sometimes reduced to a powdery mass; fertile pseudopodetia horny, perforate, perforations irregular, sorediose on the inner walls, branched towards the apex, hollow pseudopodetia completely devoid of medullary tissue. *Apothecia* terminal on the branches of the fertile pseudopodetia, lecideine, 0·3-0·5 mm diam.; disk slightly concave to flat, dull, brownish-black to black; margin slightly raised at first, disappearing at maturity; hymenium up to 40 μm tall; asci 30-40 x 8-11 μm; ascospores eight in ascus, simple, hyaline, ellipsoidal 8-10 x 3 μm. *Pycnidia* terminal on the lobes of the sterile pseudopodetia, ellipsoidal, 120 μm long x 60 μm diam.

Reactions: K−, C−, KC−, P−.

Figure: Habit, plate 5D (MEL 1022008).

Selected specimens examined: 3 km north of Carey Gully, *J. A. Elix 2287*, 22.v.1974 (MEL 1017115); Roadside between Prospect Hill and Kuitpo, *R. W. Rogers 1864*, 19.v.1970 (MEL 1011692); Comaum Forest c. 30 km south-east of Naracoorte, *R. D. Seppelt 2599*, 3.v.1973 (MEL 1015510); 6 km east of Penola, *R. B. Filson 15397*, 12.xi.1975 (MEL 1015502).

This species occurs also in Western Australia, Tasmania, Victoria and New South Wales.

Cladia sullivanii (Müll. Arg.) Martin 1965:9

Cladonia sullivanii Müll. Arg. 1882:294.

Thallus fruticose, composed of pseudopodetia up to 4 cm tall, usually in clumps, stramineous, cinnamon-brown to blackish-brown; sterile pseudopodetia rigid and horny when dry, coarsely farinose, up to 5 mm diam. in expanded specimens, unevenly branched, walls perforate, perforations irregularly rotund to elliptic; medulla compactly woven below the algal layer and loosely filling the whole of the hollow interior of the pseudopodetia; hyphae hyaline below the algal layer becoming brown to brownish-black in the centre; fertile pseudopodetia similar but much taller. *Apothecia* terminal on the upper branches of the fertile pseudopodetia 0·2-0·7 mm diam.; disk flat becoming strongly convex at maturity, dull, reddish-brown to brownish-black; margin just discernible when young, disappearing; hymenium 60-70 µm tall; ascospores eight in ascus, simple hyaline slightly pointed at one end, 15-17 x 5 µm. *Pycnidia* terminal on the smaller branches of the sterile pseudopodetia c. 320 x 120 µm.

Reactions: K−, C−, KC− or + yellow, P−.

This species has not yet been collected in South Australia but as it occurs in Victoria close to the South Australian border it is likely to be found in the south-east of the State. It occurs also in Tasmania and New South Wales.

Cladia aggregata is widespread on soil and rotting logs in the wetter parts of the State and is probably the most commonly seen fruticose lichen in South Australia. The other species in this genus have more localised distribution. *Cladia ferdinandii* is endemic in South Australia and Western Australia. The record of *Cladia retipora* (Labill.) Nyl. in Weber and Wetmore (1972:26) refers to the collection from Kangaroo Island by Tate which was first determined as that species. However, *C. ferdinandii* is a much taller and more robust species.

24. CLADONIA Hill. 1773:91

Literature: Martin 1958, Thompson 1968.

Primary thallus of squamules, granular or foliose, the upper surface corticate; podetia arising from the primary thallus, cylindrical, trumpet-shaped irregular or branched, with or without cups, with or without squamules, podetia may be tiered one proliferating from the other; *podetia* variously corticate or ecorticate, sorediose or esorediose. *Apothecia* on margins of cups or branches of podetia; disk flat to convex, scarlet or brown; margin usually disappearing; asci clavate; ascospores eight in ascus, hyaline, ellipsoidal, simple.

ARTIFICIAL KEY TO SPECIES

1\. Apothecia scarlet 2
1\. Apothecia brown 3
  2\. Thallus P+ orange, K+ yellow, soredia very fine, basal squamules present . . . . *C. macilenta*
  2\. Thallus P−, K−, squamules up the podetia . . . . *C. didyma*
3\. Thallus pale, yellow or yellowish-grey (usnic acid present) . . *C. capitellata*
3\. Thallus not yellow or yellowish-grey, (usnic acid absent) 4
  4\. Medullary hyphae longitudinally arranged, podetia longitudinally split . . . . *C. capitata*
  4\. Medullary hyphae not longitudinally arranged podetia not conspicuously longitudinally split 5
5\. Podetia cupless, axils usually perforate 6
5\. Podetia with cups, axils imperforate 11
  6\. Thallus K+ yellow 7

6. Thallus K− 8
7. Covered with squamules or granules, P+ yellow turning orange . . . . *C. squamosula*
7. Without squamules or granules P+ weakly yellow . . . . *C. aueri*
8. Without small squamules or granules in upper part of the podetium . . . . *C. furcata*
8. With small squamules or granules in the upper part of the podetium . . . 9
9. Podetia 5-8 cm tall, quite cupless, axils clearly open . . . . *C. scabriuscula*
9. Podetia up to 5 cm tall, sometimes with narrow cups axils not open 10
10. Podetia short, less than 2·5 cm tall, growing up from persistent basal squamules . . . . *C. balfourii*
10. Podetia taller, not growing up from persistent squamules . . . . *C. pityrea*
11. Cups proliferating in tiers from the centre 12
11. Cups not proliferating 13
12. Podetia flaring smoothly into non-lacerating cups, with narrow, incised basal squamules . . . . *C. verticillata*
12. Podetia flaring abruptly into deeply lacerate cups without conspicuous basal squamules . . . . *C. calycantha*
13. Podetia dilated into broad cups 5 mm . . . . *C. chlorophaea*
13. Podetia narrowing into minute cups, or without cups 14
14. With granular soredia, podetia less than 2·5 cm high . . . . *C. balfourii*
14. With farinose soredia, podetia taller, never with cups . . . . . *C. farinacea*

Cladonia aueri Räs. 1932:53.

Podetia whitish-grey or brown up to 2 mm diam. and 6 cm tall, little branched, the axils gaping open, cupless, usually without squamules. *Apothecia* brown.

Reactions: Thallus K+ weakly yellow, P+ weakly yellow.

Specimen examined: Mount Burr, *Wilson 549,* 7.ix.1966 (AD).

Apparently rare, fringing a *Melaleuca* swamp.

Cladonia balfourii Cromb. 1876:433

Primary thallus persistent, minutely crenulate. *Podetia* arising from the primary thallus, ashy-white, up to 2·5 cm tall and 2-3 mm diam., often with very narrow cups in the tapering tips, ecorticate except for a narrow squamulose part towards the base, granular sorediose throughout. *Apothecia* single on the tip of the podetia or in a small ring around the rim of the narrow cup, brown.
Reactions: K−, C−, KC−, P+ red.

Selected specimens examined: Mount Lofty, *R. W. Rogers 551,* 24.ix.1966 (R.W.R.); Hindmarsh Valley, *R. W. Rogers 1046,* 25.iv.1967 (R.W.R.); Ashbourne, *D. Whibley 1397,* 2.vi.1964 (AD 97519493); Naracoorte, *D. Hunt,* 6.vii.1962 (AD 97733136).

This species grows on sand or humus in moist places in Victoria, Tasmania and New South Wales.

Cladonia calycantha Del. ex Nyl. 1859:209

Primary thallus usually persistent but sometimes disappearing. *Podetia* corticate, without soredia or squamules, up to 8 cm tall, with distinct cups, whitish- to greenish-grey, cups flaring abruptly, proliferating from the centre of the cup up to seven times, margins lacerate. *Apothecia* brown, stipitate on the margins of the cups.

Reactions: K−, C−, KC−, P+ red.

Specimens examined: 2 km west of Bascombe Well, Eyre Peninsula, *N. N. Donner 2348,* 7.x.1967 (MEL 27385); Sandy Creek, *R. W. Rogers 1486,* 29.x.1968 (R.W.R.); Mount Bonython, *R. D. Seppelt,* 23.vii.1969 (R.W.R.); Encounter Bay, *R. W. Rogers 1041,* 25.iv.1967 (R.W.R.); Mount Burr, *I. B. Wilson 866,* 7.ix.1968 (AD 97412385).

Occurs also in Western Australia, Victoria, Tasmania and New South Wales.

Cladonia capitata (Michx.) Spreng. 1827:271.

Helopodium capitatum Michx. 1803:329.

Primary thallus persistent, undivided. *Podetia* rising from the primary thallus up to 1·5 cm tall and 1-2 mm thick, without cups, grey to brownish-grey, corticate, squamulose near the base, ribbed, twisted, longitudinally split, distorted, simple or sparingly branched. *Apothecia* brown, large, bulging over the top of the podetium.

Reactions: K+ yellow becoming brown, C−, KC−, P+ red.

Selected specimens examined: hundred of Blesing, Eyre Peninsula, *N. N. Donner 2272,* 5.x.1967 (AD 97733138); Maitland, *R. W. Rogers 951,* 9.ii.1967 (R.W.R.); Cherry Gardens, *R. W. Rogers 1653,* 19.v.1969 (R.W.R.).

The species occurs also in Victoria.

Cladonia capitellata (Hook.f. & Tayl.) Bab. 1855:296.

Cenomyce capillata (sic) Hook.f. & Tayl. 1844:652.

Primary thallus disappearing. *Podetia* up to 8 cm high and 0·5-2·0 mm diam., yellow-grey to stramineous, with or without narrow, irregular cups, axils open, without soredia, squamulose at the base. *Apothecia* stipitate, brown.

Reactions: K−, C−, KC−, P−.

Figure: Habit, plate 3A.

Specimen examined: c. 14 km south-east of Mount Burr Township, *I. B. Wilson 549,* 7.ix.1966 (MEL 27390).

C. capitellata is found also in Victoria and New South Wales.

A similar but un-named species has been recorded by E. Dahl in South Australia. It differs from the typical *C. capitellata* in having regular cups, no squamules and is P+ red.

Cladonia chlorophaea (Flörke in Sommerf.) Spreng. 1827:273.

Cenomyce chlorophaea Flörke in Sommerf. 1826:130.

Primary thallus persistent or disappearing. Podetia greenish-grey, thickset, flaring gradually into broad deep cups, up to 1·5 cm tall, coarsely granular sorediose. *Apothecia* sessile or stipitate on the cup margins, brown.

Reactions: K− or rarely K+ yellow, C−, KC−, P+ red, or rarely P−.

Specimens examined: Alligator Gorge, *L. D. Williams 1808*, 6.ix.1963 (L.D.W.); Cape Jervis, *R. W. Rogers 1472*, 1.ix.1968 (R.W.R.).

Cladonia chlorophaea is found also in Victoria, Tasmania and New South Wales. It has many chemical variants the P− is known as *C. grayi* Merr. A specimen collected by J. A. Elix (2185) 9 km east of Springton has a K+ yellow reaction (containing atranorine) and could be referred to *C. conistea* (Del.) Asah.

Cladonia didyma (Fée) Vain. 1887:137.

Scyphorus didymus Fée 1824:98.

Primary thallus persistent or disappearing. *Podetia* whitish- to greenish-grey, cupless, terete, up to 2·5 cm tall and 1-2 mm diam., corticate for the most part, with coarse soredia or granular squamules. *Apothecia* scarlet, bulging over the top of the podetium, up to 2 mm diam.

Reactions: K−, C−, KC+ orange, P−.

Figure: Habit, plate 2B (MEL 1022013).

This species has not yet been recorded in South Australia, but it is common all along the eastern coast of Australia so is likely to occur in the South-East.

Cladonia farinacea (Vain.) Evans 1950:95.

Cladonia furcata var. *scabriuscula* f. *farinacea* Vain. 1887:339.

Primary thallus persistent or disappearing. *Podetia* greenish-grey, up to 8 cm tall, dichotomously branched, axils open, corticate and squamulose at the base becoming sorediose and esquamulose in the upper parts. *Apothecia* brown, on the tips of the branches.

Reactions: K−, C−, KC−, P+ red.

Specimen examined: Ewens Ponds, South-East, *R. B. Filson 15816*, 8.iii. 1977 (MEL 1018570).

The species occurs also in Victoria and New South Wales.

Cladonia furcata (Huds.) Schrad. 1794:107.

Lichen furcatus Huds. 1762:458.

Primary thallus usually disappearing. *Podetia* arising from the margins of the primary thallus, up to 12 cm tall, pale green to olive-green to brownish-grey, sometimes almost forming cups, axils open, corticate, sometimes squamulose, esorediose. *Apothecia* rare, brown, at the tips of the branches.

Reactions: K−, C−, KC−, P+ red.

Figure: Habit, plate 3B (MEL 1021856).

Specimen examined: Mount Burr, *I. B. Wilson 516*, 7.ix.1960 (AD, MEL 27392).

This is probably the largest *Cladonia* species recorded in the State, but found only at one location, fringing a *Melaleuca* swamp. It occurs also in Victoria, Tasmania and New South Wales.

Cladonia macilenta Hoffm. 1796:126

Primary thallus persistent. *Podetia* rising from the upper surface of the primary thallus, up to 1·5 cm tall, pale grey to grey, with narrow and indistinct apical cups or tapering apically, corticate, squamulose at the base or part way up the podetia; soredia diffused, farinose. *Apothecia* terminal or in a ring or part ring on cup margin, bright scarlet.

Reactions: K+ deep yellow, C−, KC−, P+ orange.

Specimen examined: Naracoorte, *D. Hunt,* June-July 1962 (AD 97733141).

Cladonia macilenta is a common red-fruited species occurring in southern States.

Cladonia pityrea (Flörke) Fr. 1826:21.

Capitularia pityrea Flörke 1808:135.

Primary thallus usually persisting. *Podetia* arising from the upper side of the primary thallus, simple, or rarely with long narrow cups, up to 4 cm tall, corticate, abundantly sorediose with coarse granular soredia, sometimes squamulose at the base. *Apothecia* terminal on the podetia, reddish-brown to dark brown.

Reactions: K− or K+ yellow, C−, KC−, P+ red.

Figure: Habit, plate 3C (MEL 1021857).

Although no specimens were examined, this species is known to occur in the wetter areas of the South-East. It is an extremely common and polymorphic species found in Victoria, Tasmania and New South Wales.

Cladonia scabriuscula (Del. in Duby) Nyl. 1875:447.

Cenomyce scabriuscula Del. in Duby 1830:623.

Primary thallus disappearing. *Podetia* light grey or greenish-grey up to 8 cm tall, cupless, dichotomously branched, axils open, sometimes granular sorediose, sometimes squamulose at the base. *Apothecia* small, terminal, brown.

Reactions: K−, C−, KC−, P+ red.

This species has not been recorded in South Australia, but it is widespread in New South Wales and Victoria and is likely to be found in dry sclerophyll forest.

Cladonia squamosula Müll. Arg. 1883:19.

Primary thallus persistent or disappearing. *Podetia* dark grey or dark greenish-grey, up to 2·0 cm tall and 1·0-1·5 mm thick, cupless, tapering to the apices, corticate in the lower part, covered in coarse granules or squamules, sometimes the ultimate tips bare and decorticate. *Apothecia* small, terminal, brown.

Reactions: K+ deep yellow, C−, KC−, P+ yellow becoming orange.

Figure: Habit, plate 4A (MEL 1021282).

Selected specimens examined: Angaston, *R. W. Rogers 1823,* 31.xii.1967 (R.W.R.); Balhannah, *R. W. Rogers 351,* ?1965 (R.W.R.); Kuitpo, *R. W. Rogers 1439,* 28.vii.1968 (R.W.R.).

This species is common on rotting stumps in the wetter areas and sometimes completely covers old stumps. It is found in all southern States.

Cladonia verticillata (Hoffm.) Schaer. 1823:31.

Cladonia pyxidata C. verticillata* Hoffm., 1796:122.

Primary thallus persistent or disappearing. *Podetia* greenish-grey, up to 8 cm tall with smoothly dilated cups proliferating from the centre, margins of the cups smooth rarely lacerate, corticate, esorediose, sometimes with well developed basal squamules. *Apothecia* brown, stipitate, on the margins of the cups.

Reactions: K−, C−, KC−, P+ red.

Figure: Habit, plate 4C (MEL 1021199); ascospores, fig. 13O.

Specimen examined: Mylor, *V. M. Cruikshank,* 26.vi.1966 (R.W.R.).

This species occurs in all southern States.

25. COCCOCARPIA Pers. 1826:206.

Literature: Malme 1926.

Thallus foliose, attached to the substrate by rhizines or tomentum, upper and lower cortex of longitudinal hyphae. *Apothecia* lecideine, sessile or adnate, disk convex; ascospores eight in ascus, simple, hyaline. Phycobiont *Scytonema.*

Coccocarpia pellita var. **cocoes** (Fée) Zahlbr. 1925:286.

Circinaria cocoes Fée 1824: 127.

Coccocarpia pellita var. *semiincisa* Müll. Arg. 1882:321.

Thallus silver-grey or lead-grey forming rosettes, attached to the substrate by a dense black tomentum; upper surface longitudinally finely striate; lobes sublinear, 2·0-4·0 mm broad, isidiose near the centre of the thallus. *Apothecia* dark brown or black.

Figure: Ascus containing spores, fig. 13M.

Recorded for South Australia by Weber and Wetmore (1972:33). This variety, or others in this very plastic genus, may be found on bark or rock in wetter areas. It occurs in Victoria, New South Wales and Queensland.

26. COLLEMA Web. *in* Wigg. 1780:89.

Literature: Degelius 1954, 1974.

Thallus variable, subcoralline or lobate, adnate or ascending, thick or thin, esorediose, with or without isidia. *Apothecia* common, lecanorine, adnate or sessile; disk concave to flat or slightly convex; margin thin to thick, entire or irregular; ascospores eight in ascus, hyaline, cylindrical to fusiform, transversely septate or muriform.

ARTIFICIAL KEY TO SPECIES

1\. Thallus isidiose 2
1\. Thallus non-isidiose 4
  2\. Ascospores transversely septate, thallus lobes lobulate 3
  2\. Ascospores muriform, lobes not lobulate .... *C. subconveniens*
3\. Thallus rosulate, on earth (in arid and sub-arid areas) ascospores 1-3 septate .... *C. coccophorum*
3\. Thallus lobes not rosulate, amongst mosses, ascospores 5-8 septate .... *C. rugosum*
  4\. Thallus rosulate 5
  4\. Thallus not rosulate, lobes lobulate, amongst mosses ascospores 5 septate .... *C. durietzii*
5\. Thallus lobes lobulate, on earth (in arid and sub-arid areas) ascospores 1-3 septate .... *C. coccophorum*
5\. Thallus lobes not lobulate, corticolous, ascospores 6-13 septate 6
  6\. Apothecia glaucous-white .... *C. glaucophthalmum*
  6\. Apothecia reddish-brown .... *C. glaucophthalmum* var. *implicatum*

Collema coccophorum Tuck. 1862:385.

Thallus dark-olive-green to black, forming small sub-fruticose to subfoliose rosettes up to 2·5 cm across, often partly buried in the substrate; lobes radiate, 0·5-3·0 mm broad, with or without isidia, often with swollen margins which may be lobulate; lobules sometimes terete. *Apothecia* common 1·0-2·0 mm diam.; ascospores hyaline, 1-3 septate.

Figure: Ascospores, fig. 13L.

Specimens examined: Port Wakefield, *R. W. Rogers 909*, 9.xi.1967 (AD 97733144); Kingoonya, *R. W. Rogers 204*, 23.ii.1966 (AD 97733140); Cowell, *R. W. Rogers 642*, 1.x.1966 (AD 97733142); Yunta, *R. W. Rogers 1142*, 18.v.1967 (AD 97733143); Renmark, *R. W. Rogers 280*, 8.iii.1966 (AD 97733139).

This species is very widespread, especially on calcareous, arid zone soils in Victoria, Western Australia and New South Wales.

Collema durietzii Degelius 1974:98.

Thallus foliose to subfoliose, of scattered lobes or irregular in shape, deep olive green to brownish-green; lobes short and broad, imbricate, incised and undulate, lobulate. *Apothecia* not seen.

Specimen examined: By waterhole in Frome River, 6 km north of Evans Outstation, 40 km east-south-east of Copley, Flinders Ranges, *R. B. Filson 15617*, 19.xi.1975 (MEL 1018582).

Collema glaucophthalmum Nyl. 1858:377 var. **glaucophthalmum.**

Thallus dark olive-green to black forming rosettes up to 10 cm diam., closely adnate to the substrate; lobes 0·5-1·0 cm broad, pustular and ridged, without isidia. *Apothecia* common 0·5-1·0 mm diam.; disk densely white pruinose; ascospores hyaline, acicular, 30-95 x 3-6·5 μm transversely 6-13 septate.

Figure: Habit, plate 4B (MEL 1021281).

Specimens examined: Memory Cove, Cape Catastrophe, Eyre Peninsula, *R. B. Filson 11845*, 24.x.1970 (MEL 1018616); Point Drummond, west coast of Eyre Peninsula, *R. B. Filson 11874*, 25.x.1974 (MEL 1018614); Mambray Creek, *L. D. Williams 1981*, 12.ix.1964 (L.D.W.); Angaston, *R. W. Rogers 1349*, 31.xii.1967 (R.W.R.); Robe, *L. D. Williams 1552*, 8.x.1962 (L.D.W.).

Collema glaucophthalmum var. **implicatum** (Nyl.) Degelius 1974:167.

Collema implicatum Nyl. 1863a:428.

This variety differs from the species in having shining red-brown disk to the apothecium; in all other ways it resembles the species.

Specimens examined: Point Drummond, west coast of Eyre Peninsula, *R.B. Filson 11874a*, 25.x.1970 (MEL 1018615); along the track into Memory Cove, 24 km south-south-west of Port Lincoln, *R.B. Filson 11850*, 24.x.1970 (MEL 1018617).

Both var. *glaucophthalmum* and var. *implicatum* grow on the bark of trees in the wetter parts of the State. They are also widespread in Western Australia, Victoria, Tasmania, New South Wales and Queensland.

Collema rugosum Kremp. 1870:128.

Thallus foliose, broadly lobate, adnate to ascending, deep olive-green to brown, matt or slightly shining, lobulate, isidiose; isidia numerous towards the centre covering tops of ridges. *Apothecia* rare in South Australia, sessile; ascospores eight in ascus 40-75 x 4-6·5 μm, fusiform, hyaline, 5-8 septate.

Specimen examined: Canunda National Park, 9 miles (14 km) west of Millicent, *R. B. Filson 14658 (in part)*, 17.v.1973 (MEL 1018600).

This species is common in Victoria and New South Wales.

Collema subconveniens Nyl. 1888:8.

Thallus light-green to blue-green, forming rosettes up to 8 cm diam., adnate or ascending at the margins, sparsely isidiose; lobes smooth, 4-8 mm broad. *Apothecia* numerous, 0·7-2·0 mm diam.; disk pale or dark red, epruinose; ascospores muriform, up to 7 transverse septa and 1-3 longitudinal septa, sometimes markedly constricted at the septa, 26-36 x 10-13 μm.

Although we have not seen specimens collected in South Australia it is reported from Mount Gambier on bark by Degelius (1974:139). It occurs also in Western Australia, Victoria, Tasmania, New South Wales and Queensland.

27. CYPHELIUM Ach. 1815:261.

Thallus crustose, powdery to more or less areolate. *Apothecia* sessile or almost immersed in thalline warts; disk at first almost closed, opening at maturity; margin either lecideine or double with an additional thalline rim; ascospores brown, uniseptate, constricted at the septum; paraphyses little branched.

Figure: Ascospores, fig. 13N.

This genus has not been recorded in South Australia, but collections are likely to be made from dry wood or bark.

28. DERMATOCARPON Eschw. 1824:21.

Thallus squamulose to crustose, upper surface corticate. *Perithecia* immersed, without hymenial algae; ascospores eight in ascus, simple, hyaline; paraphyses soon gelatinise and disappear.

ARTIFICIAL KEY TO SPECIES

1. Thallus growing on rock .... *D. compactum*
1. Thallus growing on soil .... *D. lachneum*

Dermatocarpon compactum (Mass.) Lettau 1912:97.

Placidium compactum Mass. 1856a:32.

Thallus of small dark brown to black squamules 0·2-0·3 mm diam., packed together to form a crust. *Perithecia* immersed; ascospores eight in ascus, simple.

Specimen examined: Koonamore Vegetation Reserve, *R. W. Rogers 1772*, 22.ix.1969 (R.W.R.).

This is probably a common species but as it is inconspicuous it is rarely collected. It grows on calcareous pebbles.

Dermatocarpon lachneum (Ach.) A.L. Smith 1911:270.

Lichen lachneus Ach. 1798:140.

Dermatocarpon hepaticum (Ach.) Th. Fr. 1861b:356.

Thallus of tan to dark brown squamules 1·0-3·0 mm diam., at first ovate, entire, plane to slightly convex, becoming crenate and distorted with age; attached to substrate by fine hyphal rhizoids. *Perithecia* immersed; ascospores eight in ascus, simple, 10-16 x 6-8 μm ellipsoidal.

Figure: Habit, plate 6A (MEL 1022009); ascus containing spores, fig. 16A

Specimens examined: 1·6 km west of Barton on the East-West Railway Line, *R. B. Filson 11931*, 27.x.1970 (MEL 1018622); 11 miles (17 km) north-west of "Nullarbor" H.S., *R. B. Filson 9475*, 11.i.1967 (MEL 25450); Ceduna, *R.B. Filson 9399*, 26.xii.1966 (MEL 25439); 31 km west of Oodnadatta, *R. B. Filson 15633*, 21.xi.1975 (MEL 1018592); Frome River 6 km north of "Evans O.S.", Flinders Ranges, *R. B. Filson 15616*, 19.xi.1975 (MEL 1018583); Port Wakefield, *R. W. Rogers 907*, 9.xi.1967 (AD); Murray Bridge, *R. W. Rogers 378*, 11.v.1966 (AD).

This species is very common on calcareous soils throughout the Mallee and Saltbush regions. It is a major component of many areas of soil surface lichen crust in Western Australia, Victoria, New South Wales, Queensland and Northern Territory.

29. DIMERELLA Trev. 1880:65.

Thallus crustose, effuse, ecorticate, margins clearly hyphal. *Apothecia* sessile; disk pale to intensely yellow to orange; margin lecideine, pale; ascospores eight in ascus, two-celled, hyaline; paraphyses simple, unbranched.

Dimerella lutea (Dicks.) Trev. 1880:65.

Lichen luteus Dicks. 1785:11.

Thallus crustose, thin, ecorticate, pale green to greenish-white. *Apothecia* sessile, lecideine, up to 1·5 mm diam.; disk concave to flat becoming convex at maturity, pale yellow-orange; margin prominent, becoming flexuose, concolourous with the disk; ascospores eight in ascus, uniseptate, hyaline, 10-14 x 3-4 μm.

Figure: Ascospores, fig. 16B.

Although this species has not been recorded in South Australia, it is widespread in Victoria, and is likely to be found in the wetter parts of the State on the bark of trees or amongst mosses on dead wood.

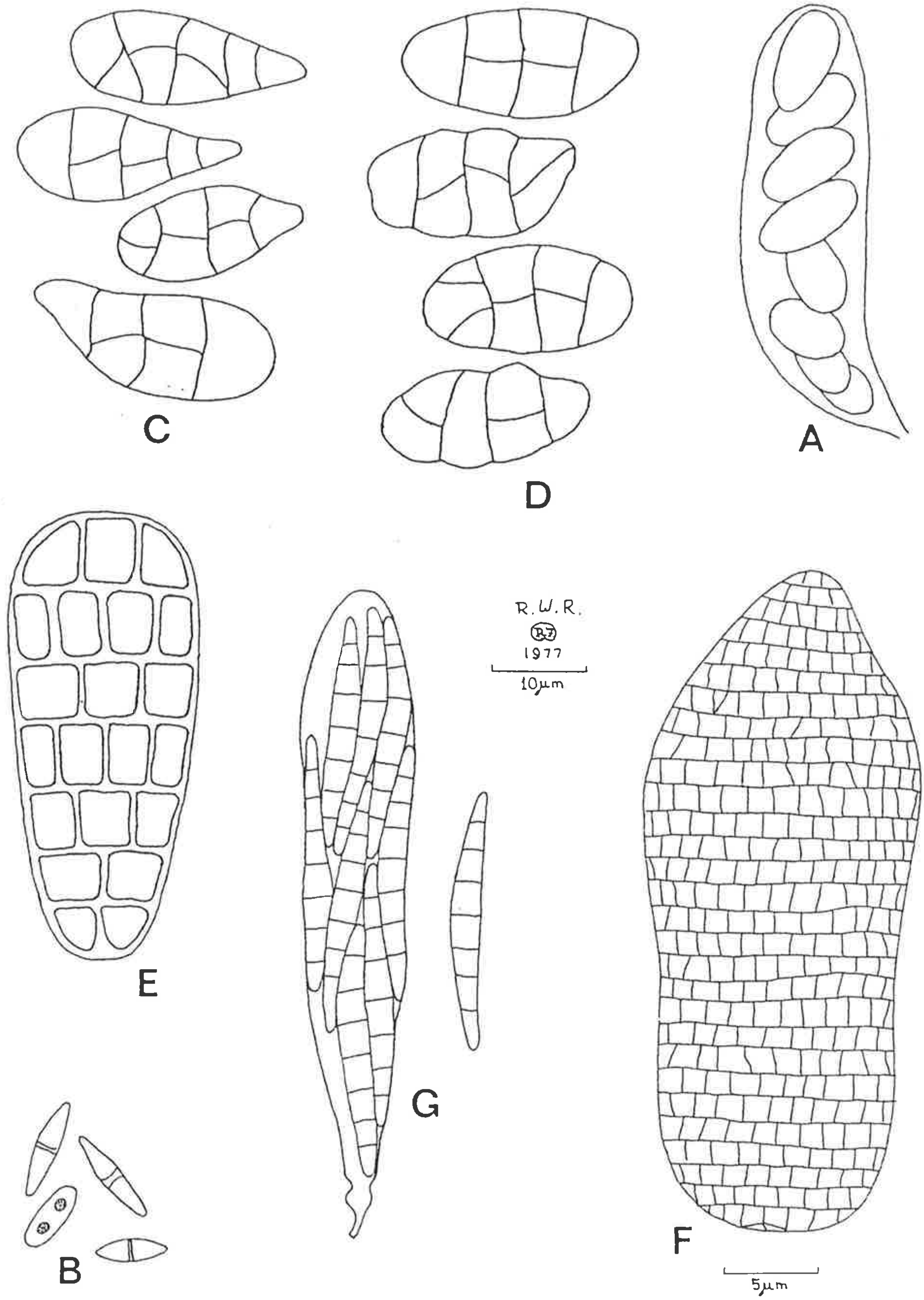

Fig. 16 A, *Dermatocarpon lachneum*, ascus containing spores; B, *Dimerella lutea*, ascospores; C, *Diploschistes scruposus*, ascospores; D, *Diploschistes ocellatus*, ascospores; E, *Endocarpon victorianum*, ascospore; F, *Endocarpon* sp., ascospore (note separate scale); G, *Enterographa* sp., ascus containing spores and one free ascospore.

30. DIPLOSCHISTES Norm. 1853:7

Literature: Magnusson 1955:281-287.

Thallus crustose, areolate, warty with a cortex of entangled hyphae. *Apothecia* immersed in the thallus or adnate; disk almost closed, open at maturity, black; margin bipartite, the inner proper exciple concolourous with the disk and the outer thalline concolourous with the thallus; ascospores brown, 2-8 per ascus, muriform.

ARTIFICIAL KEY TO SPECIES

1. Thallus thick, chalky-white, apothecia adnate, 2-4 mm diam . . *D. ocellatus*
1. Thallus thin, greyish-white to brownish-white, apothecia immersed, up to 1 mm diam 2
    2. On soil, thallus K+ . . . . *D. scruposus*
    2. On rock, thallus K− . . . .*D. gypsaceus*

Diploschistes gypsaceus (Ach.) Zahlbr. 1892:35.

Urceolaria gypsacea Ach. 1810:338.

Thallus crustose, areolate, white to greyish-white patches on rocks. *Apothecia* less than 1 mm diam., immersed, proper margin black or white-pruinose, almost enclosing the disk.

Reactions: Medulla K−, C−, KC−, P−, I−.

Figure: Habit, fig. 14B.

Specimens examined: Torrens Gorge, *R. W. Rogers 1740*, ?1968 (R.W.R.); Yunta Hills, *R. W. Rogers 1280*, 18.viii.1967 (R.W.R.).

This species is fairly common on rocks but is not often collected. It is known also in Victoria.

Diploschistes ocellatus (Vill.) Norm. 1853:232.

Lichen ocellatus Vill. 1789:988.

Thallus forming a thick extensive, white or greyish-white crust, areoles smooth, 0·5-1·5 mm diam. *Apothecia* up to 4 mm diam.; disk almost black sometimes pruinose; thalline margin prominent.

Reactions: Medulla K+ yellow becoming red, C−, KC−, P−, I−.

Figure: Habit, fig. 14C; ascospores, fig. 16D.

Selected specimens examined: Hesso, 50 km north-west of Port Augusta, *R. W. Rogers 46*, 24.ix.1965 (R.W.R.); "Tregolana" Station 18 km north of Whyalla, *R. D. Seppelt*, 7.vi.1969 (R.W.R.); "Koonamore" Station, 60 km north of Yunta, *R. W. Rogers 1641*, 19.iv.1969 (R.W.R.); "Quondong" Station 120 km north-north-east of Morgan, *R. W. Rogers 1340*, 19.xi.1967 (R.W.R.).

Diploschistes ocellatus, known also from Victoria and New South Wales, is widespread but not common on arid and sub-arid soil. Material referred to *D. subocellatus* (Nyl. ex Cromb.) Zahlbr. by Weber and Wetmore (1972:37) has been treated here as *D. ocellatus*.

Diploschistes scruposus (Schreb.) Norm. 1853:232.

Lichen scruposus Schreb. 1771:133.

Thallus crustose, areolate, forming extensive white to grey to brownish-grey patches, up to 20 cm diam.; areoles smooth to rugulose, less than 1 mm diam. *Apothecia* deeply immersed, proper margin black, sometimes almost enclosing the disk, radiately striate.

Reactions: Thallus K+ yellow or yellow turning red, C+ rose or purple-grey, I+ blue.

Figure: Habit, plate 14D; ascospores, fig. 16C.

Selected specimens examined: Tarcoola, *R. W. Rogers 213*, 23.iii.1966 (AD); *R. W. Rogers 1155*, 22.v.1967 (AD 97733147); Port Wakefield, *R. W. Rogers 904*, 9.ii.1967 (AD 97733146); Tarlee, *R. W. Rogers 1509*, 29.x.1968 (AD 97733147); Loxton, *R. W. Rogers 422*, 11.v.1966 (AD 97733145); Finniss, *R. W. Rogers 1545*, 6.xi.1968 (AD 97733149).

This species is one of the most common arid soil lichens. It has been recorded from all States with the exception of Tasmania.

31. ENDOCARPON Hedw. 1789:56.

Thallus squamulose, sometimes appearing almost crustose; medulla, algal layer and upper cortex differentiated. *Perithecia* immersed, or the apex just protruding; algae present in the hymenial layer; ascospores 2-4 in ascus, muriform, brown; paraphyses soon gelatinise.

ARTIFICIAL KEY TO SPECIES

1. Ascospores one per ascus 2
1. Ascospores two per ascus .... *E. pusillum*
  2. Ascospores 75-107 × 24-35 μm .... *E. victorianum*
  2. Ascospores 140 × 60 μm .... *E. sp.*

Endocarpon pusillum Hedw. 1789:56.

E. helmsianum Müll. Arg. 1892:197.

Thallus of thick brown to greenish-brown squamules 2-5 mm diam.; margins entire or crenate; undersurface with extensive rhizoidal and stolon development. *Perithecia* immersed, thallus raised into a rim around the ostiole; ascospores two per ascus, muriform, brown.

Specimens examined: 14 miles (22 km) east-south-east of "Kenmore Park", *A. C. Beauglehole 25680,* 2.vii.1968 (MEL 1018671); Tarcoola, *R. W. Rogers 211,* 23.ii.1966 (AD 97733151); Cowell, *R. W. Rogers 641,* 1.x.1966 (AD 97733150); Hope Valley, *R. W. Rogers 1553,* 12.xi.1968 (AD 97733137); Koonamore Vegetation Reserve, *R. W. Rogers 1330,* 20.xi.1967 (R.W.R.); Mount Rescue Conservation Park near Gosse Hill, 30 km east-south-east of Tintinara, *R. W. Rogers 1447,* 6.vii.1968 (R.W.R.).

Endocarpon pusillum appears to involve two distinct taxa. One a large pale to clay-brown squamulose thallus, with a smooth to rugulose, dull, upper surface and crenulate margins. This is identical with the type of *Endocarpon helmsianum* Müll. Arg. The other is smaller with pale to reddish-brown or greenish-brown thallus, upper surface is always smooth and sometimes shining, margins smooth, mostly deflexed. This agrees with the accepted interpretation of *E. pusillum.* Perithecial structures of both entities appear to be the same.

It is known from all Australian States.

Endocarpon victorianum Müll. Arg. 1893b:62.

Thallus of creamy-brown to pale brown squamules up to 10 mm diam., with entire to crenulate margins; upper surface flat to deeply concave, smooth, sometimes incised or flexuose. *Perithecia* immersed, ostiole indistinct; ascospores solitary in ascus, at first grey becoming brown to black at maturity, 75-105 × 24-35 μm

Figure: Ascospores, fig. 16E.

Specimens examined: Mona, 6·5 km south-west Bute, *R. B. Filson 12012,* 31.x.1970 (MEL 1018620); 3 km north of Kokatha on the Poochera-Kingoonya road, *R. B. Filson 11920,* 26.x.1970 (MEL 1018624).

Endocarpon victorianum was first described from Victoria.

This species is easily confused with *E. pusillum.* Macroscopically it appears to be intermediate between forms *pusillum* and *helmsianum* but differs from both in the large ascospores which are solitary in the ascus. There could be justification for including this entity with *E. pusillum* but we have never observed intermediates containing large and small, single and double-spored asci.

Endocarpon sp.

Thallus strongly convex to pulvinate, appearing polyphyllous, clay-brown to charcoal-brown up to 10 mm diam.; upper surface strongly rugulose and cracked. *Perithecia* immersed, ostiole indistinct; ascospores solitary in ascus, hyaline, to grey becoming brown to black, 140 x 60 μm.

Figure: Ascospore, fig. 16F.

Specimen examined: South side of Carappee Hill 8 km north-east of Darke Peak, Eyre Peninsula, *R. B. Filson 11773,* 22.x.1970 (MEL 1018630).

Unfortunately this species is known only from a single collection. The pulvinate, apparently polyphyllous thallus and the very large ascospores make it distinctive.

32. ENTEROGRAPHA Fée 1824:xxxii & 57.

Thallus crustose, ecorticate. *Pseudothecia* immersed in stromatic bodies on the upper surface, simple to elongate or stellate, with well developed rudimentary exciple; hypothecium pale; asci clavate; ascospores 8, transversely many septate, hyaline; paraphyses reticulately branched and interwoven.

Figure: Ascus containing spores and one free spore, fig. 16G.

This genus has not been collected in South Australia, but it is likely to occur on bark and rocks.

33. EPHEBE Fr. 1825:256.

Literature: Henssen 1963.

Thallus of thin-walled, many-celled hyaline hyphae extending longitudinally and laterally within the gelatinous sheath of the phycobiont, sometimes protruding through the sheath, sometimes the hyphae intertwine and form plechtenchyma towards the base of the filaments. *Apothecia* minute, immersed, often in groups; asci short-clavate to cylindrico-clavate; ascospores eight, hyaline, simple or obscurely once septate.

Ephebe lanata (L.) Vain. 1888:20.

Lichen lanatus L. 1753:1155.

Thallus deep olive-green to black, forming inconspicuous turf-like tufts over the substrate, of very thin, cylindrical, branched filaments, taking its general form from the phycobiont *Stigonema.*

Specimen examined: Marble Range near Elliston, *R. B. Filson 11859,* 24.x.1970 (MEL 1018571).

This species is probably common over rocks, growing in water run-off channels. It is known also in Victoria and Tasmania.

34. ERIODERMA Fée 1824:145.

Literature: Keuck 1977.

Thallus foliose, loosely attached to the substrate; upper surface corticate, covered with a dense layer of soft hairy tomentum; lower surface ecorticate, rhizinate. *Apothecia* peltate, lecideine; asci eight-spored; ascospores hyaline, simple, paraphyses unbranched. Phycobiont *Scytonema.*

At present this genus is unknown in South Australia but it is likely to occur on bark and rotting wood in the very wet areas of the South-East.

35. FULGENSIA Mass. et de Not. *in* Mass. 1853b:10.

Literature: Poelt 1965a.

Thallus crustose, thick, marginal lobes with both upper and lower cortex; upper surface becoming granular sorediose. *Apothecia* deep orange-red to reddish-brown, sessile; asci eight-spored; ascospores simple or rarely two-celled, hyaline.

Fulgensia subbracteata (Nyl.) Poelt 1961:137.

Lecanora subbracteata Nyl. 1883:534.

Caloplaca subbracteata (Nyl.) Lett. 1958:28.

Thallus small, 1-2 cm diam., white to pale lemon-yellow to yellow-orange, continuous or areolate with small but distinct marginal lobes, becoming granular sorediose. *Apothecia* uncommon, up to 1·5 mm diam.; disk flat, reddish-brown; margin crenulate, concolourous with the thallus; ascospores hyaline, simple, 13-15 x 5-6 μm.

Reactions: Apothecial disk K+ purple or violet.

Figure: Ascospores, fig. 17A.

Selected specimens examined: 26½ miles (42 km) west-south-west of Koonalda, Nullarbor Plain, *A. C. Beauglehole 14908*, 24.ix.1965 (MEL 22841); "Colona" H.S., Yalata Aboriginal Reserve, *J. H. Willis*, 27.viii.1947 (MEL 9221); by Lincoln Highway, 17 miles (29 km) south of Cowell, *R. B. Filson 11792*, 23.x.1970 (MEL 1018686); south-west Fishery Bay, 21 miles (34 km) south of Port Lincoln at Whalers Way fence, *R. B. Filson 11803*, 23.x.1970 (MEL 1018682); Mona, 6 km south-west of Bute, *R.B. Filson 12013*, 31.x.1970 (MEL 1018685).

This species is widespread on soil in arid and semi-arid areas of Western Australia, Victoria and New South Wales.

36. GRAPHINA Müll. Arg. 1880:22.

Literature: Wirth and Hale 1963.

Thallus crustose, epi- or endophloic, ecorticate or with a rudimentary cortex. *Apothecia* immersed, adnate or sessile, generally elongate, simple or sparsely branched often contorted; disk narrow and slit-like; margin sometimes carbonaceous; asci clavate 1-3 spored; ascospores hyaline, muriform; paraphyses unbranched.

Figure: Ascospores, fig. 17B.

At present this genus is not known in South Australia, but it is likely to occur on bark or fence posts.

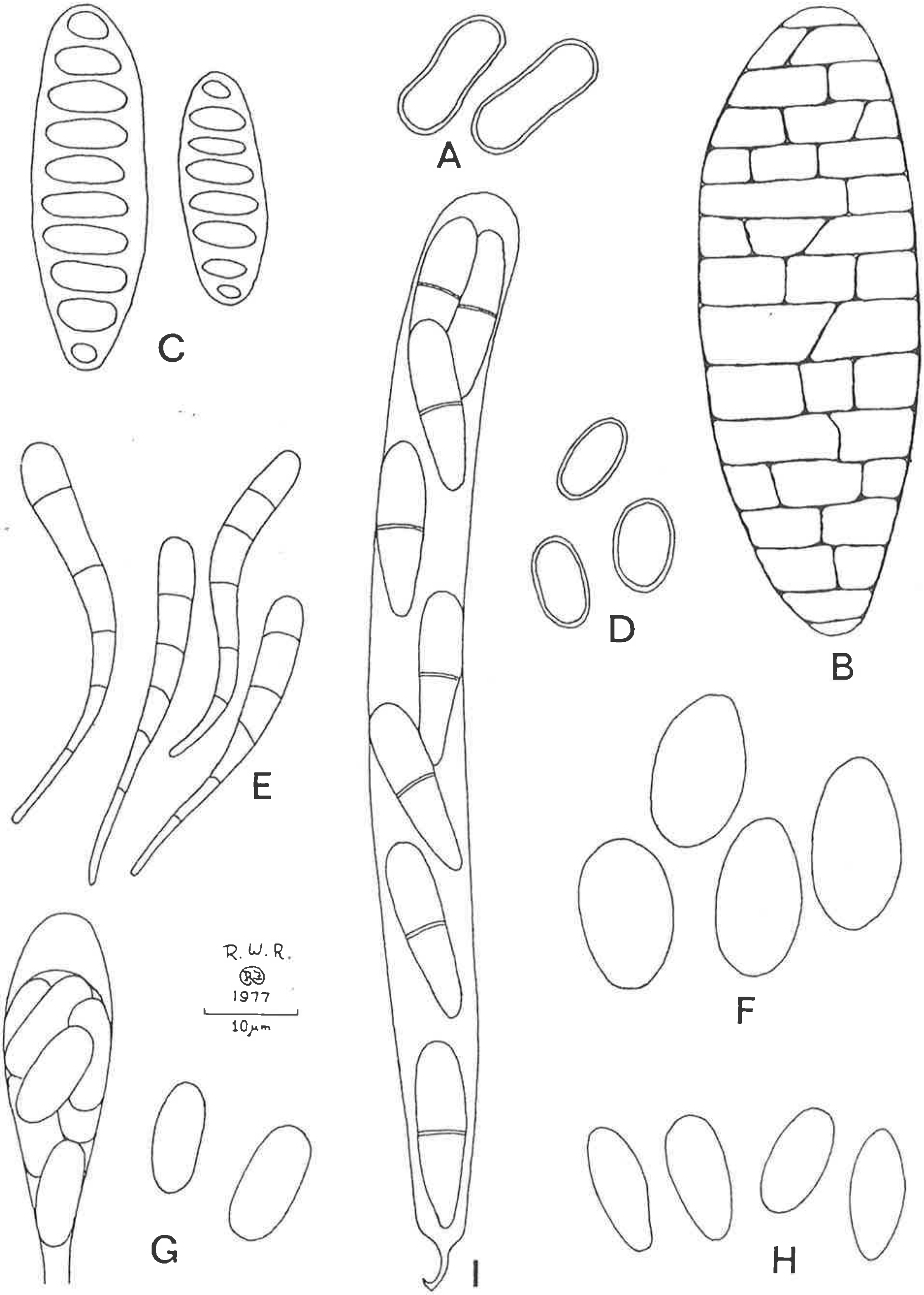

Fig. 17. A, *Fulgensia subbracteata,* ascospores; B, *Graphina* sp., ascospore; C, *Graphis desquamescens,* ascospores; D, *Gymnoderma melacarpum,* ascospores; E, *Haematomma puniceum,* ascospores; F, *Heppia lutosa,* ascospores; G, *Heterodea muelleri,* ascus containing spores and two free ascospores; H, *Hypogymnia pulchrilobata,* ascospores; I, *Icmadophila ericetorum,* ascus containing spores.

37. GRAPHIS Adans. 1763:11

Literature: Nakanishi 1966, Wirth & Hale 1963.

Thallus crustose, epi– or endophloic, ecorticate or with a rudimentary cortex. *Apothecia* immersed, adnate or sessile, generally elongate, simple or sparsely branched, often contorted; disk narrow and slit-like; margin sometimes carbonaceous; asci clavate to oblong, 1-8 spored; ascospores hyaline, transversely one- to many- septate; paraphyses unbranched.

Figure: Ascospores, fig. 17C.

At present there are no records of this genus for South Australia, but it is probably quite common on bark of trees.

38. GYMNODERMA Nyl. 1860:26.

Literature: Yoshimura and Sharp 1968, Hawksworth and Yoshimura 1973.

Gymnoderma melacarpum (F. Wils.) Yoshimura 1973:287.

Neophyllus melacarpa F. Wils. 1891:372.

Thallus squamulose, minute, yellow-green, finely divided, laciniae ascending, 0·1-0·2 mm wide. *Apothecia* marginal, black, globose or subglobose, capitate on short podetia up to 1 mm tall; ascospores eight in ascus, simple, ellipsoid, 10-13 x 4-7 μm.

Figure: Ascospores, fig. 17D.

This species is at present unknown in South Australia but it is likely to occur on rotting logs in the wetter parts of the State.

39. HAEMATOMMA Mass. 1852a:32.

Literature: Culberson 1964.

Thallus crustose, continuous, rugulose or smooth, cracked or continuous, sometimes powdery. *Apothecia* adnate or sessile; disk red to brownish-red; margin concolourous with the thallus; ascospores eight in ascus, 3- many septate, hyaline, acicular.

Haematomma puniceum (Sm. *apud* Ach.) Mass. 1860:253.

Lichen puniceus Sm. *apud* Ach. 1803:167.

Thallus crustose, rugulose, cracked, greyish- to brownish-white. *Apothecia* sessile: disk red to orange-red, up to 1·75 mm diam.; margin prominent, crenulate, concolourous with the thallus; ascospores hyaline, acicular 3-6 septate, 40 x 5 μm.

Figures: Habit, fig. 18A; ascospores, fig. 17E.

Specimen examined: Adelaide, *A. L. Smith*, Aug. 1914 (BM).

Haematomma puniceum occurs widely in Victoria, Tasmania, New South Wales and Queensland.

40. HEPPIA Naeg. *in* Hepp 1853:49.

Literature: Wetmore 1970.

Thallus squamulose, attached to the substrate by hyphae. *Apothecia* immersed; ascospores eight in ascus, hyaline, simple.

Heppia lutosa (Ach.) Nyl. 1863c:45.

Collema lutosum Ach. 1814:309.

Thallus squamulose, grey to olive, irregularly round to elongate, sometimes forming a rosette-like group, concave or flat, margins becoming granular sorediose. *Apothecia* usually one per squamule, immersed, 0·5-1·5 mm diam.; disk concave to flat, yellowish-brown.

Reactions: Thallus K−, hymenium I+ wine-red.

Figure: Ascospores, fig. 17F.

Selected specimens examined: "Mount Eba" Station, *R. W. Rogers 515*, 8.ix.1966 (AD 97733152); "Quondong" Station, 120 km north-north-east of Morgan, *R. W. Rogers 1131*, 23.ii.1967 (AD 97733154); Alford, 20 km north-east of Wallaroo, *R. W. Rogers 934*, 9.ii.1967 (AD 97733153).

This lichen is common but obscure on soils in arid areas of the state.

41. HETERODEA Nyl. 1867:47.

Literature: Filson 1978.

Thallus foliose, becoming erect or spreading irregularly on the substrate; upper surface smooth without soredia or isidia; lower surface ecorticate, felt-like, sometimes veined, sparse to moderately rhizinate. *Apothecia* on the margins of the lobes; ascospores single, hyaline, ellipsoidal. *Pycnidia* marginal subspherical, sessile.

ARTIFICIAL KEY TO SPECIES

1. Lower surface black with paler depressions or pores, or pale with a network of black veins . . . . *H. muelleri*
1. Lower surface white or pale grey sometimes indistinctly pitted, but never with a network of black veins . . . . *H. beaugleholei*

Heterodea beaugleholei R. Filson 1978:18.

Cladonia alcicornis var. *firma* sensu Müll. Arg. non Nyl.

Thallus foliose forming loosely irregular patches up to 5 cm diam.; lobes ascending at the margins; upper surface smooth, dull to slightly shining, grey-green to yellow-brown; lower surface dirty-white to pale grey, ecorticate, beset with scattered fasciculate rhizines and occasionally indistinctly pitted; rhizines mainly marginal, black. *Apothecia* terminal on marginal lobes, up to 3 mm diam,. reddish-brown; ascospores eight in ascus, simple, hyaline. *Pycnidia* marginal, stipitate, spherical.

Reactions: K−, C−, KC−, P−.

Specimens examined: Arcoellinna well, Everard Ranges, *R. Helms 18*, 28.v.1891 (ADU); Kimba to Cowell road, 18 km north-west of Cowell, *R. B. Filson 11778*, 22.x.1970 (MEL 1017087); 5 km east of Murray Bridge on Karoonda road, *R. W. Rogers 381*, 11.v.1966 (R.W.R.); Weary Paddock, "Quondong" Station, *R. W. Rogers 1333*, 20.xi.1967 (R.W.R.).

A common soil-growing lichen in Western Australia, Victoria, New South Wales, Queensland and Northern Territory.

Heterodea muelleri (Hampe) Nyl. 1867:47.

Sticta muelleri Hampe 1852:711.

Thallus foliose becoming erect or spreading up to 10 cm across and up to 4 cm tall, lobes ascending and recurved at margins; upper surface smooth, dull to slightly shining, yellow-green to yellow-brown; lower surface ecorticate, densely beset with brown to black rhizines, sometimes pale with a network of dark veins, sometimes black with paler depressions or spots, sometimes wholly black. *Apothecia* on the margins of the lobes up to 1 mm diam., pale reddish-brown to dark reddish-brown; margin not prominent; ascospores eight in ascus, ellipsoidal, simple, hyaline. *Pycnidia* marginal, stipitate, spherical.

Reactions: K−, C−, KC−, P−.

Figures: Habit, plate 7A (MEL 1022010); ascus containing spores and two free spores, fig. 17G.

Selected specimens examined: Everard Ranges, *R. Helms 20*, 1.vi.1891 (MEL 7275, ADU); south side of Carappee Hill, Eyre Peninsula, *R. B. Filson 11772*, 22.x.1970 (MEL 1017088); in Mount Lofty Ranges, *F. Mueller*, 1847 (MEL 7279); Para Wirra Recreation Park, *R. W. Rogers 94*, 17.i.1966 (R.W.R.); Rabbit Island soak, Mount Rescue Conservation Park, *R. W. Rogers 1449*, 19.viii.1968 (R.W.R.); near Barossa Reservoir, *R. W. Rogers 1475*, 30.x.1968 (ADU); 2 miles (3 km) north-east of Native Valley, *R. W. Rogers 1518*, 5.xi.1968 (ADU); Koonamore Vegetation Reserve, *R. W. Rogers 1642*, 2.v.1969 (R.W.R.); Ferguson Park, Burnside, *R. W. Rogers 1842*, 6.i.1970 (R.W.R.); Monster Mount, 10 km south of Keith, *R. D. Seppelt 2804*, 28.vii.1973 (MEL 1015509).

Heterodea muelleri occurs in all Australian States.

42. HYPOGYMNIA Nyl. 1881:537.

Literature: Bitter 1901a, Filson 1970, Elix 1979.

Thallus foliose, solid or hollow, dorsiventral, corticate, imperforate, naked below. *Apothecia* round, lecanorine, pedicillate to stipitate; disk brown, concave to strongly convex; margin prominent, concolourous with the thallus; ascospores eight in ascus, hyaline, simple.

ARTIFICIAL KEY TO SPECIES

1. Thallus solid 2
1. Thallus hollow 3
    2. Lobes narrow free, without extensive lateral contact ...... *H. mundata*
    2. Lobes broad, contiguous, flattened and expanded towards apices .... *H. billardieri*
3. Thallus sorediose, usually sterile, medulla usually P− or P+ .... *H. subphysodes*
3. Thallus esorediose, frequently fertile, medulla P− .... *H. pulchrilobata*

Hypogymnia billardieri (Mont.) Filson 1970:325.

Cetraria billardieri Mont. 1856:322.

Thallus grey to greenish-grey, forming loosely attached rosettes over the substrate, lobes broad, imbricate, without soredia or isidia; lower surface black, dull, naked, showing at the margins of the lobes from above. *Apothecia* common, up to 10 (−12) mm diam., concave at first becoming lumped and irregular with age; margin thin smooth at first becoming crenulate; ascospores hyaline, ellipsoid, 5-8 x 4·5-6·5 μm.

Reactions: Thallus K+ yellow; medulla K+ yellow becoming dingy brown, KC+ red, P−.

Specimens examined: Springton, *J. A. Elix 181,* 31.xii.1973 (MEL 1012604); western slopes of Mount Crawford, *J. A. Elix 3840,* 2.ix.1977 (J.A.E.).

This species occurs also in Victoria, Tasmania, New South Wales and Queensland.

Hypogymnia mundata (Nyl.) Rassad. 1956:11.

Parmelia mundata Nyl. 1860:401.

Thallus whitish-grey to greenish-grey, large, irregular, lobes enlongate, loosely branched, free, without extensive lateral contacts, without soredia or isidia. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K−, KC+ red, P−.

Specimen examined: 6·5 km west of Springton along the High Eden road, *J. A. Elix 2240,* 20.v.1976 (J.A.E.).

As yet only one specimen has been collected in South Australia. It occurs also in New South Wales and Tasmania.

Hypogymnia pulchrilobata (Bitt.) Elix in press 1979.

Parmelia pulchrilobata Bitt. 1901a:244.

Thallus whitish-grey forming a rosette up to 10 cm diam., adnate to the substrate; lobes elongate, imbricate, 1·0-2·0 mm broad, without soredia or idia; lower surface black, dull, naked. *Apothecia* numerous, distinctly edicillate, up to 20 mm diam.; margin entire, sometimes involute at first, ecoming crenulate; ascospores hyaline, ellipsoid, 7·5-8·5 x 5-6 µm.

Reactions: Thallus K+ yellow; medulla K−, KC+ red, P−.

Figure: Habit, plate 7B (MEL 1021190); ascospores, fig. 17H.

Specimen examined: Millbrook, *R. W. Rogers 1777*, 24.ix.1969 (AD 97650005).

Hypogymnia pulchrilobata is found also in Victoria, New South Wales and Western Australia.

Hypogymnia subphysodes (Kremp.) Filson 1970:325.

Parmelia subphysodes Kremp. 1880:338.

Thallus greyish-white, forming a loose mat over the substrate, attached mostly at the base of the lobes which are up to several centimetres long and very sparsely branched, densely sorediose on the older lobes; lower surface black, dull, naked, clearly visible from above. *Apothecia* not seen.

Reactions: Thallus K+ yellow; medulla K+ yellow turning brown, KC+ red, P+ pale yellow-orange to red.

Figure: Habit, plate 6B (MEL 1021853).

Specimens examined: Mount Lofty, *E. Dahl*, 4.v.1970 (CANB 228124); Kuitpo Forest, *R.W. Rogers 1423*, 21.viii.1968 (MEL 1018688); western side of the border road, 13 km north of Nelson-Caveton road, *R.B. Filson 14627*, 16.v.1973 (MEL 1018689).

Hypogymnia subphysodes is found growing over old stumps and on the persistent bark at the base of trees in the dry sclerophyll forests. It has been recorded in Western Australia, Victoria, New South Wales and Queensland.

43. ICMADOPHILA Trev. 1851-52:267.

Thallus crustose, granular, ecorticate. *Apothecia* lecideine, sessile or shortly stipitate, disk pale pink or brownish-pink, margin concolourous with the disk, ascospores eight in ascus, hyaline, uniseptate, rarely three-septate.

Figure: Ascus containing spores, fig. 17I.

Icmadophila has not yet been recorded in South Australia but species in this genus have been collected on roadside cuttings and earth banks in western Victoria.

44. LECANORA Ach. 1810:77.

Literature: Imshaug and Brodo 1966, Magnusson 1931.

Thallus crustose to subfoliose, usually poorly differentiated into layers, upper and lower cortex distinct or indistinct. *Apothecia* lecanorine, sessile; disk flat to

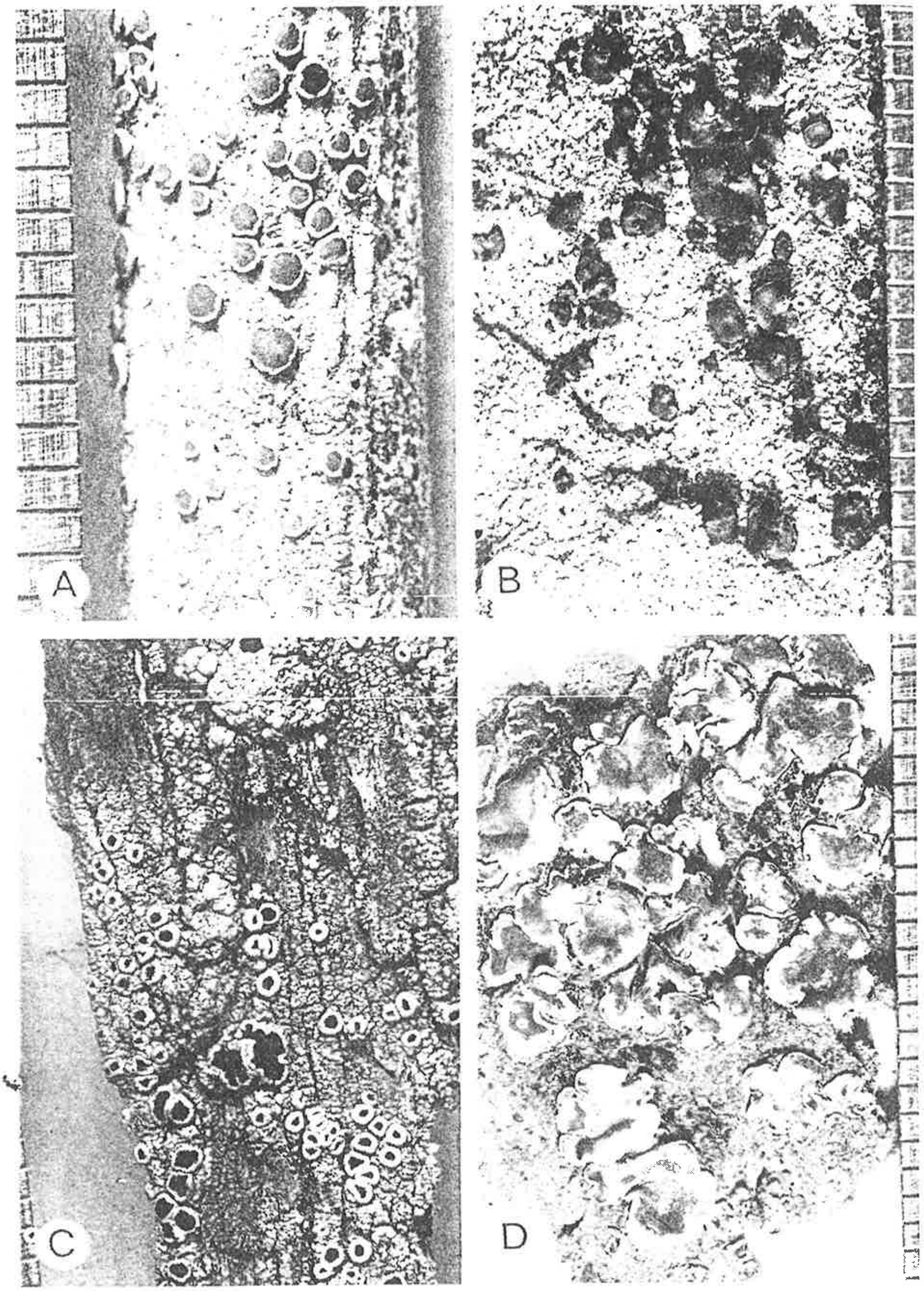

Fig. 18. A, *Haematomma puniceum*; B, *Peltula euploca*; C, *Lecanora atra*; D, *Lecidea decipiens*. Scale in millimetres.

convex; margin concolourous with the thallus; ascospores eight in ascus, hyaline simple.

Figures: Lecanora atra, habit, plate 7C (MEL 1021202) and fig. 18C; ascospores, fig. 19A.

Lecanora is a large genus, and the Australian material is not well known. A number of species have been collected in South Australia. *L. atra* (Huds.) Ach., has a white to greyish-white rugulose thallus, flat to convex black disk with a crenulate margin, concolourous with the thallus. This species is common in the drier areas on soil, rock and wood especially on old fence posts. *L. subcarnea* (Sw.) Ach., has large pale apothecia and is found on rocks in wetter areas. *L. sphaerospora* Müll. Arg. with its bluish-white pruinose, black apothecia and white thallus, the upper surface of which is cracked into solid angles giving it a crystalline appearance, is common on limestone pebbles in the arid areas. *L. varia* (Hoffm.) Ach., has a thin greenish-white thallus with flat, pale brown apothecia with lighter coloured prominent margins and is found on the smooth-barked trees in the dry sclerophyll forests.

45. LECIDEA Ach. 1803:32 em Zahlbr. 1905:130.

Literature: Hertel 1967, 1968, 1969b.

Thallus crustose or squamulose, mostly ecorticate with sessile apothecia. *Apothecia* lecideine; disk usually black or dark brown; margin concolourous with the disk; ascospores eight in ascus, simple, hyaline.

This is one of the largest of the crustose lichen genera, containing about 1 500 described species. The Australian material, as with other crustose genera, is poorly known except for the few squamulose species. A number of species of *Lecidea* occur on rocks, and soil, for which reliable names are not available.

ARTIFICIAL KEY TO THE SQUAMULOSE SPECIES

1. Squamules pink to brownish-pink with or without a white pruinose margin .... *L. decipiens*
1. Squamules grey, brown or cream but not pink 2
  2. Upper surface cracked into solid angles, thus having a crystalline appearance .... *L. crystallifera*
  2. Upper surface smooth 3
3. Squamules dark brown, round .... *L. globifera*
3. Squamules cream, crenate .... *L. psammophila*

Lecidea crystallifera Tayl. 1847:148.

Thallus squamulose, thick, grey or brown, up to 3 mm diam., sometimes much larger; upper surface cracked into pyramid-like polygons making it appear like a mass of crystals. *Apothecia* common, flat to strongly convex, marginal or laminal.

Figure: Habit, fig. 15C.

Selected specimens examined: Koonalda Cave, Nullarbor Plain, *R. B. Filson 9415,* 28.xii.1966 (MEL 25428); Gawler Ranges, *D. N. Krahenbuehl 2416,* 15.ix.1968 (MEL 37628); Memory Cove, Cape Catastrophe, *R. B. Filson 11823,* 24.x.1970 (MEL 1018623); 17 km north-east of Kimba, *A.C. Beauglehole 15113,* 27.ix.1965 (MEL 27922); Kingoonya, *R. W. Rogers 488,* 7.ix.1966 (AD 97733160); Port Wakefield, *R. W. Rogers 906,* 9.ii.1967 (AD 97733162); Two Wells, *R. W. Rogers 1568,* 11.xi.1968 (AD 97733163); Swan Reach, *R. W. Rogers 451,* 11.v.1966 (AD 97733159); Pinnaroo, *R. W. Rogers 323,* 9.iii.1966 (AD 97733158).

This species is common on arid and sub-arid soils where it is found covering small spaces between pebbles or forming rosettes on open areas. It has been recorded in Victoria and Western Australia.

Lecidea decipiens (Hoffm.) Ach. 1803:80.

Psora decipiens Hoffm. 1794:68.

Thallus squamulose, thin, pink to brownish-pink, up to 3 (−6) mm diam., commonly with a white pruinose margin, becoming crenate or lobed; upper surface smooth, cracking on older squamules, sometimes heavily white pruinose. *Apothecia* common, black, convex to hemispheric, usually marginal.

Figures: Habit, fig. 18D; ascospores, fig. 19B.

Selected specimens examined: Vicinity of Koonalda Cave, Nullarbor Plain, *R. B. Filson 9412,* 28.xii.1966 (MEL 25427); Gawler Ranges, *D. N. Krahenbuehl 2418,* 15.ix.1968 (MEL 37629); Koonamore Vegetation Reserve, *C. M. Eardley* 24.vi.1946 (MEL 7236); 9 miles (14 km) east of Springton, *J. A. Elix 471,* 15.x.1974 (MEL 1013130); Two Wells, *R. W. Rogers 1567,* 11.xi.1968 (AD); Kadina, *R. W. Rogers 938,* 9.ii.1967 (AD); Milang, *R. W. Rogers 1539,* 5.xi.1968 (AD).

This very common and widely distributed lichen apparently comprises several physiologically and chemically different races. It is recorded from all continents except South America, and from hot tropical deserts to within the Arctic Circle.

Lecidea globifera Ach. 1810:213.

Thallus squamulose, thin, brown, up to 2 mm diam., becoming irregularly lobed; upper surface, smooth or slightly rough. *Apothecia* black, flat to covex, laminal.

Figure: Habit, fig. 15D.

Specimen examined: Cape Jervis, *R. W. Rogers 1469,* 1.ix.1968 (AD 97649767).

This species is apparently rare, growing on exposed soil.

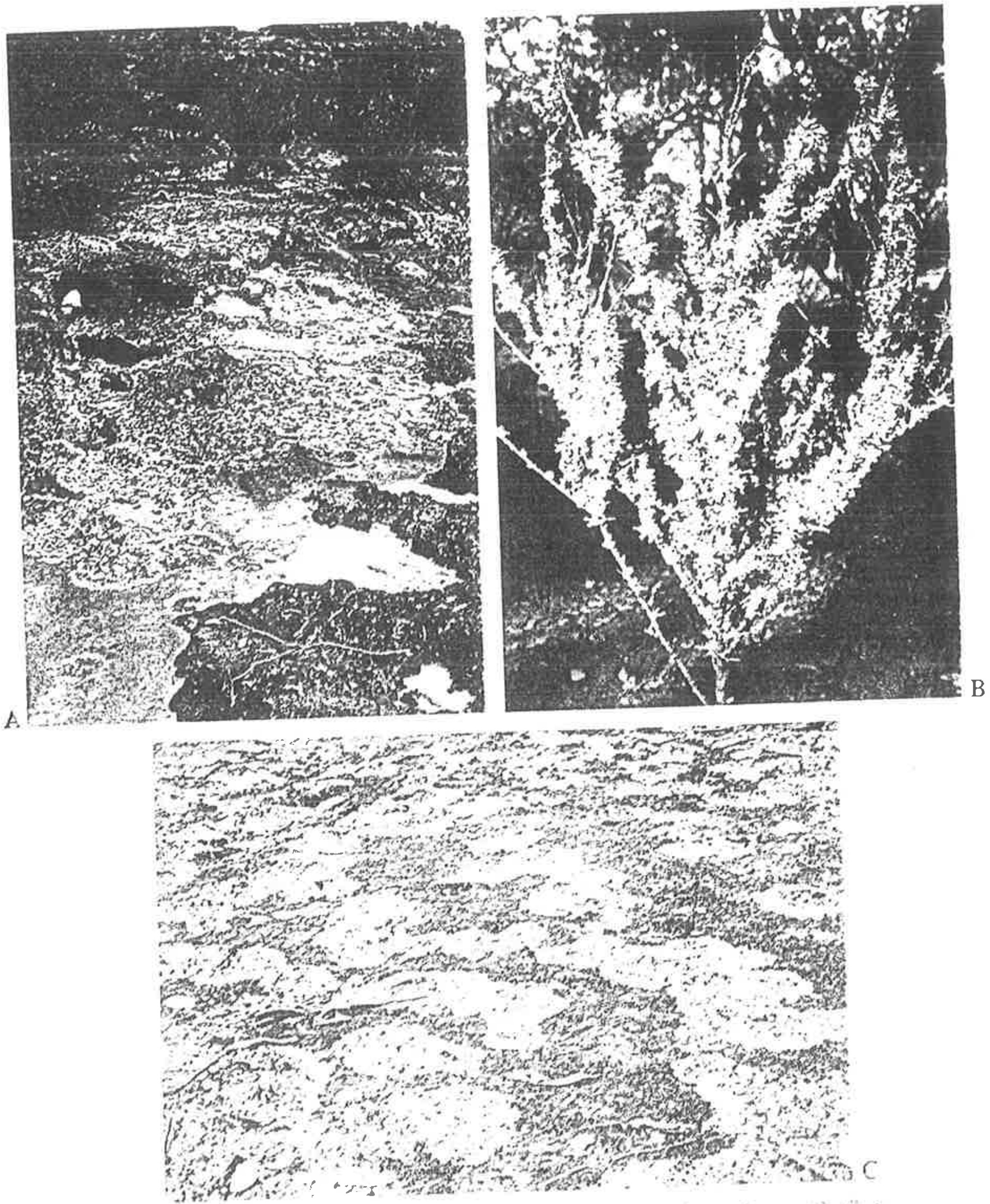

Plate 1. Lichen habitats: A. rock faces; B. branches; C. earth flats

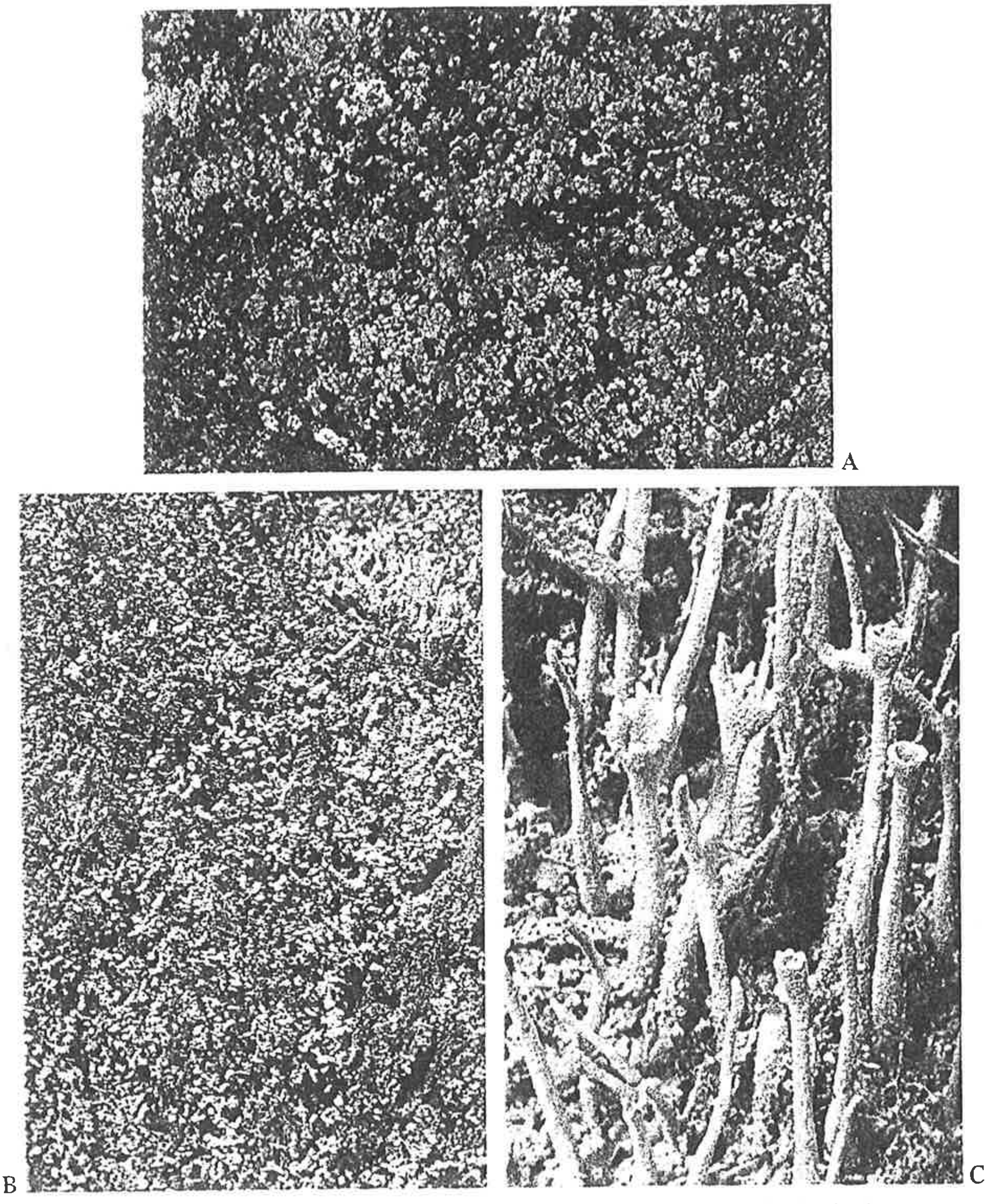

Plate 2. A. *Caloplaca fulgens*; B. *Cladonia didyma*; C. *Cladonia fimbriata*.

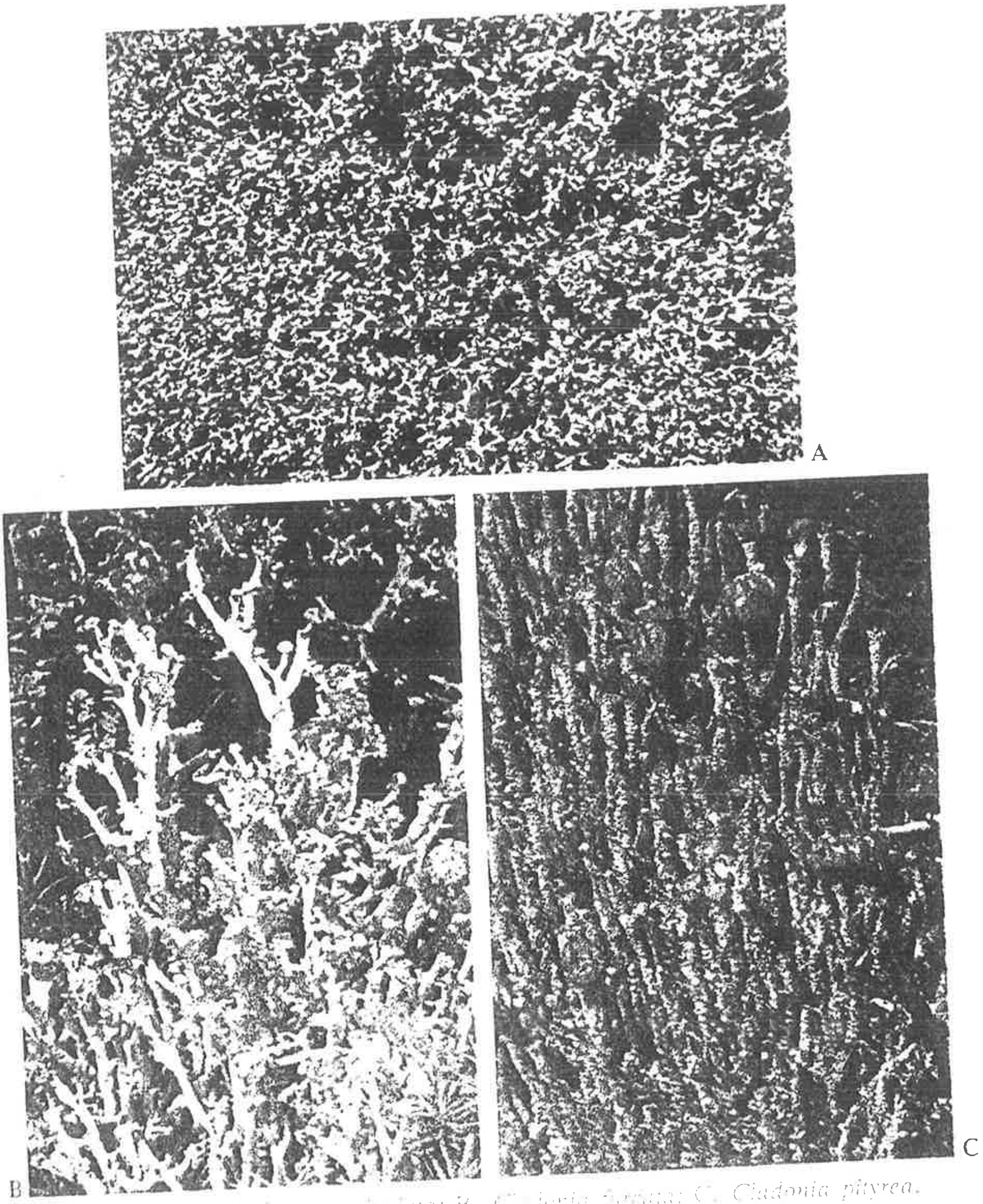

Plate 3 — A. *Cladonia capitellata*; B. *Cladonia* [illegible]; C. *Cladonia pityrea*.

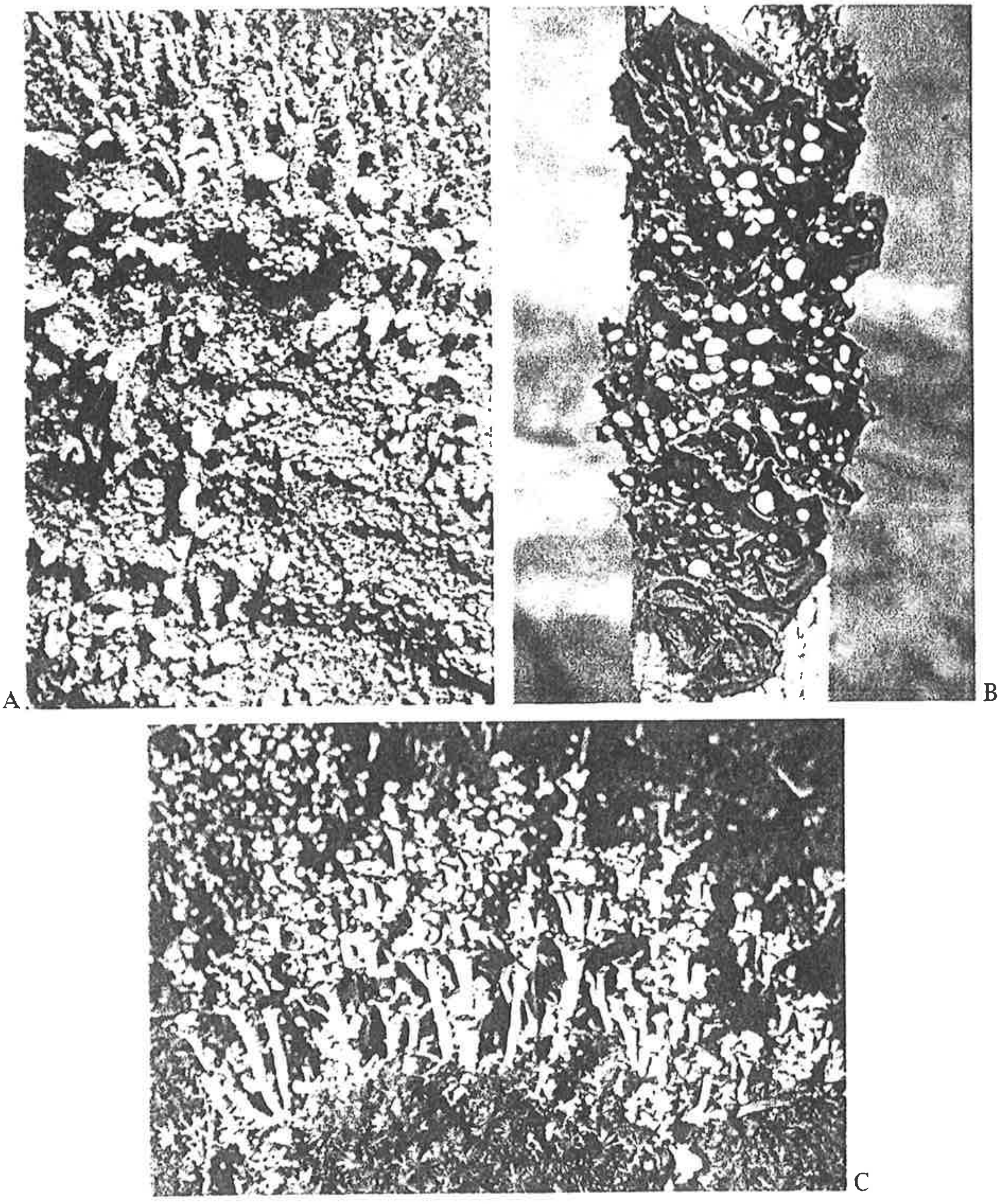

Plate 4. A. *Cladonia squamosula*; B. *Collema glaucophthalma*; C. *Cladonia verticillata*.

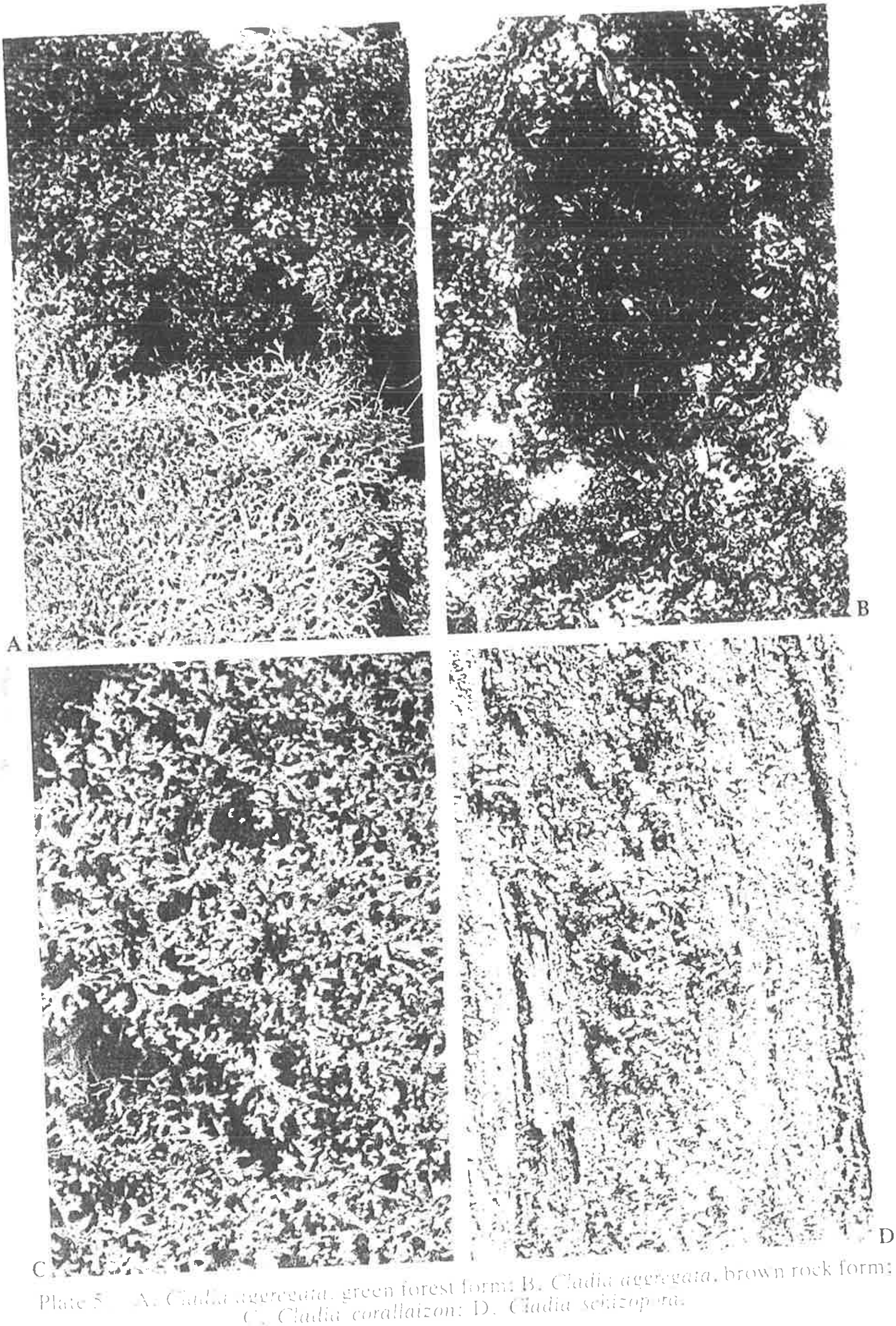

Plate 5 A. *Cladia aggregata*, green forest form; B. *Cladia aggregata*, brown rock form; C. *Cladia corallaizon*; D. *Cladia schizopora*.

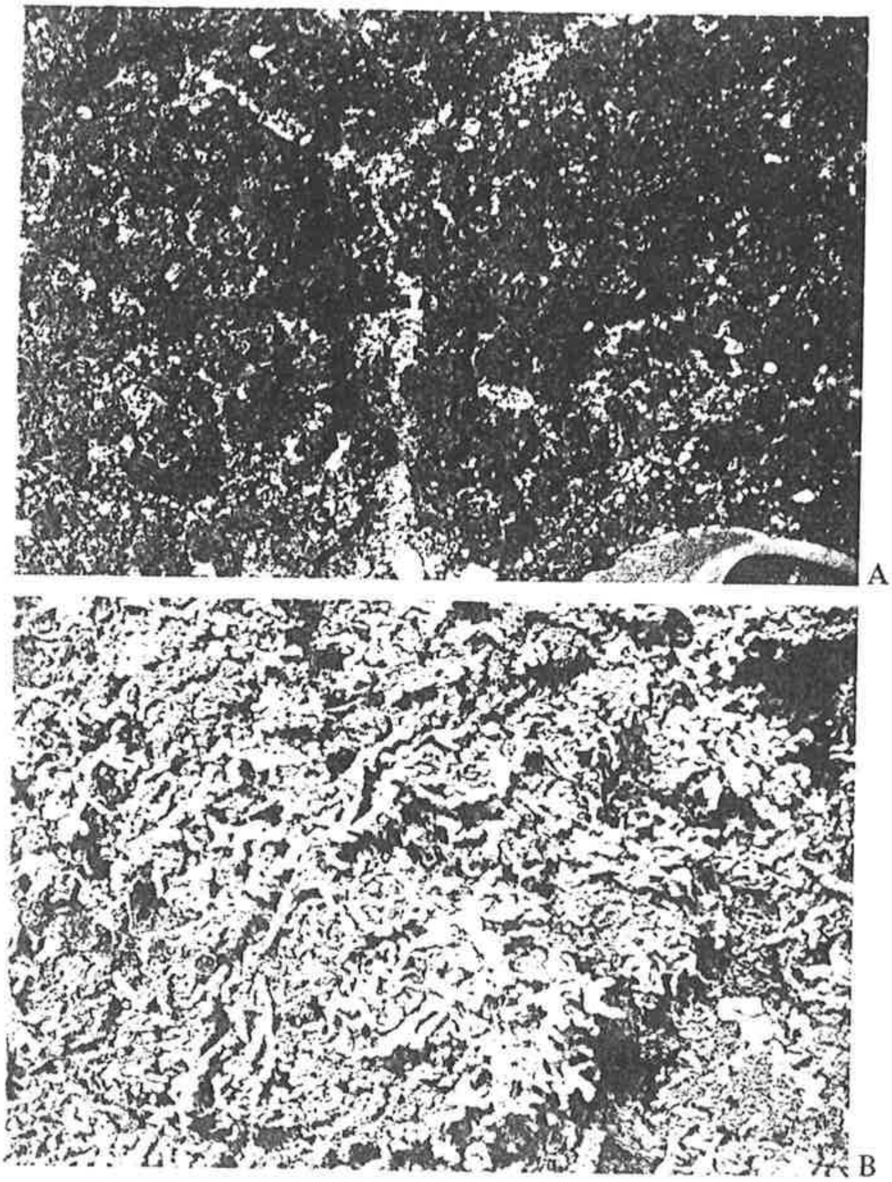

Plate 6. A. *Dermatocarpon lachneum*; B. *Hypogymnia subphysodes*.

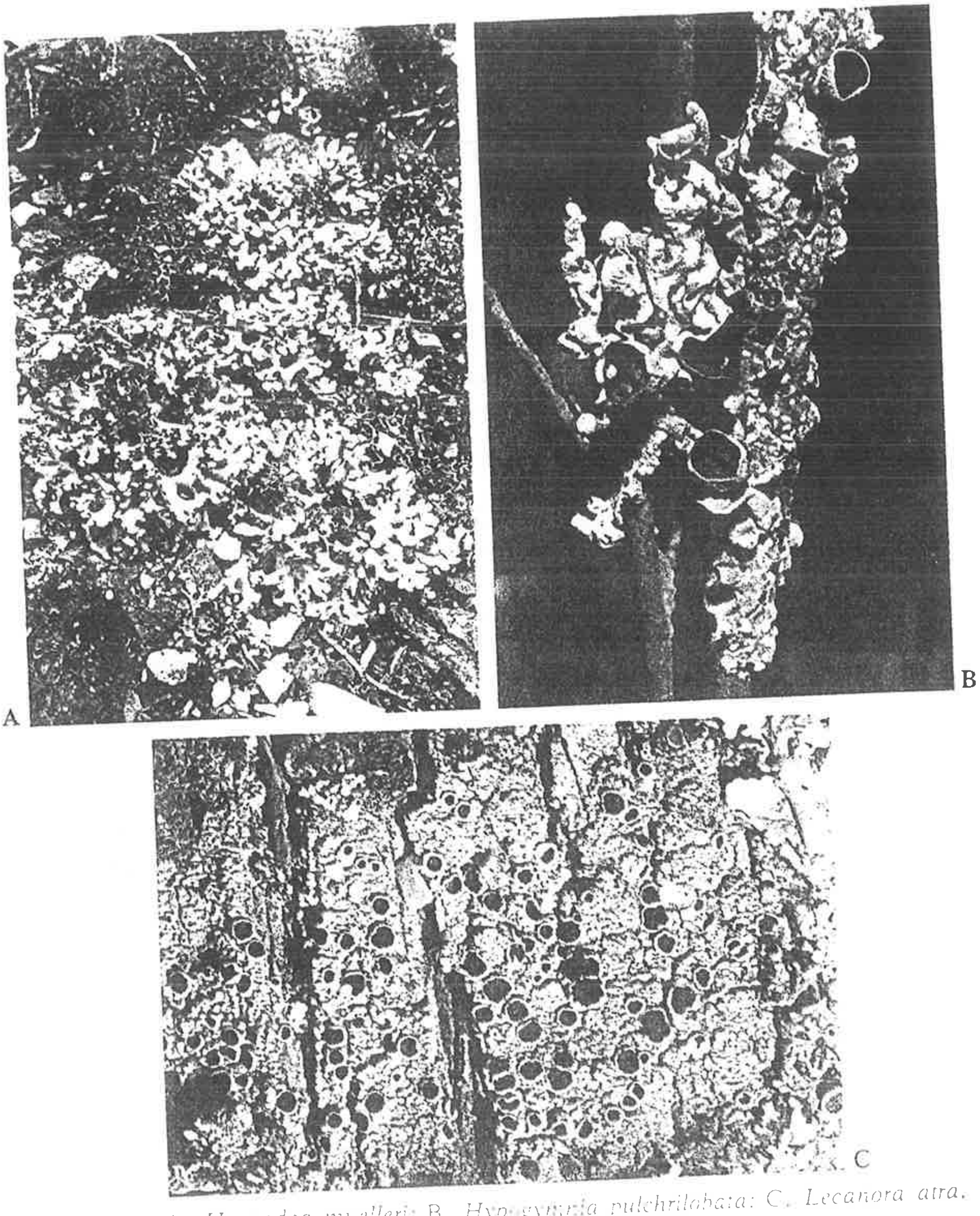

Plate 7. A. *Heterodea muelleri*; B. *Hypogymnia pulchrilobata*; C. *Lecanora atra*.

Plate 8. A. *Leprocaulon microscopicum;* B. *Lepraria membranaceae;* C. *Lepraria candelaris.*

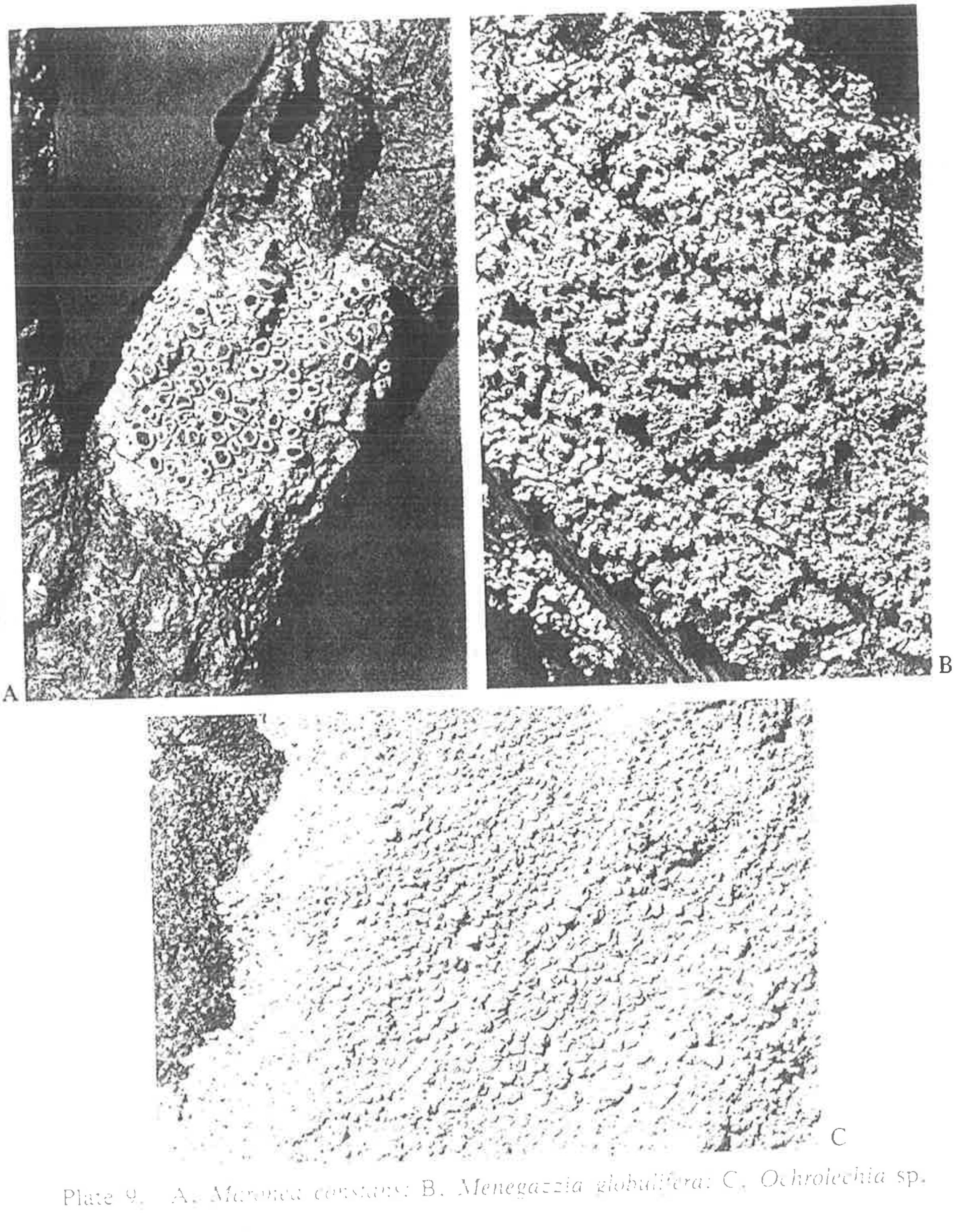

Plate 9. A. *Maronea constans*; B. *Menegazzia globulifera*; C. *Ochrolechia* sp.

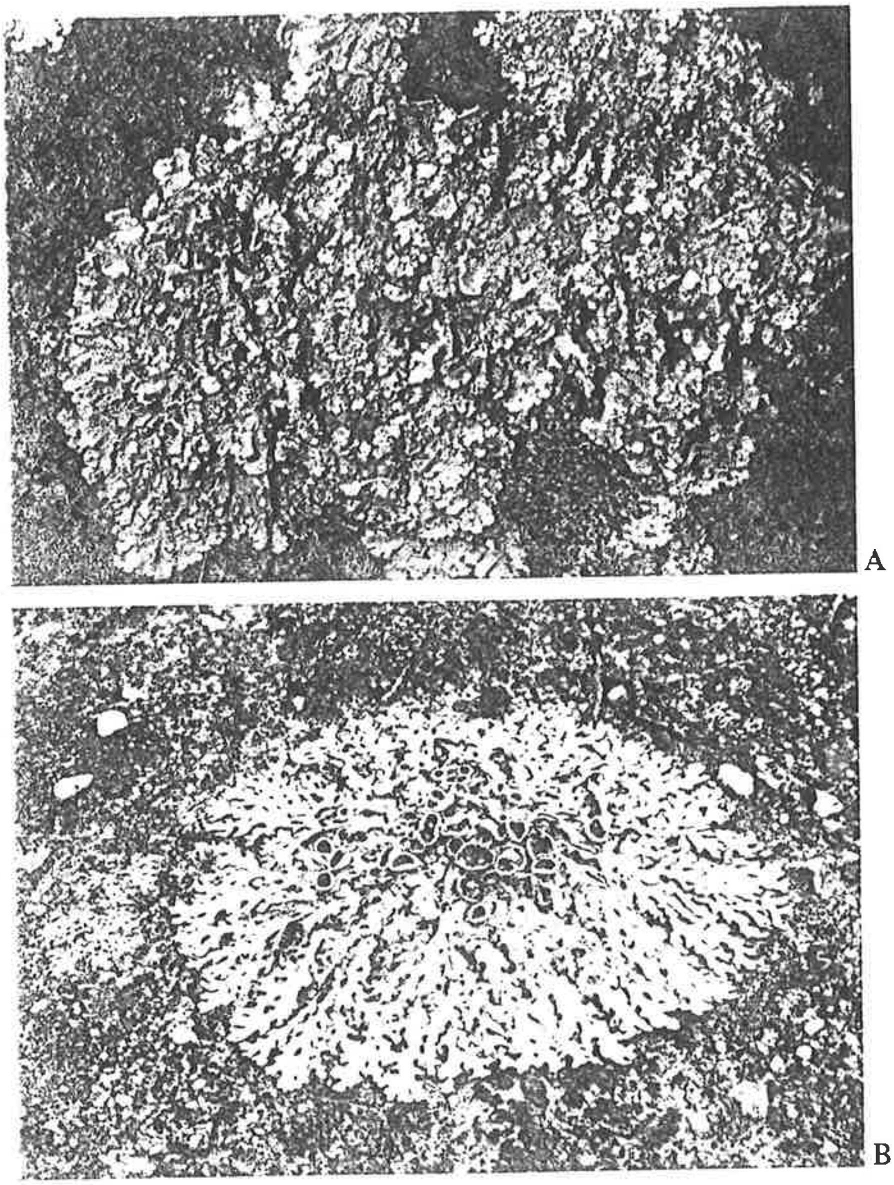

Plate 10. A. *Parmelia caperata*; B. *Parmelia cheelii*.

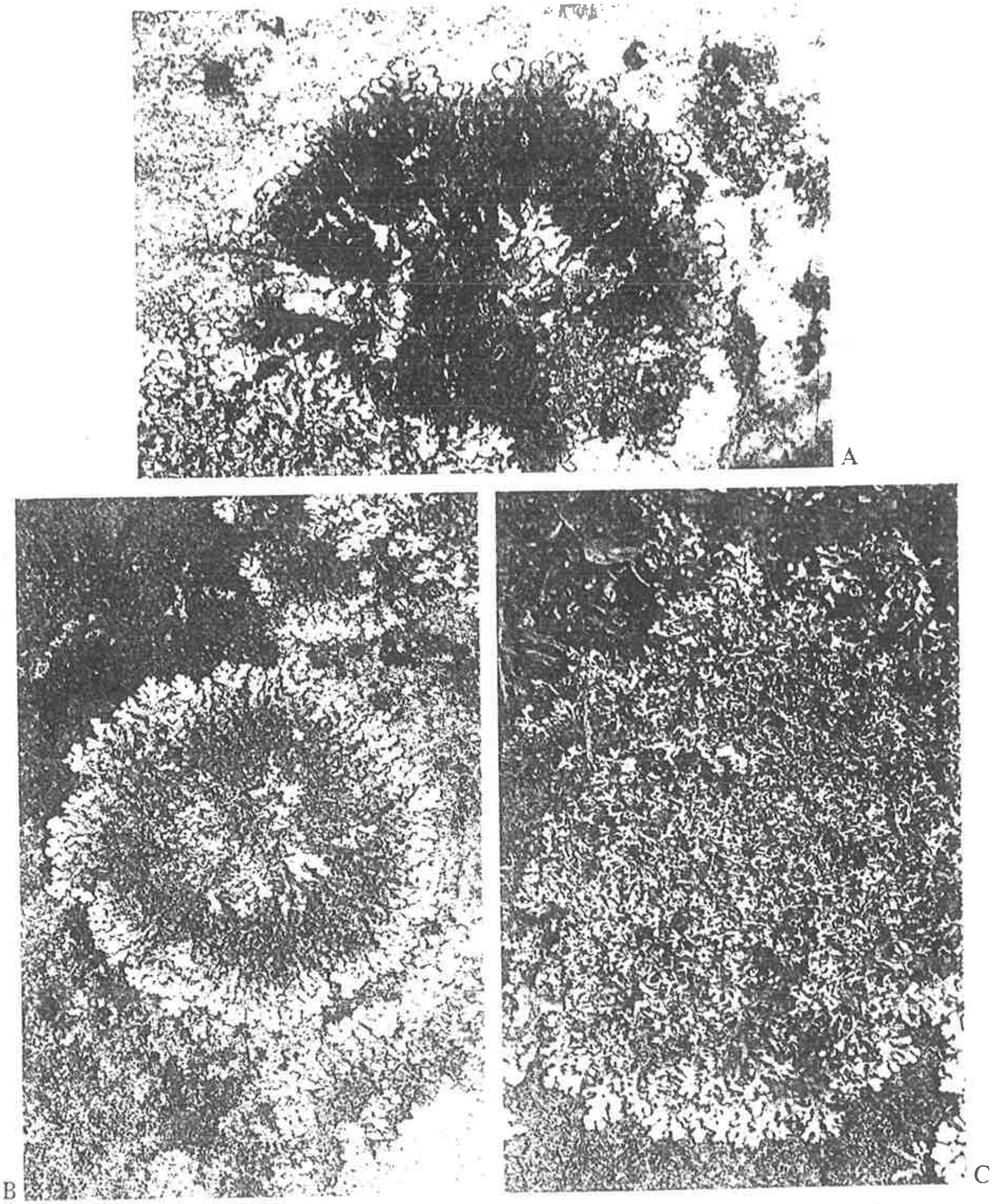

Plate 11. A. *Parmelia cinerascens*; B. *Parmelia congesta*; C. *Parmelia furcata*.

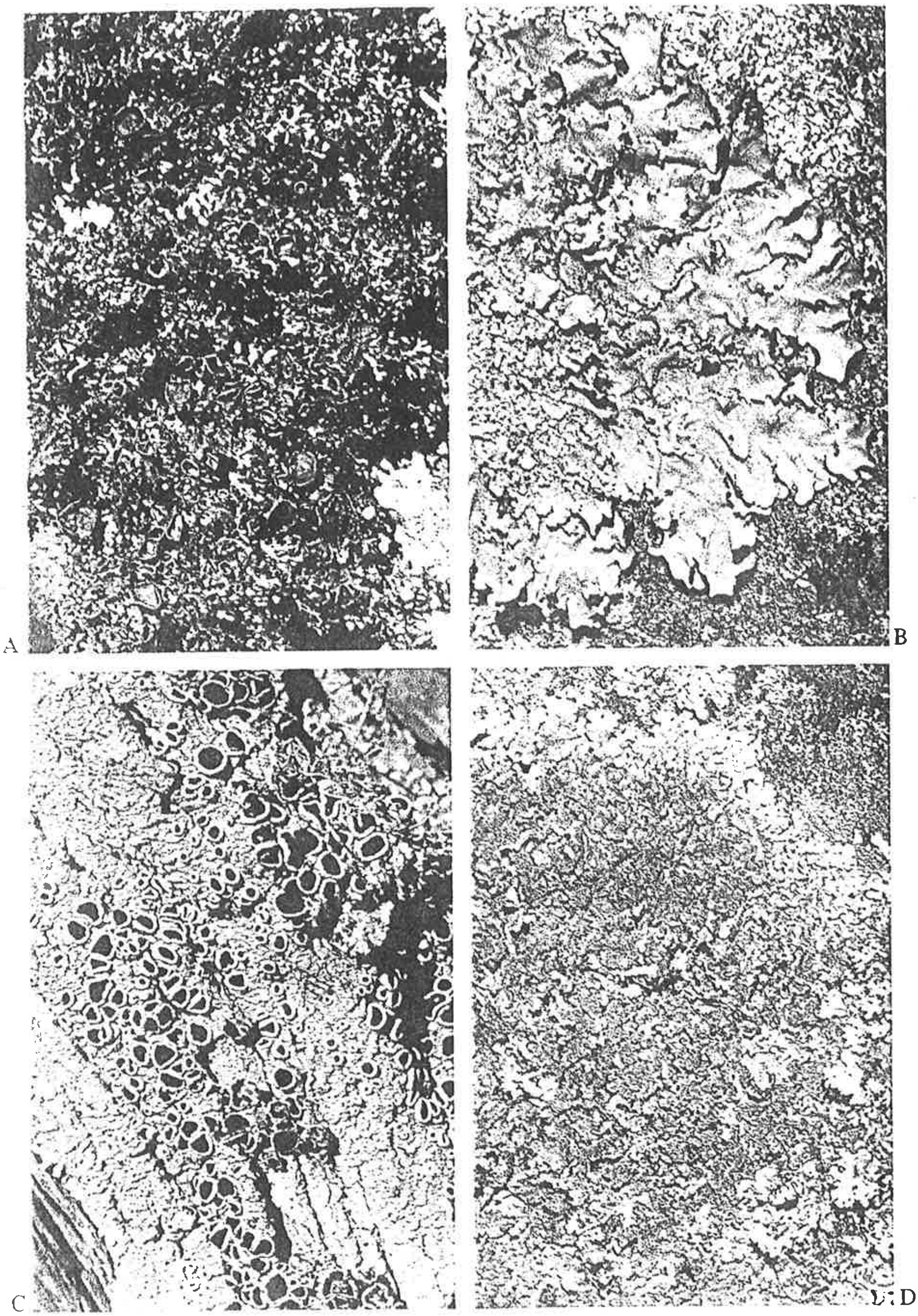

Plate 12. A. *Parmelia pulla*; B. *Parmelia perlata*; C. *Parmelia rutidota*; D. *Parmelia scabrosa*.

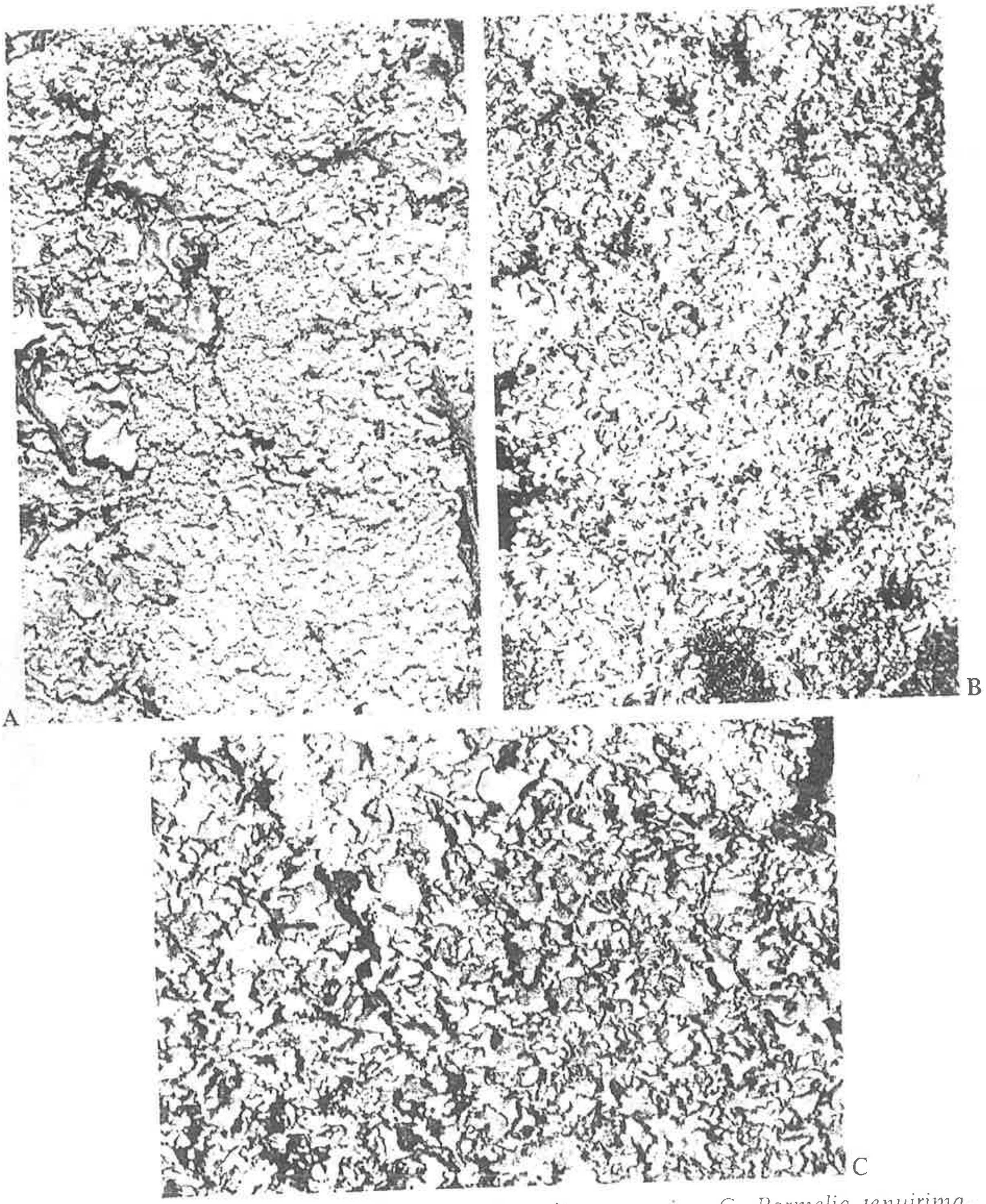

Plate 13. A. *Parmelia subrudecta*; B. *Parmelia tasmanica*; C. *Parmelia tenuirima*.

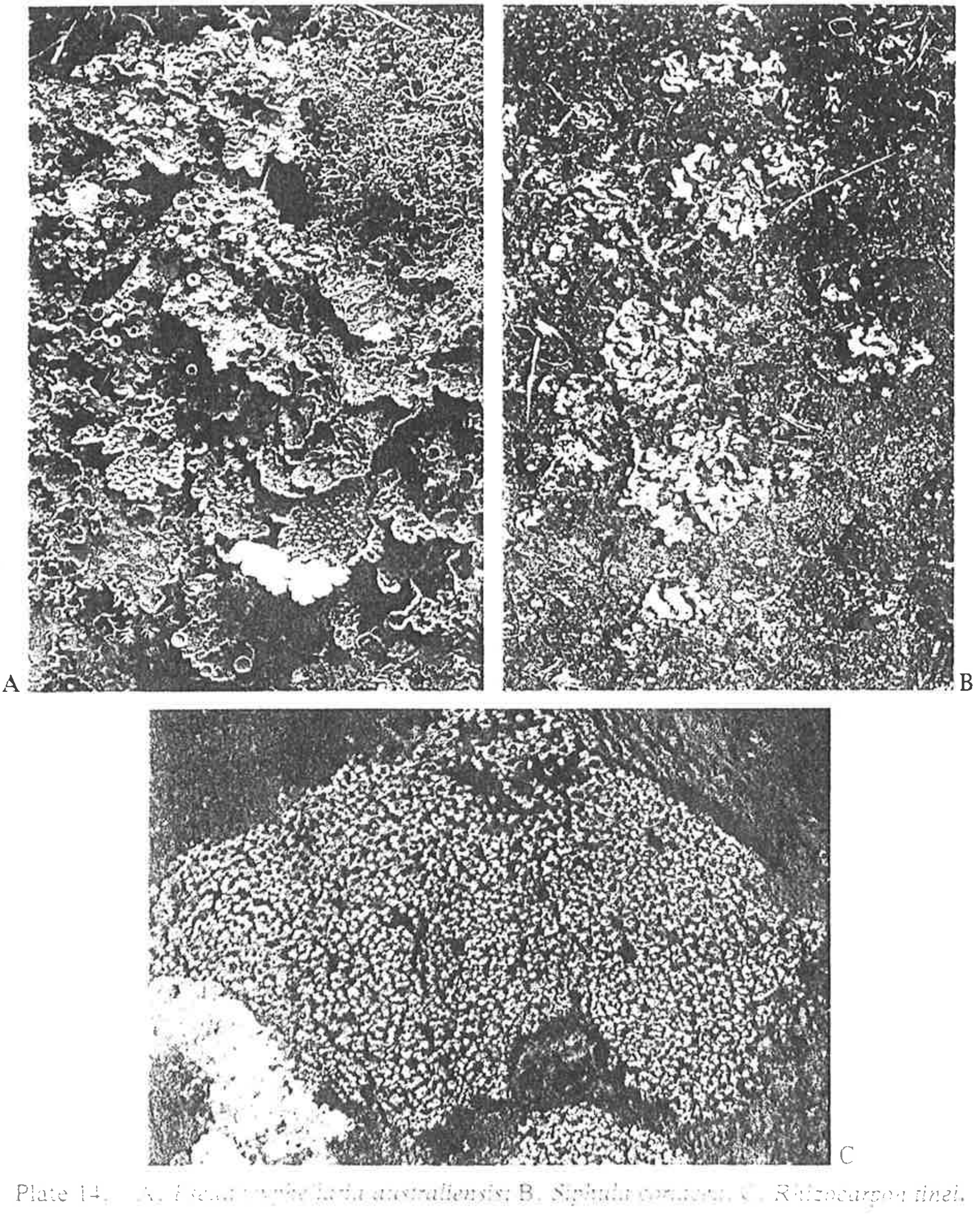

Plate 14. A. *Pseudocyphellaria australiensis*; B. *Siphula coriacea*; C. *Rhizocarpon tinei*.

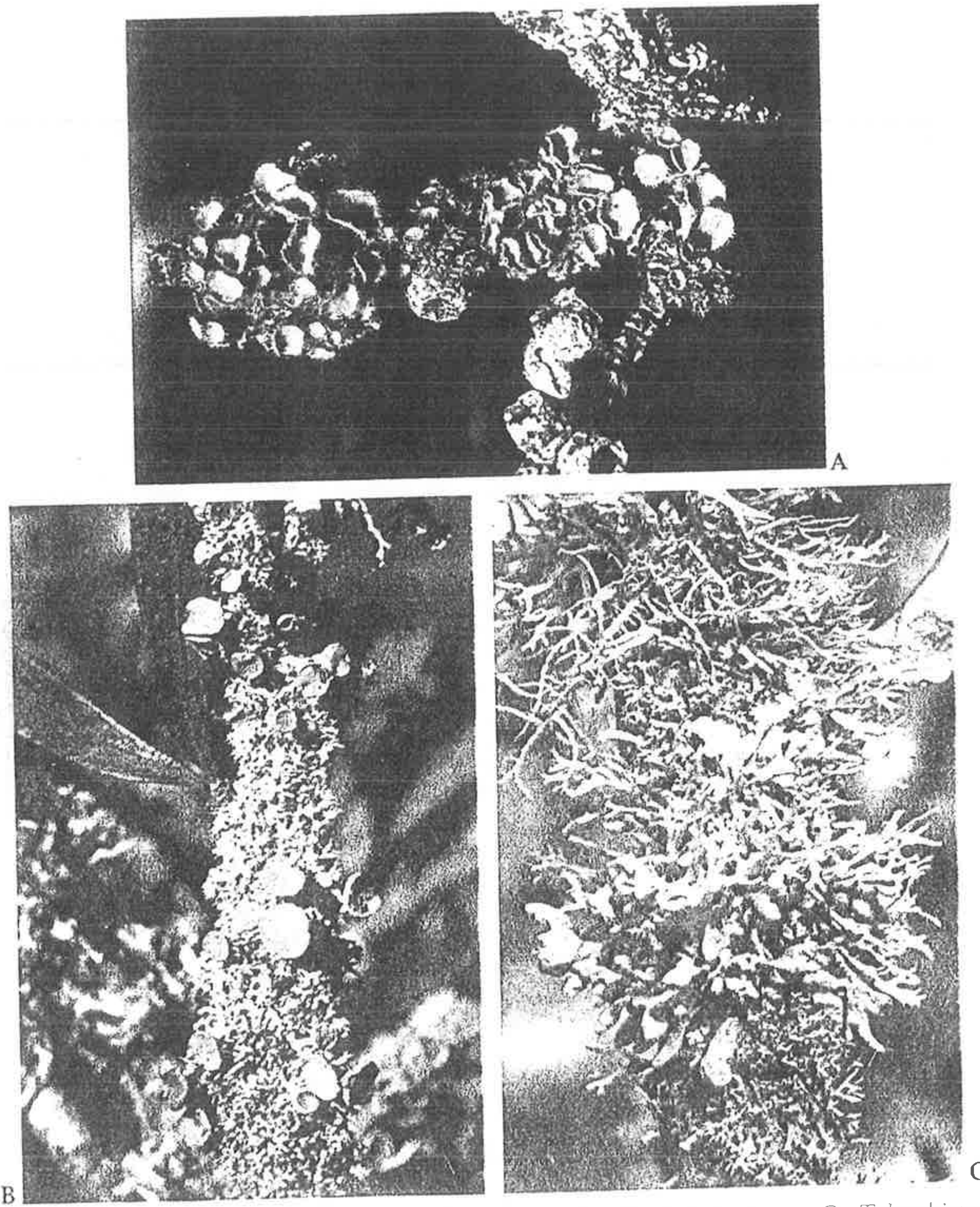

Plate 15. A. *Teloschistes chrysophthalmus*; B. *Teloschistes sieberianus*; C. *Teloschistes velifer*.

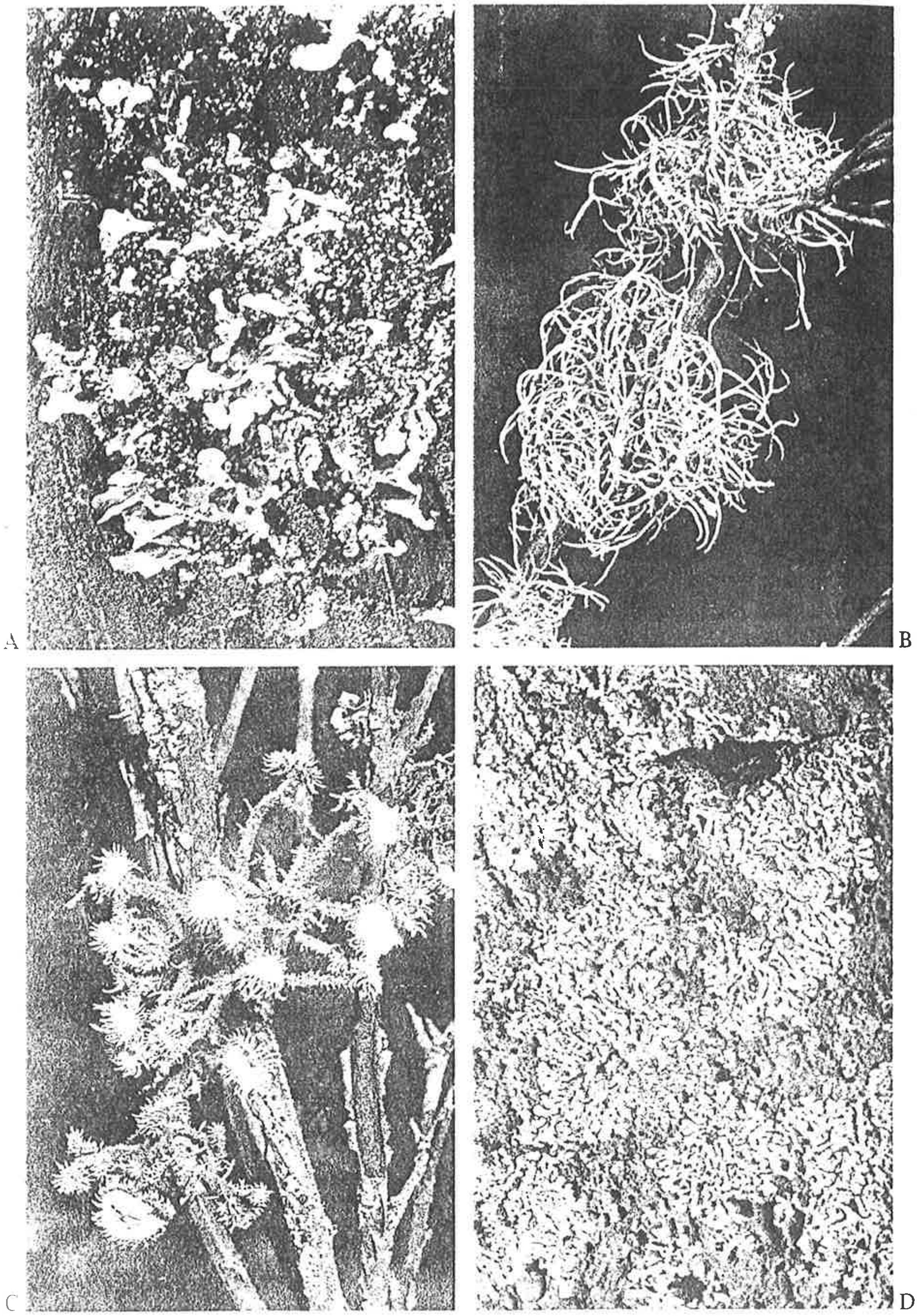

Plate 16. A. *Thysanothecium hyalinum*; B. *Usnea arida*; C. *Usnea ramulosissima*; D. *Xanthoria ectanea*.

Lecidea psammophila (Müll. Arg.) Zahlbr. 1925:889.

Psora psammophila Müll. Arg. 1892:194.

Thallus squamulose, cream or pale brown, thick, crenulate; upper surface more or less smooth, concave. *Apothecia* black.

Specimens examined: Camp 10, 14 miles (22 km) west of Turner Hill, *R. Helms 24,* 28.v.1891 (MEL 7147); "Quondong" Station, 120 km north-east of Morgan, *R. W. Rogers 1089,* 17.v.1967 (AD 97733166); Greenock, *R. W. Rogers 1491,* 29.x.1968 (AD 97733164); Murray Bridge, *R. W. Rogers 368,* 11.v.1966 (AD 97733167); Kanmantoo, *R. W. Rogers 1527,* 4.xi.1968 (AD 97733165).

This species is also found in the arid and sub-arid environments of Victoria and New South Wales.

46. LEPRARIA Ach. 1803:3.

Thallus crustose, leprose-sorediose, powdery, sometimes as scattered granules sometimes aggregated into clusters sometimes continuous; granules ecorticate. Fruiting bodies unknown.

ARTIFICIAL KEY TO SPECIES

1. Thallus primuline-yellow to gold, usually corticolous........ *L. candelaris*
1. Thallus white to greyish-white, usually muscicolous or terricolous........ .... *L. membranaceae*

Lepraria candelaris (L.) Fr. 1824:16.

Byssus candelaris L. 1753:1169.

Thallus crustose, of primuline-yellow to golden granules scattered on the substrate, sometimes forming a continuous mass and covering large areas.

Figure: Habit, plate 8C (MEL 1021195).

Although there appear to be no representatives of this species in the collections, it is known to occur in the wetter areas of the South-East.

Lepraria membranaceae (Dicks.) Lett. 1958:127.

Lichen membranacea Dicks. 1790:21.

Thallus crustose of white to greyish-white granules, usually held together by wefts of fungal hyphae, sometimes scattered on the substrate, sometimes in clusters and sometimes continuous.

Specimens examined: Southern face of Mount Illbillie, Everard Ranges, *R. B. Filson 15673,* 25.xi.1975 (MEL 1018605); Naracoorte, *M. Beek 194,* 12.v.1974 (MEL 1018658).

Figure: Habit, plate 8B (MEL 1021205).

This species grows on bare earth and amongst mosses under shaded overhangs, often in dry places. It has been recorded in Victoria and the Northern Territory.

L. membranaceae may be confused with *Leprocaulon* sp. but it is always granular-sorediose and never produces fruticose pseudopodetia.

47. LEPROCAULON Nyl. ex Lamy 1868:352.

Literature: Lamb and Ward 1974.

Thallus fruticose, cartilaginous, simple or branched, terete or subterete, leprose-sorediose. Fruiting bodies unknown.

ARTIFICIAL KEY TO SPECIES

1. Thallus faintly yellowish-grey, slender filiform, more or less covered with mealy powdery granules . . . . *L. microscopicum*
1. Thallus white to whitish-grey more or less dorsiventral without fine powdery granules . . . . *L. arbuscula*

Leprocaulon arbuscula (Nyl.) Nyl. 1889:8.

Stereocaulon arbuscula Nyl. 1860:253.

Thallus in small scattered groups or tufts, branched, distinctly dorsiventral, soft and fragile, up to 2 cm tall, ultimate branches very fine; pseudopodetia leprose-sorediose above becoming bare below, grey to greyish-white to pale greyish-green.

Reactions: K+ brown, P± red.

Specimen examined: Port Germein Gorge, Southern Flinders Ranges, *R. B. Filson 15505,* 15.xi.1975 (MEL 1018587).

L. arbuscula grows on bark, mosses over rock or on bare rock and occurs in shaded moist habitats. Recorded also in Victoria.

Leprocaulon microscopicum (Vill.) Gams ex Hawksworth in Hawksworth and Skinner 1974:128.

Lichen microscopicus Vill. 1789:949.

Thallus crowded into tufts, more or less erect up to 3 cm tall, slender filiform, subsimple to sparingly branched; pseudopodetia completely covered with mealy-powdery sorediose granules, pale yellowish-green to pale yellowish-white.

Reactions: K−, P−.

Figure: Habit, plate 8A (MEL 1021207).

Specimen examined: On rocky hillside, "Olive Grove" Station, 14·5 km south of Quorn, *R. B. Filson 11989,* 30.x.1970 (MEL 1018602).

L. microscopicum is usually found on soil in crevices of rocks, under overhangs, in shady but often dry habitats. It is recorded also from Victoria.

48. LEPTOGIUM (Ach.) S. F. Gray 1821:400.

Literature: Sierk 1964.

Thallus foliose, irregular in shape, with an upper and lower cortex, each usually of a single layer of cells; medulla poorly developed, the algal cells scattered amongst the loosely woven hyphae; attached to the substrate by rhizines. *Apothecia* adnate, sessile or shortly stipitate, laminal; disk reddish-brown to black; margin concolourous with the thallus, sometimes disappearing; ascospores usually eight in ascus hyaline, fusiform to ellipsoid, muriform.

ARTIFICIAL KEY TO SPECIES

1. Upper surface smooth, margins of lobes lacerate, lobulate, lower surface bare . . . . *L. lichenoides*
1. Upper surface smooth, margins of lobes entire, lower surface covered with light tomentum . . . . *L. sp.*

Leptogium lichenoides (L.) Zahlbr. 1924:136.

Tremella lichenoides L. 1753:1157.

Thallus forming patches up to 5 cm diam., pulvinate, composed of erect to semi-erect foliose lobes, lead-grey to brown; lobes orbicular to elongate, margins entire or finely divided sometimes fimbriate; upper surface smooth to distinctly wrinkled; lower surface smooth, bare. *Apothecia* sessile on the upper surface, up to 1·5 mm diam.; disk concave to slightly convex, brown to reddish-brown; margin entire paler than the disk, thalloid margin thin, sometimes lobulate, concolourous with the thallus; ascospores ellipsoid to fusiform, 27-30 x 10-13 µm, hyaline, muriform.

Figure: Ascospore, fig. 19D

Specimens examined: Aldgate, *L. D. Williams 1934e*, 2.viii.1964 (L.D.W.); Coonalpyn, *L. D. Williams 2348*, 22.viii.1965 (L.D.W.).

Leptogium lichenoides grows also in Victoria, Tasmania and New South Wales.

Leptogium sp.

Thallus continuous or of scattered lobes amongst mosses, at the base of trees or terricolous, grey, greenish-grey to brown; lobes up to 8 mm wide, margins smooth sometimes lobulate; upper surface smooth, dull or shining towards the margins; lower surface with dense tomentum in the centre of lobes, bare towards the margins. *Apothecia* up to 0·75 mm diam., laminal, sessile; disk concave, reddish-brown; margin entire paler than the disk, thalloid margin very thin sometimes with scattered rhizines towards the base; ascospores 27-31 x 11-12 µm, hyaline, muriform.

Figure: Ascospores, fig. 19C.

Specimens examined: Meningie, *L. D. Williams 871*, 28.vii.1960 (L.D.W.); Canunda National Park, 14 km west of Millicent, *R. B. Filson 14658*, 17.v.1973 (MEL 1018600).

This species has affinities with *L. menziesii* Mont. but differs in having smaller apothecia and less dense tomentum on the under surface. It is also similar to *L. inflexum* Nyl. differing from that species in the smaller apothecia, smaller spores and in the rhizines on the lower parts of the thalloid margin.

49. LICHINA C.Ag. 1821:104.

Literature: Henssen 1963.

Thallus minutely fruticose, more or less erect, of densely clustered branches; cortex indistinctly plechtenchymatous or of tangled hyphae; algal layer irregular. *Apothecia* minute, immersed in tip of the branches; disk more or less closed; asci cylindrical; ascospores eight in ascus, hyaline, oblong, simple.

Lichina pygmaea (Lightf.) C.Ag. var. **intermedia** Bab. 1855:311.

Thallus dark olive-green to black, forming small, tufty cushions of erect terete lobes 0·1-0·2 mm diam., up to 10 mm tall, lobes much branched. *Apothecia* mostly terminal, immersed in swollen flask-like structures 0·3-0·5 mm diam.

Figure: Ascospore, fig. 19E.

Specimens examined: Port Victoria, Yorke Peninsula, *R. D. Seppelt 637*, 21.i.1973 (MEL 515807); rocky outcrop on coast 3 miles (5 km) north of Arno Bay turnoff on the Lincoln Highway, Eyre Peninsula, *R. B. Filson 11799*, 23.x.1970 (MEL 1018655); Cape Northumberland, 2 km west of Port MacDonnell, *R. B. Filson 15819*, 9.iii.1977 (MEL 1018656).

Growing on rocks in the littoral zone, mostly in a westerly aspect. It occurs also in Western Australia, Victoria, Tasmania and New South Wales.

50. MARONEA Mass. 1856a:291.

Literature: Magnusson 1934.

Thallus crustose, ecorticate. *Apothecia* adnate to sessile; margin concolourous with the thallus; asci clavate; ascospores numerous in ascus, hyaline, simple or uniseptate.

Maronea constans (Nyl.) Hepp 1860:771.

Lecanora constans Nyl. 1855b:199.

Thallus crustose, grey-green to brown, continuous, granulose, up to 2 cm diam. *Apothecia* sessile, up to 1·5 mm diam.; disk warm brown to dull black; margin crenulate, concolourous with the thallus, ascospores numerous, hyaline, simple, 4-7 x 3-4 μm.

Figures: Habit, plate 9A (MEL 1021855); ascus containing spores and one free ascospore, fig. 19F.

Specimens examined: Mount Whyalla, *R. W. Rogers 1809*, 5.xi.1969 (R.W.R.); Seppeltsfield, *R. D. Seppelt*, ? 1969 (R.W.R.); Hamley Bridge, *R. W. Rogers 1323*, 18.xi.1967 (R.W.R.); Two Wells, *R. W. Rogers 1579*, 11.xi.1968 (R.W.R.).

Maronea constans is widespread on the bark of trees and is recorded from Victoria and New South Wales.

51. MELASPILEA Nyl. 1856:416

Literature: Wirth and Hale 1963.

Thallus crustose, thin, endo- or epiphloic, ecorticate. *Apothecia* immersed, adnate or sessile, round to irregular or elongate, simple or branched, with a proper exciple; asci oblong to clavate; ascospores eight in ascus, becoming brown, usually uni-septate but occasionally more, locules usually unequal, constricted at the septum; paraphyses unbranched, sometimes absent.

Figure: Ascospores, fig. 19G.

At present this genus has not been recorded in South Australia, but it is likely to occur on bark.

52. MENEGAZZIA Mass. 1854:3.

Literature: Santesson 1943.

Thallus foliose, inflated, hollow, lobate, radiate, dorsiventral, corticate; upper surface smooth, perforate; lower surface naked, attached to the substrate by the lower cortex. *Apothecia* round, somewhat pedicillate, lecanorine; ascospores two to eight in ascus, hyaline, ellipsoidal, simple.

Menegazzia globulifera Sant. 1943:30.

Thallus blue-grey to greenish-grey, forming small rosettes up to 4 cm diam., closely adnate to the substrate; lobes up to 2 mm broad, perforated at the ends; soralia globose becoming crateriform and then opening into the thalline cavity; lower surface black, dull naked. *Apothecia* not seen.

Reactions: Medulla K+ yellow, C−, P+ ochre-red.

Figures: Habit, plate 9B (MEL 1021201); ascospores, fig. 19H.

Specimens examined: Port Lincoln. *R. B. Filson 11852*, 24.x.1970 (MEL 1018654); Cape Jervis, *R. W. Rogers 1859*, 8.vi.1969 (R.W.R.); Myponga, *R. W. Rogers 1707*, 16.vi.1969 (R.W.R.); Millbrook, *R. W. Rogers 1774*, 20.xi.1969 (R.W.R.); Millicent, *L. D. Williams 3382C*, 2.viii.1969 (L.D.W.); Penola, *D. Hunt*, 25.xi.1962 (AD 97733169).

As an uncommon species on the bark of trees in the wetter areas of the state; recorded also in Victoria.

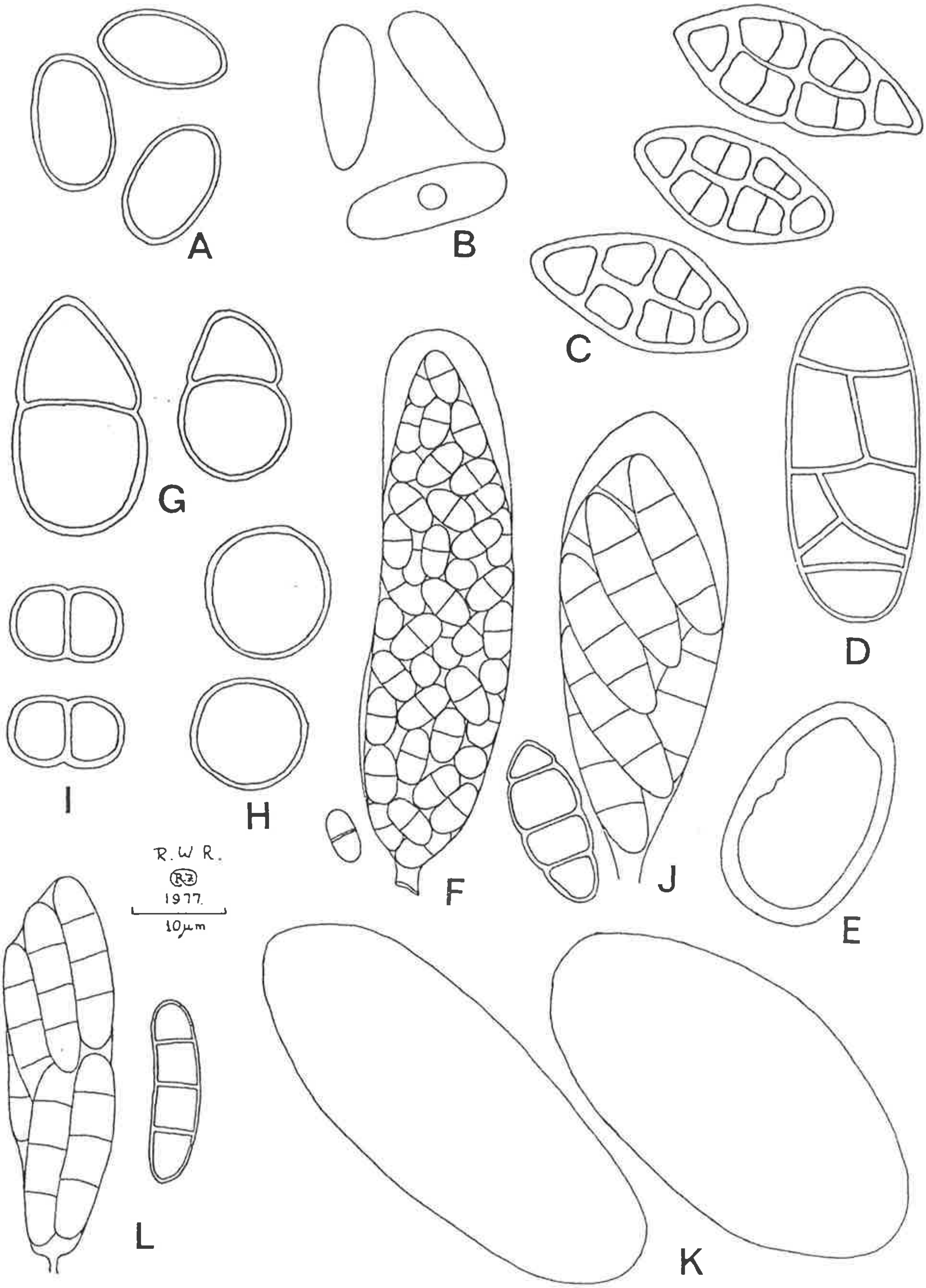

Fig. 19. A, *Lecanora atra*, ascospores; B, *Lecidea decipiens*, ascospores; C, *Leptogium* sp., ascospores; D, *Leptogium lichenoides*, ascospore; E, *Lichina pygmaea* var. *intermedia*, ascospore; F, *Maronea constans*, ascus containing spores and one free ascospore; G, *Melaspilea* sp., ascospores; H, *Menegazzia* sp., ascospores; I, *Microthelia aterrima*, ascospores; J, *Nephroma cellulosum*, ascus containing spores and one free ascospore; K, *Ochrolechia pseudotartarea*, ascospores; L, *Opegrapha* sp., ascus containing spores and one free ascospore.

ARTIFICIAL KEY TO SPECIES

1. Growing on wood or bark 2
1. Growing on rock .... *O. parella*
    2. Thallus discernible, thick to thin, smooth to verrucose 3
    2. Thallus obscure, evanescent, K−, KC−, apothecial disk K−, KC+ red .... *O. subathallina*
3. Thallus K−, KC−, apothecial disk K−, KC− .... *O. pseudotartarea*
3. Thallus K−, KC+ red, apothecial disk K−, KC+ red− . . *O. subpallescens*

Ochrolechia parella (L.) Mass. 1852a:32.

Lichen parellus L. 1767:132.

Thallus grey to greyish-white to pinkish-white, thick to thin, continuous or cracked into areolae, smooth to rugulose. *Apothecia* sessile; disk at first concave becoming convex, pale to pinkish-white with or without pruina; margin prominent and thick at first becoming thin and almost disappearing at maturity concolourous with the thallus; ascospores six to eight in ascus, 18-22 × 44-48 µm.

Reactions: Thallus K−, C−, KC−, P−, apothecial disk K−, C+ rose, KC+, red, P−.

This species has not yet been recorded in South Australia but it is common on granite outcrops in Victoria close to the border.

Ochrolechia pseudotartarea (Vain) Verseghy 1962:21.

Ochrolechia pallescens var. *pseudotartarea* Vain. 1903:21.

Thallus white, smooth. *Apothecia* sessile up to 2 mm diam.; disk concave, white granulose; margin thick concolourous with the thallus; ascospores six to eight in ascus 63-70 x 30-35 µm.

Reactions: Thallus K−, C−, KC−, P−, apothecial disk K−, C−, KC−, P−.

Figure: Ascospores, fig. 19K.

Specimens examined: Meningie, *L.D. Williams 3685*, 17.iv.1971 (L.D.W.); Iron Knob, *R.W. Rogers 558,* 1.x.1966 (R.W.R.).

Ochrolechia pseudotartarea is probably widespread on the bark of trees. It is recorded also in Victoria.

Ochrolechia subathallina Magn. 1939:252.

Thallus crustose, white, thin to evanescent. *Apothecia* sessile, up to 2 mm diam.; disk white to pale pink, pruinose; margin prominent, thick, white; ascospores eight in ascus, hyaline, 18-20 x 51-55 µm.

Reactions: Thallus K−, C−, KC−, P−, apothecial disk K+ pale yellow or K−, C+ red, KC+ red or KC−.

Specimens examined: Comaum Forest Headquarters, *K. Alcock*, 26.viii.1973 (MEL 1012144); Ewen Ponds, east of Port MacDonnell, *R. B. Filson 15815*, 8.ii.1977 (MEL 1018575).

This species is common on the bark of trees in the damper areas, sterile thalli occur as white stains on the surface.

Ochrolechia subpallescens Verseghy 1962:118.

Thallus crustose, white, thick, granulose, uneven. *Apothecia* sessile up to 3 mm diam.; disk plane, pink, epruinose; margin prominent, thick, concolourous with the thallus; ascospores eight in ascus, 44-50 x 20-25 μm.

Reactions: Thallus K−, C+ rose, KC+ red, P−, apothecial disk K−, C+ rose, KC+ red, P−.

Specimens examined: Para Wirra, *R. W. Rogers 88*, 17.i.1966 (R.W.R.); Comaum Forest Headquarters, *K. Alcock*, 26.viii. 1973 (MEL 1012143).

Figure: Habit, fig. 22A.

This species is possibly also common on the bark of trees. It is found in Western Victoria.

57. OPEGRAPHA Humb. 1793:57.

Thallus crustose, ecorticate. *Pseudothecia* immersed to adnate or sessile, pseudothecia round, to more commonly elongated with a slit-like disk, enclosed by a carbonaceous proper exciple; ascospores eight in ascus, hyaline, one to eight celled with transverse septa only; paraphyses reticulately branched and interwoven.

Figure: Ascus containing spores and one free ascospore, fig. 19L.

This genus has not yet been recorded in South Australia, but it is likely to be found on bark or wood.

58. PANNARIA Del. in Bory 1828:20.

Literature: Tavares 1966, Weber 1965.

Thallus squamulose, occasionally sub-foliose, closely attached to the substrate by rhizines, on a distinct hypothallus, differentiated into a distinctly cellular upper cortex, algal and medullary layers and a cellular lower cortex. *Apothecia* adnate to sessile; disk concave to convex, reddish-brown to black; margin concolourous with the thallus; ascospores eight in ascus, hyaline, simple. Phycobiont *Nostoc*.

Pannaria rubiginosa (Thunb. ex Ach.) Del. 1828:20.

Lichen rubiginosus Thunb. ex Ach. 1798:99.

Thallus foliose or squamulose, radiating at the margins; marginal lobes imbricate, crenulate, deeply concave; older lobes becoming lobulate-isidiose;

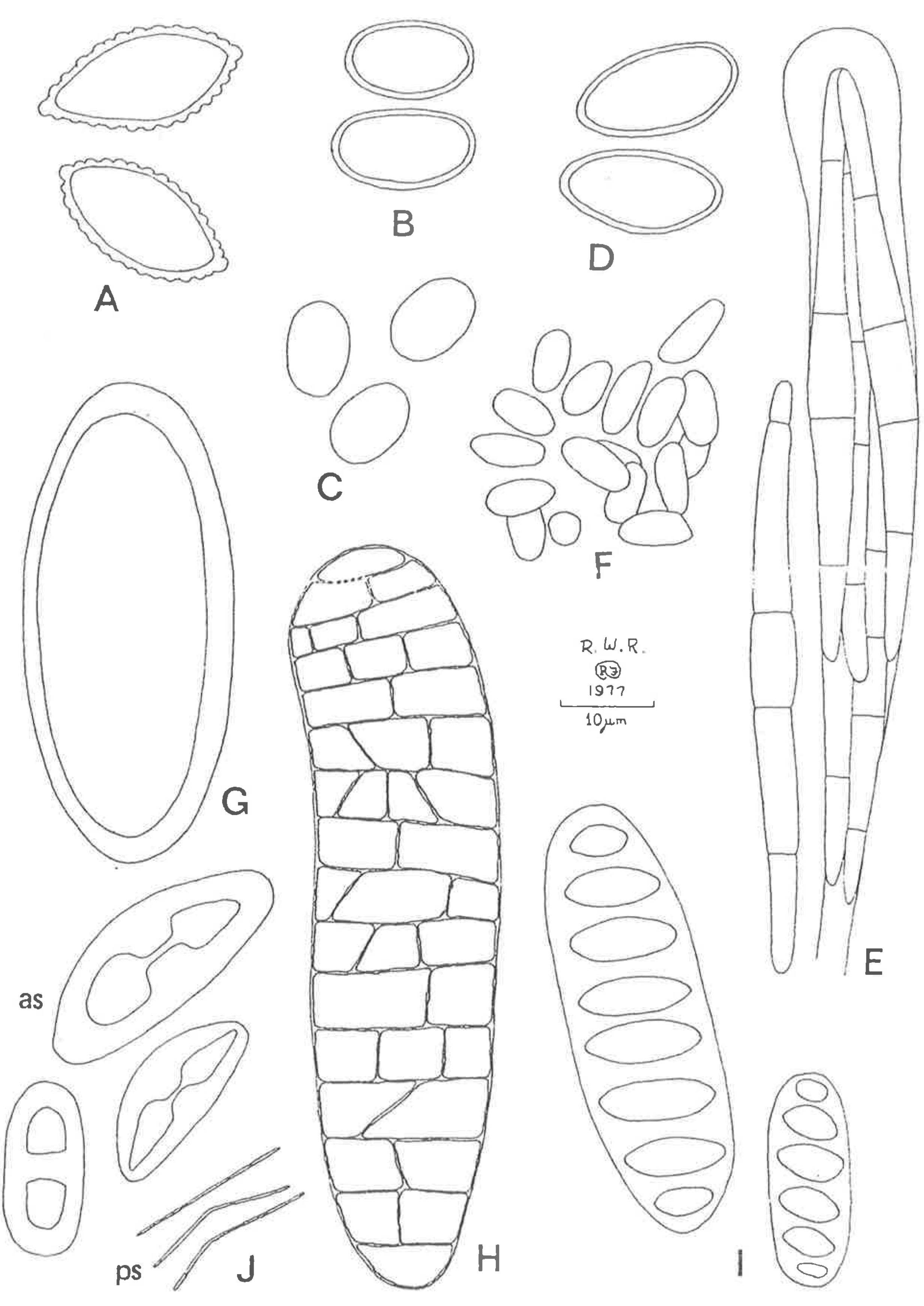

Fig. 21. A, *Pannaria rubiginosa*, ascospores; B, *Parmelia pseudotenuirima*, ascospores; C, *Parmelia subdistorta*, ascospores; D, *Parmeliella* sp., ascospores; E, *Peltigera spuria*, ascus containing spores and one free ascospore; F, *Peltula obscurens*, ascospores; G, *Pertusaria* sp., ascospore; H, *Phaeographina*, ascospore; I, *Phaeographis* sp., ascospores; J, *Physciopsis elaeina*, ps. pycnidiospores, as. ascospores.

upper surface reticulate rugulose, brown, buff or bluish-grey, margins a little lighter coloured; under surface pale, densely covered with felted brown rhizines which turn bluish-black and form a hypothallus which sometimes protrudes from under the lobe ends. *Apothecia* up to 2·0 mm diam., lecanorine; disk red-brown; margin prominent, coarsely crenulate, lobulate, concolourous with the thallus; ascospores 16-18 x 9-11 µm, hyaline, acutely ellipsoid, verrucose.

Reactions: Thallus K+ pale yellow, KC+ intense yellow, medulla K−, KC−, C−, P−.

Figure: Ascospores, fig. 21A.

Specimen examined: Canunda National Park, north of Lake Bonney, 14 km west of Millicent, *R. B. Filson 14655,* 17.v.1973 (MEL 1018649).

P. rubiginosa grows also in Victoria, Tasmania, New South Wales and Queensland.

Another species of *Pannaria* with affinities close to *P. leucosticta* Tuck. occurs on soil; both of these species are apparently restricted to the wetter areas.

59. PARMELIA Ach. 1803:153.

Literature: Hale & Kurokawa 1964, Hale 1965, 1976a, b, Esslinger 1977, Kurokawa & Filson 1975.

Thallus foliose, appressed, adnate, subascending or loose on the substrate; lobes narrow-elongate to broad-rotund, margins entire naked or ciliose; lower surface black, brown or pale, rhizinate; rhizines simple or branched, matted or sparse. *Apothecia* adnate to shortly pedicellate; ascospores eight in ascus, simple, hyaline, globose to ellipsoid.

ARTIFICIAL KEY TO SPECIES

1. Thallus yellow-green, green, green-grey or grey 2
1. Thallus yellowish-brown, brown or brownish-black 64
    2. Thallus without soredia or isidia 3
    2. Thallus with soredia or isidia 42
3. Lower surface pale to dark brown 4
3. Lower surface black 28
    4. Lower surface pale to ivory or light brown 5
    4. Lower surface brown to dark brown 21
5. Thallus mineral grey 6
5. Thallus yellowish-green 7
    6. Corticolous, thallus lobes flat, apothecia abundant . . . . . *P. subalbicans*
    6. Saxicolous, thallus lobes convex-pulvinate, apothecia rare *P. spodochroa*
7. Terricolous 8
7. Saxicolous 17
    8. Thallus unattached, loose on the substrate 9
    8. Thallus attached to the substrate, but the marginal and secondary lobes may be free 13

9. Thallus rolling into a ball when dry, lower surface pale, completely devoid of rhizines .... *Chondropsis semiviridis*
9. Thallus not rolling into a ball when dry, lower surface sparsely rhizinate 10
10. Medulla K+ 11
10. Medulla K− 12
11. Medulla K+ yellow becoming red .... *P. convoluta*
11. Medulla K+ constant yellow or gold .... *P.* sp. *nov.* 7
12. Medulla P+ orange .... *P. reptans*
12. Medulla P− .... *P. australiensis*
13. Medulla K− 14
13. Medulla K+ 15
14. Medulla P+ orange .... *P. reptans*
14. Medulla P− .... *P. subdistorta*
15. Thallus repeatedly dichotomous branched 16
15. Thallus not repeatedly dichotomous .... *P.* sp. *nov.* 6
16. With stictic and norstictic acids .... *P. amphixantha*
16. With salacinic acid .... *P.* sp. *nov.* 1
17. Medulla K+ 18
17. Medulla K− 19
18. Thallus marginal lobes tightly appressed to the substrate, apothecia smaller than 2·5 mm diam. .... *P. rimalis*
18. Thallus marginal lobes loose on the substrate, apothecia larger than 3 mm and up to 7 mm diam. .... *P. metaclystoides*
19. Medulla KC+ 20
19. Medulla KC− .... *P. ustulata*
20. Thallus lobes revolute or convolute .... *P. incrustata*
20. Thallus lobes almost plane, never revolute or convolute .... *P. flavescentireagens*
21. Thallus yellowish-green 22
21. Thallus mineral grey .... *P. subcaperata*
22. Medulla K− 23
22. Medulla K+ 25
23. Medulla KC− 24
23. Medulla KC+ rose .... *P. furcata*
24. Medulla P− .... *P.* sp. *nov.* 4
24. Medulla P+ red .... *P. pertinax*
25. Medulla K+ yellow becoming red, P+ gold or red 26
25. Medulla K+ pale brown, P+ red .... *P. pertinax*
26. Thallus forming a thick mat, marginal lobes loose on the substrate ... 27
26. Thallus not such a thick mat, fewer secondary lobes, marginal lobes adnate to substrate .... *P. incerta*
27. Lobes long, narrow 2 mm wide .... *P. polyphylloides*
27. Lobes rotund 3 mm wide .... *P. hypoclystoides*
28. Thallus mineral grey 29
28. Thallus yellowish-green 31
29. Medulla K+ yellow becoming red 30
29. Medulla K− .... *P. quercina*

30. Yellow pigment in the lower medulla . . . . *P. corrugativa*
30. Yellow pigment lacking in the lower medulla . . . . *P. tenuirima*
31. Corticolous or lignicolous 32
31. Terricolous or saxicolous 34
32. Yellow pigment in the lower medulla . . . . *P. jeleneckii*
32. Yellow pigment lacking in the lower medulla (two chemical species) . 33
33. Medulla K− . . . . *P. rutidota*
33. Medulla K+ salmon pink . . . . *P. ferax*
34. Terricolous 35
34. Saxicolous 37
35. Thallus loose on substrate, secondary lobes dorsiventral, up to 1·5 mm wide 36
35. Thallus closely adnate, secondary lobes subterete, 0·5 mm diam . *P. pumila*
36. Rhizines dichotomous, thick right to the margins of lobes, sparingly ciliate . . . . *P.* sp. *nov.* 2
36. Rhizines simple, sparse, lobes eciliate . . . . *P. callifolia*
37. Medulla K− 38
37. Medulla K+ 39
38. Medulla KC+ rose . . . . *P. hypoprotocetrarica*
38. Medulla KC− . . . . *P. praeterissima*
39. Yellow pigment in the lower medulla . . . . *P. dichromatica*
39. Yellow pigment lacking (three species which only differ macroscopically in lobe shape and degree of imbrication) 40
40. Containing norstictic acid, lobes small and sometimes imbricate . . . . *P. congesta*
40. Containing salacinic acid, lobes densely imbricate 41
41. Lobes wider than long . . . . *P. tasmanica*
41. Lobes longer than wide . . . . *P. cheelii*
42. Thallus sorediose 43
42. Thallus isidiose 49
43. Lower surface black 44
43. Lower surface pale to brown . . . . *P. subrudecta*
44. Thallus yellowish-green 45
44. Thallus mineral grey 47
45. Soredia arising from pustules mainly on the older lobes . . . . *P. caperata*
45. Soredia not arising from pustules, occurring right to the marginal lobes . 46
46. Thallus large, lobes broad, K+ . . . . *P. soredians*
46. Thallus small, lobes narrow, K− . . . . *P. soredians* forma
47. Upper surface reticulate, K+ yellow becoming red 48
47. Upper surface not reticulate K+ persistent yellow . . . . *P. perlata*
48. Lower surface of lobe with a bare or very sparsely rhizinate brown marginal zone . . . . *P. reticulata*
48. Lower surface of the lobe without bare zone, rhizines thick right to margin of lobe . . . . *P.* sp. *nov.* 5
49. Lower surface pale to dark brown 50
49. Lower surface black 59
50. Lower surface pale ivory to light brown 51

50. Lower surface brown to dark brown 55
51. Medulla K+ yellow becoming red 52
51. Medulla K− 53
52. Isidia inflated, globose .... *P. plittii*
52. Isidia cylindrical, not inflated .... *P. mexicana*
53. Saxicolous 54
53. Terricolous .... *P. constipata*
54. Thallus mineral grey with faint pale yellow tinge in parts .. *P. schistaceae*
54. Thallus green .... *P. scabrosa*
55. Medulla K+ yellow becoming red 56
55. Medulla K− 57
56. Corticolous .... *P. pseudotenuirima*
56. Saxicolous .... *P. scotophylla*
57. Isidia small nipple-shaped .... *P. sp.*
57. Isidia not as above 58
58. Isidia strongly inflated at top .... *P. globulifera*
58. Isidia not inflated .... *P. scabrosa*
59. Thallus yellowish-green 60
59. Thallus mineral grey 63
60. Thallus lobes 1 mm wide 61
60. Thallus lobes <1 mm, closely adnate to the substrate ..... *P. adhaerens*
61. Thallus loose on substrate, isidia not inflated towards the tips 62
61. Thallus adnate to the substrate, isidia inflated towards the tips .... *P. refringens*
62. Isidia light and sparse .... *P. tinctina*
62. Isidia dense, sometimes the centre of the thallus completely covered to make a continuous isidiose mat .... *P.* sp. *nov.* 3
63. Thallus large, lobes broad, saxicolous .... *P. cinerascens*
63. Thallus small, lobes narrow, corticolous .... *P. dissecta*
64. Thallus sorediose or isidiose 67
64. Thallus not sorediose or isidiose 65
65. Lower surface dark brown to black 66
65. Lower surface pale tan to pale brown .... *P. luteonotata*
66. Medulla KC+ red .... *P. imitatrix*
66. Medulla KC+ rose .... *P. pulla*
67. Thallus isidiose 68
67. Thallus sorediose .... *P. fuscosorediata*
68. Medulla KC− 70
68. Medulla KC+ 69
69. Medulla KC+ rose .... *P. incantata*
69. Medulla KC+ red turning orange .... *P. loxodella*
70. Lower surface dark brown to black .... *P. verrucella*
70. Lower surface pale tan .... *P. subverrucella*

Parmelia adhaerens Nyl. *in* Cromb. 1876:19.

Thallus foliose, forming small rosettes on smooth rocky substrates; lobes small, flat to slightly convex, less than 1 mm wide and not imbricate; marginal lobes radiate, centre of the thallus becoming crustose-areolate, isidia light and very sparse sometimes only on the marginal lobes. *Apothecia* small up to 0·75 mm diam.; margin thin, persistent; disk concave to irregular, dark brown.

Reactions: Medulla K+ yellow becoming red, C−, P+ faint yellow becoming pale orange, KC−.

Specimens examined: Memory Cove, Cape Catastrophe, *R. B. Filson 11835*, 24.x.1970 (MEL 1011752); Humbug Scrub, 40 km north-east of Adelaide, *J. Curtis*, 9.iv.1967 (MEL 34813p/p).

Parmelia adhaerens occurs also in Victoria, Tasmania, New South Wales and Queensland.

Parmelia amphixantha Müll. Arg. 1888:139.

Thallus foliose forming rosettes on earth, up to 5 cm diam.; lobes dichotomously branched 0·5-1·5 mm wide.; upper surface plane to convex, marginal lobes maculate, otherwise smooth or minutely wrinkled and cracked on the older lobes, isidia and soredia absent; lower surface pale yellow-green to dark brown sparsely rhizinate. *Apothecia* very rare sessile.

Reactions: Medulla K+ yellow becoming red, C−, P+ yellow becoming red under the cortex, KC−.

Specimens examined: Hill top, 12 miles (19 km) west of Murray Bridge, *R. W. Rogers 364*, 11.v.1966 (R.W.R.); Kimba to Cowell road, 18 km north-west of Cowell, *R. B. Filson 11782*, 22.x.1970 (MEL 1011819); Camp 7, west of Moolapinna Hill, *R. Helms 61*, 30.x.1891 (MEL 6218); Yudnapinna, c. 70 km north-west of Port Augusta, *R. W. Rogers 19*, 11.ii.1965 (MEL 10386).

The species occurs also in Western Australia, Victoria and New South Wales.

Parmelia amphixantha is morphologically similar to three other species *P.* sp. *nov.* 1, *P. reptans* and *P.* sp. *nov.* 7. These four species are included in the "amphixantha group".

Parmelia australiensis Cromb. 1879:395.

Thallus unattached, loose on substrate; lobes elongate, convolute, contorted; upper surface pale yellow-green, smooth rugulose and cracked on the older parts, isidia and soredia absent, marginal lobules sometimes present; lower surface pale yellow-green to pale brown, sparsely rhizinate. *Apothecia* not seen.

Reactions: Medulla K−, C−, KC− rose, P−.

Specimens examined: "Nullarbor" H. S., *J. H. Willis*, 29.viii.1947 (MEL 6207); "White Wells" (abandoned), *D. Kemsley*, 7.i.1952 (MEL 6208), Eyre Highway 11 miles (17 km) east of Koonalda, *J. H. Willis*, 8.x.1961 (MEL 6237); Knowles Cave, Nullarbor Plain *R. B. Filson 9453*, 5.i.1967 (MEL 25312).

This species is very similar to *P. convoluta* and in most cases can only be separated from it by the chemical tests.

Parmelia sp. *nov.* 1

Thallus forming rosettes on earth up to 4 cm diam.; lobes dichotomously branched 0·5-1·6 mm wide; upper surface smooth, moderately convex, marginal lobes emaculate, pale yellow-green sometimes darker greenish-yellow towards the centre, soredia and isidia absent; lower surface canaliculate, pale brown with narrow marginal band concolourous with the upper surface, sparsely rhizinate. *Apothecia* not seen.

Reactions: Medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming orange.

Specimens examined: 16 miles (25 km) north of "Lords Well" O.S., *R. W. Rogers 1105*, 27.x.1967 (R.W.R.); Eyre Highway, 40 km east of Kimba, *R. B. Filson 11733a*, 20.x.1970 (MEL 1011830); Loveday, *E. Gaube*, 28.x.1943 (MEL 11292).

Parmelia callifolia Kurokawa in Kurokawa and Filson 1975:42.

Parmelia versicolor Müll. Arg. 1881:506.

Thallus loosely adnate to soil substrate, up to 15 cm diam., often growing over litter; lobes at the margins up to 3 mm wide, free, imbricate; secondary lobes growing out from lobules on the margins of older lobes, flat, up to 1·5 mm wide, irregularly branched, sometimes convolute; upper surface pale yellow-green, smooth at marginal lobes, older portions becoming rugulose and cracked; lower surface brown at marginal lobes becoming progressively darker until black at the centre. *Apothecia* not seen.

Reactions: Medulla K+ yellow slowly brown to blackish-red, C−, KC−, P+ yellow becoming orange to red.

Specimens examined: 25·5 km north of Port Augusta, *R. W. Rogers 133*, 21.ii.1966 (R.W.R.); Koonamore Vegetation Reserve, *R. W. Rogers 1644*, 19.iv.1969 (R.W.R.); Wilgena Hill, 6·5 km north of the Kingoonya-Tarcoola road, 67·5 km west of Kingoonya, *R. B. Filson 11925*, 26.x.1970 (MEL 1011838); 3·2 km north of Kokatha on the Poochera-Kingoonya road, *R. B. Filson 11918a*, 26.x.1970 (MEL 1011846): Iron Knob-Yardea road, 40 km west of Iron Knob, *R. W. Rogers 1172*, 22.v.1967 (R.W.R.); 11 miles (17 km) east of "Koonalda" H.S., Nullarbor Plain, *J. H. Willis*, 18.x.1961 (MEL 10178); hillside near "Lake Everard" Station, western end of the Gawler Ranges, *D. N. Krahenbuehl 2422*, 15.ix.1968 (MEL 37634).

Found also in Western Australia, Victoria and New South Wales.

Parmelia callifolia forms part of the "callifolia group". It is a dry soil inhabiting species and likes sheltered positions under bushes and is often found growing amongst litter. It may be confused with *P. pumila* but this species is more adnate on the substrate. It may also be confused with *P. subdistorta* but it is easily separated from this species in the broader marginal lobes and the narrower secondary lobes growing out from lobules, the black lower surface and the positive reaction of KOH on the medulla.

Parmelia caperata (L.) Ach. 1803:216.

Lichen caperatus L. 1753:1147.

Thallus foliose, saxicolous rarely corticolous, loosely attached to the substrate, pale straw coloured to light yellow-green, up to 15 cm diam.; lobes irregular up to 3 mm wide, strongly imbricate; upper surface dull to slightly shining, smooth at the margins becoming pustulate towards the centre, pustules bursting to form granular soredia; lower surface jet black with a pale brown zone at the margins. *Apothecia* not seen.

Reactions: Thallus K−, medulla K−, C−, KC−, P+ orange-red.

Figure: Habit, plate 10A (MEL 1021206).

Specimens examined: Sellick Hill, 72 km south of Adelaide, *R. B. Filson 15491*, 14.xi.1975 (MEL 1014890).

The species occurs also in Victoria, Tasmania, New South Wales and Queensland.

Of the eight species which form the "caperata group" *P. caperata* is possibly the easiest to distinguish in the field. The pustulate soredia coupled with the lack of pigment in the lower medulla clearly separate it from others in this group. The species included in this group are *P. caperata*, *P. soredians*, *P. rutidota*, *P. ferax*, *P. jeleneckii (P. euplecta* is similar to *P. caperata* but differs in having a yellow pigment in the lower medulla which is K+ purple. *P. helmsii* is similar to *P. rutidota* but contains barbatic acid rather than protocetraric acid. Neither of these two species are dealt with in this handbook).

Parmelia cheelii Gyel. 1938:271.

Thallus saxicolous, loosely attached to the substrate; lobes numerous, densely imbricate, narrow 1·0-2·0 (-3·0) mm wide, elongate; upper surface yellow-green with black border, isidia and soredia lacking; lower surface jet black. *Apothecia* up to 7 mm diam., deeply concave; disk reddish-brown; margin persistent; ascospores 10-11 × 6-7 µm.

Reactions: Medulla K− yellow becoming red, C−, KC−, P+ red.

Figure: Habit, plate 10B (MEL 1022012).

Specimens examined: South side of Carappee Hill, Eyre Peninsula, *R. B. Filson 11766*, 22.x.1970 (MEL 1011812); beside the Eyre Highway, 35·5 km east of Kimba, *R. B. Filson 11757*, 22.x.1970 (MEL 1011720); on rocky hillside, "Olive Grove" Station, 14·5 km south of Quorn, *R. B. Filson 12001*, 30.x.1970 (MEL 1011741); Humbug Scrub, 40 km north-east of Adelaide, *J. Curtis*, 9.iv.1967 (MEL 34828).

The species occurs in Victoria and New South Wales.

P. cheelii resembles *P. tasmanica*, differing from it in the shorter and narrower marginal lobes.

Parmelia cinerascens Lynge 1914:104.

Thallus foliose, saxicolous, moderately adnate, forming irregular patches up to 8 cm diam.; lobes up to 5 mm wide, irregularly branched, sometimes incised, with rounded apices, hardly imbricated; upper surface mineral grey, slightly pale brown at the lobe ends, bordered with black, without soredia, isidia dense in the centre of the thallus, scattered on the marginal lobes, cylindrical, branched, slightly swollen at the apices; lower surface jet black. *Apothecia* up 4 mm diam., deeply concave; disk cinnamon-brown: margin thin inrolle, isidiose; ascospores 13-16 × 8-10 μm.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red, C−, KC−, P+ orange.

Figure: Habit, plate 11A (MEL 1021210).

No collections have been determined as this species but it is known to occur in the Southern Flinders Ranges. It grows also in Victoria.

Parmelia congesta Kurokawa and Filson 1975:36.

Thallus saxicolous, adnate to the substrate, up to 10 cm diam.; lobes fl sometimes imbricate, 0·7-2·0 mm wide; upper surface pale yellow-green with black border, older lobes greying, isidia and soredia lacking; lower surface black. *Apothecia* up to 8 mm diam., concave, flattening at maturity; disk dark to almost black; margin persistent, crenulate; ascospores 9-10 × 6-7 μm.

Reactions: Medulla K+ yellow becoming red. C−, KC−, P− yellow.

Figure: Habit, plate 11B (MEL 1021215).

Specimens examined: South side of Carappee Hill, Eyre Peninsula, *R.* *Filson 11765*, 22.x.1970 (MEL 1011821): Marble Range, Eyre Peninsula, *R.* *Filson 11870*, 24.x.1970 (MEL 1011837): Gum Flat, 40 km northwest of Ellist Eyre Peninsula, *R. B. Filson 11893*, 25.x.1970 (MEL 1011841); Podinna Ro 24 km north of Minnipa, *R. B. Filson 11901c*, 25.x.1970 (MEL 1011861).

Parmelia constipata Kurokawa and Filson 1975:37.

Thallus terricolous, adnate to the substrate, up to 7 cm diam.; lobes sublinear elongate, sometimes imbricate, up to 2 mm wide: upper surface yellow-green, slightly rugulose, densely isidiose; isidia cylindrical, branched, coralloid, up to 2 mm high; soredia absent; lower surface pale brown, darkening towards the lo ends. *Apothecia* not seen.

Reactions: Thallus K−, medulla K−, C−, KC± rose, P−.

Specimens examined: Koonamore Vegetation Reserve, *R. D. Seppelt*, v.19 (MEL 1013410): along the High Eden road, 6·5 km west of Springton, *J. A. E* *869*, 8.v.1975 (J.A.E.).

Parmelia convoluta Kremp. 1880:337.

Thallus unattached, loose on substrate; lobes elongate, convolute; upper surface pale yellow-green, smooth, rugulose and cracked in the older parts.

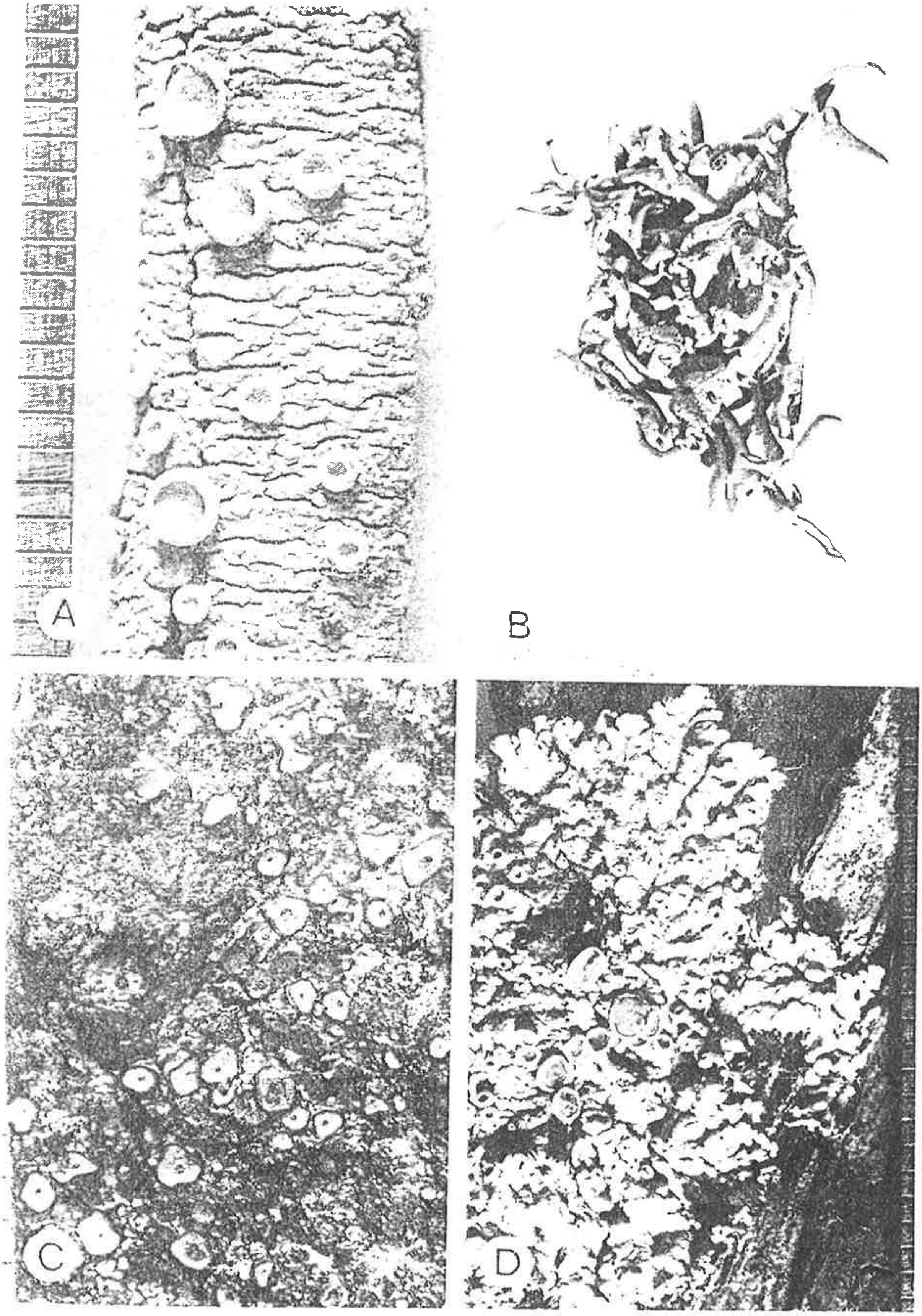

Fig. 22. A, *Ochrolechia subpallescens*; B, *Parmelia convoluta*; C, *Peltula australiensis*; D, *Physcia aipolia*. Scale in millimetres.

isidia and soredia absent, marginal and laminal lobules sometimes present on the older lobes; lower surface pale to dark brown. *Apothecia* not seen.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P± orange.

Figure: Habit, fig. 22B.

Specimens examined: The Catacombs Caves, Nullarbor Plain, *R. B. Filson 9440*, 4.i.1967 (MEL 25333); Hesso, c. 50 km northwest of Port Augusta, *R. W Rogers 17*, 10.ii.1965 (MEL 1011799); Eyre Highway, 40 km east of Kimba, *R B. Filson 11730*, 22.x.1970 (MEL 1011823); Koonamore Vegetation Reserve, C *M. Eardley*, vi.1946 (MEL 6206).

Grows also in Victoria and the Northern Territory.

Parmelia convoluta often grows in close association with *P. australiensis* and can be separated from it only by the chemical tests.

Parmelia corrugativa Kurokawa and Filson 1975:38.

Thallus corticolous, adnate to the substrate, margins of the lobes free; lobes irregularly elongate, mildly imbricate, up to 4 mm wide, without cilia; upper surface mineral grey, rugulose, without isidia or soredia; lower surface black. *Apothecia* abundant adnate, up to 4 mm diam.; disk at first deeply concave, cinnamon brown; margin persistent, crenulate; ascospores 10-12 x 7-8 µm.

Reactions: Thallus K+ yellow, medulla K−, C+ red, KC−, P−, lower medulla K+ purple.

Specimens examined: Shady Grove, Unitarian Church site, Mt. Barker Junction, 5 km south-east of Balhannah, *R. W. Rogers 553*, 3.vi.1966 (MEL 1013418); Para Wirra Recreation Park, *R. W. Rogers 95*, 17.i.1966 (MEL 1013419).

P. corrugativa is a distinctive grey-*Parmelia* species growing on dead twigs and branches. It could be confused with *P. quercina* but is easily separated from this species by the deep yellow pigment in the lower medulla.

Parmelia dichromatica Hale 1971:348.

Thallus saxicolous, tightly adnate to the substrate, up to 15 cm diam.; lobes flat, scarcely imbricate, 3·0-3·5 (-4·0) mm wide; upper surface dull yellow-green, older lobes becoming cracked, rugulose and sub-areolate, isidia and soredia lacking; lower surface black. *Apothecia* up to 6 mm diam.; margin persistent, inrolled; ascospores 12 x 8 µm.

Reactions: Thallus K−, medulla K+ bright yellow becoming red to blackish red, C−, KC−, P+ pale yellow-orange, orange pigment in the lower medulla K+ purple.

Specimens examined: Wynbring Rocks, c. 1 km north of Wynbring on the East-West Railway Line, *R. B. Filson 11941*, 28.x.1970 (MEL 1011726); south side of Carappee Hill, Eyre Peninsula, *R. B. Filson 11767*, 22.x.1970 (MEL

1011813); on hill to south of old dam on western side of the Corunna Range, 6·5 km north of Iron Knob, *R. B. Filson 11723*, 21.x.1970 (MEL 1011840).

Parmelia dissecta Nyl. 1882:451.

Thallus foliose, corticolous, tightly adnate, up to 4 cm diam.; lobes up to 1·5 (−2·0) mm broad, subdichotomous, short, rounded, hardly imbricate; upper surface pale grey, sometimes with a pale brown tinge at the lobe ends, distinctly black bordered, weakly pseudocyphellate, without soredia, isidia papillate becoming cylindrical, simple, with dark grey apices; lower surface jet black, with a pale brown bare zone at the tips of the lobes. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K−, C+ red, KC+ rose, P−.

Specimen examined: Western side of the border road, 13 km north of the Nelson-Caveton road, *R. B. Filson 14632*, 16.v.1973 (MEL 1018690).

The species grows also in Victoria and New South Wales.

Parmelia ferax Müll. Arg. 1886:257.

Thallus lignicolous on dead wood and old fence posts, pale yellow-green, up to 10 cm diam.; lobes irregular up to 3·0 mm wide, margin crenulate, imbricate, lobulate, without soredia; upper surface more or less rugulose at the margins, densely rugulose towards the centre; lower surface black, rugulose. *Apothecia* up to 6 mm diam.; disk cinnamon brown to dark brown; margin persistent, strongly inrolled; ascospores 13-15 x 7-8 μm.

Reactions: Thallus K−, KC+ pale yellow, medulla K± pale brown, C−, KC−, P+ deep orange.

Specimens examined: Stuart Highway c. 40 km north-west of Port Augusta, *J. H. Willis*, 2.viii.1966 (MEL 34883); Warren Gorge, Flinders Ranges, *R. B. Filson 11987*, 30.x.1970 (MEL 1011715); "Canegrass" Station, 53 km north of Morgan, *R. W. Rogers 1074*, 17.v.1967 (R.W.R.); Koonamore Vegetation Reserve, *R. W. Rogers 1304*, 27.xi.1967 (R.W.R.).

Occurs in Victoria and New South Wales.

P. ferax is a chemical species. It is very close to and easily confused with *P. rutidota. P. ferax* contains physodalic acid whilst *P. rutidota* contains protocetraric acid. Whilst these substances are easily separated by microcrystal tests in the field it is a little more difficult. The lobes of *P. ferax* are on the whole slightly smaller and the central portions of the thallus far more rugulose. It is debatable whether it is a distinct species.

Parmelia flavescentireagens Gyel. 1934:154.

Thallus saxicolous, loosely attached to the substrate, pale yellow-green to pale yellow-blue-green, up to 15 cm diam.; marginal lobes broad subrotund up to 2·5 mm wide; secondary lobes narrower than marginal lobes sometimes building up the thallus into a thick mat; upper surface flat to slightly convex, without isidia or soredia; lower surface varying in colour from pale ivory to light brown. *Apothecia* uncommon up to 10 mm diam.: disk deeply concave, pale brown; margin thin, crenulate, deeply incised: ascospores 13-14 x 7 μm.

Reactions: Thallus K−, medulla K−, C+ faint rose, KC+ rose, P−.

Specimens examined: Humbug Scrub, 40 km north-east of Adelaide, *J. Curtis 2*, 9.iv.1967 (MEL 34841); 6·5 km east of Eden Valley, *J. A. Elix 828*, 5.v.1975 (J.A.E.); 16 km east of Springton on rocky hillside along the Marne River Gorge, *J. A. Elix 841*, 6.v.1975 (J.A.E.).

The species occurs also in Victoria, Tasmania and New South Wales.

Parmelia furcata Müll. Arg. 1886:256.

Thallus foliose, saxicolous, loosely attached to the substrate; lobes narrow elongate, 0·5-1·5 mm wide, up to 8 mm long, irregularly dichotomous, branched, upper surface smooth, yellow-green, without soredia or isidia; lower surface pale brown to dark brown, sparsely rhizinate. *Apothecia* up to 5 mm diam.: disk brown to dark brown; margin thin, heavily inrolled, crenulate, incised.

Reactions: Thallus K−, medulla K−, C−, KC+ faint rose, P−.

Figure: Habit, Plate 11C (MEL 1021218).

No specimens have been determined as this species but it may occur in the Springton district. It grows in Victoria, Tasmania and New South Wales.

Parmelia fuscosorediata Essl. 1977:68.

Thallus foliose, corticolous, appressed to the substrate, olive-brown to reddish-brown to almost black; lobes up to 4 mm wide, short, rounded, weakly imbricate: upper surface smooth to weakly wrinkled, dull, sometimes pruinose, pruina dark grey, soredia laminal originating from small warts or isidia-like nodules; lower surface pale brown to black. *Apothecia* sessile, up to 1·5 mm diam.; disk smooth, concave, dull or slightly shining; margin thin, crenulate, becoming sorediate; ascospores ellipsoid, 9-13 x 5·5-9 μm.

Reactions: Thallus K−, HNO_3−; medulla K− very pale pink-violet or pale yellow, fading, C+rose, KC+ rose-red, P−.

Specimen examined: Gum Flat, 40·25 km north-west of Elliston, *R. B. Filson 11893*, 25.x.1970 (MEL 1011841).

The species grows also in Victoria.

Parmelia sp. *nov.* 2

Thallus terricolous, tightly adnate to substrate, yellow-green, up to 10 cm diam.; lobes irregular, elongate, imbricate with prominent black margins, up to 3·0 (−5·0) mm wide; secondary lobes 0·4-1·0 mm wide overlaying the centre of the thallus; upper surface without isidia or soredia; lower surface black.

Apothecia sessile, up to 4 mm diam., deeply concave; disk cinnamon brown; margin thin at first, strongly inrolled, slightly crenulate and lacerate; ascospores 9-10 x 6-7 μm.

Reactions: Thallus K−, medulla K− yellow becoming crimson, C−, KC−, P− bright orange.

Specimens examined: 6·5 km south of Spalding , *R.W. Rogers 687*, 28.x.1966 (R.W.R.); c. 3 km northeast of Native Valley, *R.W. Rogers 1517*, 4.xi.1968 (R.W.R.).

Occurs also in Victoria and New South Wales.

This species is found in open, arid areas where it grows on the ground.

Parmelia globulifera Kurokawa and Filson 1975:38.

Thallus saxicolous, closely adnate, areolate, straw-yellow, up to 13 cm diam.; lobes subirregular, shortly elongate with rounded apices, 1·5-3·0 mm wide; upper surface strongly convex, isidiose but without soredia; isidia inflated, sometimes breaking open at the apices; lower surface pale to brown. *Apothecia* not seen.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimen examined: Wynbring Rocks, c. 1 km north of Wynbring on the East-West Railway Line, *R. B. Filson 11940*, 28.x.1970 (MEL 1011707). As yet the species is known only from South Australia.

This is a very unusual *Parmelia* as the areolate lobes give the lichen a crustose appearance. It is morphologically similar to *P. refringens* another isidiose species in the "incrustata group" but can be separated from this species by the colour of the surface and the chemical reactions on the medulla.

Parmelia sp. *nov.* 3

Thallus saxicolous, loosely attached to the substrate, pale yellow-green to pale yellow-blue-green, covering patches up to 20 cm diam.; lobes irregular, subrotund, 1·0-2·5 mm wide, strongly imbricated, secondary lobes similar to the marginal lobes, sometimes building up thallus into a thick mat; upper surface smooth to slightly rugulose, without soredia but heavily isidiose on the older parts; isidia cylindric, coralloid; lower surface black. *Apothecia* up to 8 mm diam.; disk cinnamon brown to dark brown, deeply concave; margin thin, isidiose, inrolled at first, crenulate, incised; ascospores 10-11 x 6 μm.

Reactions: Thallus K−, medulla K+ yellow slowly brick-red to blackish-red, C−, KC−, P+ deep orange.

Specimen examined: Memory Cove, Cape Catastrophe, Eyre Peninsula, *R. B. Filson 11828*, 24.x.1970 (MEL 1011750).

The species grows in all Australian States.

It is a mat-forming *Parmelia* which can be separated from other species in this group by the black lower surface and the presence of small congested isidia.

Sometimes the central portion of the thallus can be hidden by a mass of isidia which gives the appearance of a dense isidiose mat.

Parmelia hypoclystoides (Müll. Arg.) Gyel. 1935a:25.

Parmelia conspersa var. *hypoclystoides* Müll. Arg. 1883:20.

Thallus foliose, saxicolous, loose to moderately adnate; lobes short and broad, rounded at the apices, up to 5 mm wide, irregular, strongly imbricate and mat-forming; upper surface smooth, sometimes shining at the marginal lobe becoming dull and wrinkled at the centre, without soredia or isidia; lower surface pale tan to brown, sparsely rhizinate. *Apothecia* up to 10 mm diam.; disk pale to dark brown, wrinkled; margin thin, inrolled, crenulate, deeply lacerate in older structures; ascospores 8-9 x 7 µm.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ dirty orange.

Specimens examined: Fowlers Bay, *Richards* (MEL 6194); Mount Gambier, *F. Mueller*, (MEL 6200).

The species is found also in Victoria.

Parmelia hypoprotocetrarica Kurokawa and Elix 1971:113.

Thallus saxicolous, loose to moderately adnate on the substrate, pale yellow-green, up to 8 cm diam.; lobes irregular, imbricate, margins sub-ascending, 1·0-2·0 (-3·0) mm wide; upper surface flat, heavily maculate without soredia or isidia; lower surface black. *Apothecia* up to 7 mm diam.; disk pale to dark brown, deeply concave; margin thin crenulate to deeply incised; ascospores 6-8 x 4-5 µm.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimens examined: Elder Expedition, *R. Helms 1*, 1891 (MEL 91[illegible] Springton, c. 55 km northeast of Adelaide, *J. A. Elix 203*, 27.xii.1973 (J.A.E.); Torrens Gorge, c. 3 km east of Gorge Kiosk, *N. N. Donner 1308*, 13.iii.1965 (MEL 9118).

This species is known also in Victoria and New South Wales.

Parmelia imitatrix Tayl. 1847:161.

Thallus saxicolous, appressed to substrate, olive-brown to reddish-brown; lobes elongate, up to 3 mm wide, hardly imbricate; upper surface dull, smooth to weakly wrinkled becoming rugose towards the centre, without soredia or isidia; lower surface dark brown to black. *Apothecia* up to 6 mm diam., sessile to shortly stipitate; disk concave, becoming flat; margin thin, entire, becoming crenulate, sometimes infolded; ascospores ellipsoid to almost subglobose, 7-11·5 x 4·5-6·5 µm.

Reactions: Thallus K−, HNO_3 + dark blue-green; medulla K−, C− or C− pale yellow, KC+ rose-red, P−.

Specimens examined: Kimba to Cowell road, 18 km north-west of Cowell, *R. B. Filson* 11774, 22.x.1970 (MEL 1011811); Podinna Rock, 24 km north of Minnipa, *R. B. Filson 11902*, 25.x.1970 (MEL 1012291).

Parmelia imitatrix occurs also in Western Australia, Victoria and Tasmania.

Parmelia incantata Essl. 1977:115

Thallus foliose, terricolous, saxicolous or rarely lignicolous, tightly appressed to substrate, yellow-brown to reddish-brown to dark brown; lobes up to 1·5 mm wide, broad and rounded or elongate and sublinear, hardly imbricate; upper surface smooth, becoming rugose towards the centre, dull, shining at the lobe ends, sometimes lightly pruinose, without soredia, isidiose, isidia cylindrical or claviform; lower surface dark brown or black. *Apothecia* not seen.

Reactions: Thallus K−, HNO_3−; medulla K−, C−, KC+ rose-red, P−.

Specimens examined: Sandhill 1·6 km west of Barton on the East-West Railway, *R. B. Filson 11936*, 27.x.1970 (MEL 1012288); 3·2 km north of Kokatha on Poochera-Kingoonya road, *R. B. Filson 11914*, 26.x.1970 (MEL 1012284); Wilgena Hill, 6·4 km north Kingoonya-Tarcoola road 67·5 km west of Kingoonya, *R. B. Filson 11929*, 26.x.1970 (MEL 1012285); Waterfall Gully, Mount Lofty Ranges, *A. C. Beauglehole 15064*, 30.ix.1965 (MEL 1011702).

Parmelia incantata is known also from Western Australia.

Parmelia incerta Kurokawa and Filson 1975: 39.

Thallus saxicolous, closely adnate to the substrate, pale yellowish-green, up to 5 cm diam.; upper surface flat to slightly convex; marginal lobes smooth, black bordered; older lobes rimose rugulose, without soredia or isidia; lower surface dark brown. *Apothecia* adnate, up to 8 mm diam.; disk dark brown, deeply concave; margin thin, crenulate to deeply incised; ascospores 12-13 x 7·5-8·0 μm.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ intense yellow.

Specimen examined: Warren Gorge, Southern Flinders Range, *J. Curtis 7*, 23.iv.1967 (MEL 34825).

Parmelia incerta is at present known only from South Australia.

Parmelia incrustata Kurokawa and Filson 1975:39.

Thallus saxicolous, pale straw-coloured, up to 5 cm diam.; lobes irregular imbricate, 0·7-1·2 mm wide, convex sometimes the central lobes becoming revolute; lower surface pale reddish-brown blackening at the margins. *Apothecia* up to 1·2 mm in diam.; disk dark brown, concave; margin thin, slightly crenulate; ascospores 12 x 6 μm.

Reactions: Thallus K−, medulla K−, C−, KC+ rose, P−.

Specimens examined: 23 km east-south-east of "Kenmore Park." *A. C. Beauglehole 25673*, 2.vii.1968 (MEL 1011699); 90 km south of Coober Pedy, *A. C. Beauglehole 25377*, 24.vi.1965 (MEL 1011701); summit of the Wallabyng Range, 21 km north of Kingoonya, *R. B. Filson 11958*, 28.x.1970 (MEL 1011709); near old gold mine, Waukaringa Hill, *R. W. Rogers 1287*, 9.x.1967 (R.W.R.).

Parmelia incrustata occurs also in New South Wales.

This is the name species for the "incrustata group" which comprises *P. globulifera*. *P. incrustata*. *P. pertinax*, *P. refringens* and *P. rimalis*. It can be separated from the other isidiose members of this group by the pale reddish-brown lower surface, narrow marginal lobes and the negative reaction of the medulla with Pd.

Parmelia jeleneckii Kremp. 1870:114.

Thallus corticolous, adnate to the substrate, green or yellow-green, up to 20 cm diam.; lobes irregular, subrotund, up to 10 mm wide, margins crenulate, flexuose, imbricate; upper surface more or less rugulose without isidia or soredia; lower surface jet black. *Apothecia* up to 7 mm diam.; disk cinnamon to dark brown, concave; margin strongly inrolled at first becoming less so at maturity; ascospores 15-18 x 9-12 μm.

Reactions: thallus K−, medulla K−, C−, KC−, P+ orange-red, lower medulla K+ purple.

No collections of this species have been made from South Australia; however it occurs in Victoria close to the State border and in Tasmania and New South Wales.

P. jeleneckii is part of the "caperata group" and is distinguished from other non-sorediose members of this group by the yellow lower medulla which has positive reaction with KOH.

Parmelia loxodella Esslinger 1977:120.

Thallus foliose, saxicolous, tightly appressed to the substrate, olive-brown to dark reddish-brown, up to 12 cm diam.; lobes 1-2 mm wide, short, rounded, imbricate; upper surface smooth and strongly shining on the lobe ends becoming dull and cracked on the olders parts of the thallus, without soredia; isidia cylindrical, simple or branched, continuous and dense in the centre of the thallus thinning but occurring right to marginal lobes; lower surface dull, black, ends of the lobes dark brown. *Apothecia* not seen.

Reactions: Medulla K−, C−, KC+ red turning dingy orange-red, P−.

Specimens examined: Gawler Ranges, 160 km west of Port Augusta, *D. N. Krahenbuehl 2419*, 15.ix.1968 (MEL 37631). Also recorded in Esslinger (1977:120) near Burra, *Bratt & Cashin 70/964* (TLE, not seen).

The species occurs also in Victoria.

Parmelia luteonotata J. Stein. 1902:472.

Thallus foliose, saxicolous, tightly appressed to the substrate, reddish-brown to dark brown; lobes up to 3 mm wide, hardly imbricate; upper surface dull in the centre, slightly shining on the marginal lobes, flat, becoming strongly rugose in the centre, without soredia or isidia; lower surface pale tan to pale brown. *Apothecia* common up to 5 mm diam., sessile or shortly stipitate; disk concave or flat, dull, dark reddish-brown to blackish-brown; margin thin, entire; ascospores ellipsoid, 8-9·5 x 4·5-6 µm.

Reactions: Thallus K−, HNO_3+ dark blue-green; medulla K−, C− or C+ rose, KC− or KC+ rose, P−.

Specimens examined: Eyre Highway, 40 km east of Kimba, *R. B. Filson 11743,* 22.x.1970 (MEL 1011809); Eyre Peninsula, foot of north-east side of Darke Peak, *R. B. Filson 11762,* 22.x.1970 (MEL 1011732); Summit of Wallabyng Range, 21 km north of Kingoonya, *R. B. Filson 11960a*. 28.x.1970 (MEL 1012293).

Occurs also in Victoria and New South Wales.

Parmelia metaclystoides Kurokawa and Filson 1975:40.

Thallus saxicolous, tightly adnate to the substrate, up to 7 cm diam.; lobes flat, imbricate, 0·7-1·5 mm wide; upper surface dull, yellow-green, greying to almost black on the older portions of the thallus, isidia and soredia absent; lower surface pale, becoming pale brown at the ends of the lobes. *Apothecia* adnate, up to 7 mm diam.; disk deep brown; margin inrolled at first becoming flat and undulate; ascospores 9-10 x 6 µm.

Reactions: Thallus K−, medulla K+ pale yellow becoming orange then red, C−, KC−, P+ pale yellow then orange.

Specimen examined: Kimba to Cowell road, 18 km north-west of Cowell, *R. B. Filson 11783,* 22.x.1970 (MEL 1011810).

The species is known only from the type collection.

P. metaclystoides resembles *P. hypoclystoides* in both having pale undersides. It can be separated from *P. hypoclystoides* by the smaller lobes, paler underside. In the field *P. hypoclystoides* appears to have a more greyish-green appearance towards the ends of the marginal lobes.

Parmelia mexicana Gyel. 1931:281.

Thallus saxicolous, moderately to tightly appressed to the substrate, yellow-green to yellow-blue-green, forming patches up to 10 cm diam.; lobes irregular elongate, imbricate, up to 2·0 mm wide; upper surface smooth, shining, flat to slightly convex, without soredia, isidia cylindrical, slightly inflated, coralloid, short, densely covering the central portion of the thallus; lower surface pale to light brown. *Apothecia* adnate, immersed in isidia, up to 4 mm diam.; disk dark brown, at first deeply concave becoming less on ageing.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P− immediate orange.

Specimen examined: On rocky hillside, "Olive Grove" Station, 15 km south of Quorn, *R. B. Filson 11994*, 30.x.1970 (MEL 1011714).

The species occurs also in Victoria, Tasmania and New South Wales.

P. mexicana differs from the closely related *P. plittii* in the broader subrotund lobes and the denser isidia; which is shorter and more or less inflated at the tips.

Parmelia sp. *nov.* 4.

Thallus moderately loose on the substrate; marginal lobes up to 3 mm wide, short, rounded, strongly imbricate, secondary lobes narrower, up to 1 mm wide, imbricate and entangled, sometimes overgrowing the marginal lobes; upper surface smooth, dull, pale yellow-green, without soredia or isidia; under surface brown to dark brown, sparsely rhizinate. *Apothecia* up to 5 mm diam., margin heavily inrolled, hardly crenulate or incised; disk deeply concave, dark brown: ascospores 10-11 x 6-7 μm.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimen examined: Podinna Rock, 24 km north of Minnipa, *R. B. Filson 11903,* 25.x.1970 (MEL 1011864).

This species is known only from South Australia.

Parmelia sp. *nov.* 5

Thallus corticolous, loosely attached to the substrate, pale greyish-white, up to 10 cm diam., lobes up to 6 mm wide, densely ciliose with simple or branched cilia, flexuose, hardly imbricate; upper surface maculate in a reticulate pattern sometimes tips of lobes grey pruinose, older lobes becoming thick and wrinkled without isidia, submarginally sorediose, becoming capitate; lower surface black, heavily rhizinate right to the margins of the lobes and mingling with the marginal cilia. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red, C−, KC−, P+ orange.

Specimen examined: Gum Flat, 40 km north-west of Elliston, Eyre Peninsula, *R. B. Filson 11895*, 25.x.1970 (MEL 1011865).

Occurs also in Victoria, Tasmania and New South Wales.

The species is very similar to *P. reticulata* but easily separated from that species in the rhizines occurring right to the ends of the lobes.

Parmelia perlata (Huds.) Ach. 1803:216.

Lichen perlatus Huds. 1762:448.

Thallus corticolous, loose to moderately adnate on substrate, mineral grey, up to 15 cm diam.; lobes rotund, up to 8 mm wide, ciliate; upper surface smooth without isidia, submarginally sorediose; soredia cause the lobe margin to become revolute; lower surface black becoming light to dark brown at the lobe tips. *Apothecia* very rare, up to 7 mm diam.; disk pale brown to cinnamon; margin thick, inrolled, sorediose; ascospores 25-27 x 16-18 μm.

Reactions: Thallus K+ yellow, medulla K+ yellow, C−, KC−, P+ pale orange becoming red.

Figure: Habit, plate 12B (MEL 1021204).

Specimens examined: Callendale North, 30 km south of Lucindale *M. Beek 11*, 10.vi.1970 (MEL 1012084); Hindmarsh Falls, *R. W. Rogers 1050.1*, 30.iv.1967 (R.W.R.); Tent Hill, near Deep Creek, Fleurieu Peninsula, *R. W. Rogers 1454*, 1.ix.1968 (R.W.R.); north-west slope of Mount Bonython, *R. D. Seppelt 1742*, 23.vii.1969 (R.W.R.).

The species grows also in Western Australia, Victoria, New South Wales and Queensland where it is widespread.

Parmelia perlata may be confused with two similar species, *P. reticulata* and *P. tenuirima*, but it is separated from both of these species by the smooth upper surface and the persistent yellow reaction of the medulla with KOH.

Parmelia pertinax Kurokawa and Filson 1975:41.

Thallus saxicolous, closely attached to the substrate, up to 1·0 cm diam., yellow to yellow-green; lobes up to 2·5 mm wide, not imbricate, becoming areolate towards the centre; upper surface flat, smooth at the margins, becoming rugulose and cracked towards the centre, without isidia or soredia; lower surface brown to dark brown. *Apothecia* 2·0 mm (rarely to 4·0 mm) diam.; margin thick inrolled, slightly lacerate; ascospores 8-10 x 5-7 μm.

Reactions: Thallus K−, medulla K−, C−, KC−, P+ red.

Specimens examined: On hill to the south of old dam on western side of the Corunna Range, 6 km north of Iron Knob, *R. B. Filson 11728*, 21.x.1970 (MEL 1011843); summit of Wallabyng Range, 21 km north of Kingoonya, *R. B. Filson 11959*, 28.x.1970 (MEL 1011708); Warren Gorge, 18 km north of Quorn, *R. B. Filson 11970*, 30.x.1970 (MEL 1011739).

The species is known only from South Australia.

In the field it is hard to separate *P. pertinax* from its closely related *P. rimalis*. The macroscopic differences are not well defined; *P. pertinax* is slightly more greenish-yellow in colour, lobes not imbricate. However a chemical test with KOH easily separates them as *P. pertinax* reveals a negative reaction.

Parmelia plittii Gyel. 1931:287.

Thallus saxicolous, moderately to tightly appressed to the substrate, yellow-green to yellow-blue-green, forming patches up to 10 cm diam.; lobes elongate, not or hardly imbricate, 1·0-1·5 mm wide; upper surface smooth shining, flat to slightly convex, without soredia, isidia simple, short, sparse, sometimes slightly inflated; lower surface pale to light brown. *Apothecia* not seen.

Reactions: Thallus K−, medulla K− yellow becoming red, C−, KC−, P− orange.

Specimens examined: Eyre Highway, 40 km east of Kimba, *R. B. Filson 11744*, 22.x.1970 (MEL 1011808); 3 km north of Kokatha on the Poochera-Kingoonya road, *R. B. Filson 11910*, 26.x.1970 (MEL 1011802); 4 miles (6 km) west of Oodla Wirra, *R. W. Rogers 1654*, 21.v.1969 (R.W.R.).

Occurs in Western Australia, Victoria and Tasmania.

This species is very hard to distinguish from *P. mexicana* in the field; more elongate, hardly imbricate lobes are a good guide but the most reliable feature is the simple, sparse and scattered isidia.

Parmelia polyphylloides Gyel. 1934:371.

Thallus saxicolous, loosely attached to substrate, covering patches up to 20 cm diam.; lobes irregular, elongate, up to 2 mm wide, strongly imbricate, secondary lobes similar to the marginal lobes, building up the thallus into a thick mat; upper surface smooth to slightly rugulose, pale yellow-green becoming brownish-yellow to dark grey on the older lobes, distinctly black-bordered; lower surface brown to dark brown, blackening towards the margins. *Apothecia* up to 6 mm wide; margin thin, crenulate to flexuose, at first inrolled almost disappearing at maturity; disk dark brown, dull, concave, smooth becoming rugulose; ascospores 9-11 x 5-7 µm, thin walled.

Reactions: Thallus K−, medulla K− yellow becoming red, C−, KC−, P− pale yellow becoming orange.

Specimen examined: Hill south of old dam, western side of Corunna Range, 6 km north of Iron Knob, *R. B. Filson 11726*, 21.x.1970 (MEL 1011[illegible]).

Parmelia polyphylloides may be confused with *P. flavescentireagens* differs from it in the narrower lobes, darker underside, and in the chemical reactions.

Parmelia praeterissima Kurokawa and Filson 1975:41.

Thallus saxicolous, tightly adnate to the substrate up to 8 cm diam.; lobes sublinear elongate, 1·2-3·0 mm wide; upper surface yellow-green, greying on the older lobes, wrinkled and rugulose, isidia and soredia absent; lower surface dull, brown but becoming black near the apices of the lobes. *Apothecia* numerous, adnate, up to 10 mm diam.; disk deep brown; margin inrolled at first, later unrolling but the apothecia always remaining cup-shaped; ascospores 7 × 10 µm.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimens examined: On rock outcrop by saltlake, 50 km east of Tarcoola, *R. B. Filson 11949*, 28.x.1970 (MEL 1011717); 6 km east of Oodla Wirra, *R. W. Rogers 1656*, 18.v.1969 (R.W.R.).

As yet known only from South Australia.

Parmelia praeterissima is very similar to *P. tasmanica;* however it differs in being a little more tightly adnate to the substrate; the upper surface is dull rather than shining, wrinkled rather than smooth; the lower surface brown rather than black. It differs also in the negative chemical reactions on the medulla.

Parmelia pseudotenuirima Gyel. 1931:289.

Thallus corticolous, up to 9 cm. diam., closely adnate to substrate; lobes rotund, 2-4 mm wide, without cilia, hardly imbricate; upper surface pale mineral grey, dull, heavily scrobiculate and pseudocyphellate with isidia forming on the tops of ridges; isidia cylindric, coralloid, branched, densely covering the centre of the thallus; lower surface jet black, densely rhizinate right to the margins of the lobes. *Apothecia* up to 8 mm diam., margin thin inrolled at first becoming deeply lacerate and distorted, pseudocyphellate, sometimes developing isidia on the older apothecia; disk dull, dark brown to almost black; ascospores 14-16 × 9-10 μm.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming red.

Figure: Ascospores, fig. 21B.

Specimen examined: The Gap, 48 km north of Naracoorte, *M. Beek 33*, 15.vii.1973 (MEL 1013807).

This species grows also in Victoria and New South Wales.

Parmelia pulla Ach. 1814:206.

Thallus foliose, loosely to moderately attached to substrate, olive-brown to yellowish-brown, reddish-brown to dark brown; lobes up to 5 mm wide, short, rounded to elongate and linear, imbricate to entangled; upper surface smooth to weakly wrinkled, dull to slightly shining without soredia or isidia; lower surface dark brown to black. *Apothecia* up to 8 mm diam., sessile to shortly stipitate; disk deeply concave to flat, reddish-brown; margin thin, crenulate to lacerate; ascospores ellipsoid, 8-10 × 4·5-7 μm.

Reactions: Thallus K−, HNO_3+ pale to dark blue-green; medulla K−, C− or C− rose to red, KC− or KC+ rose-red, P−.

Figure: Habit, plate 12A (MEL 1021187).

Specimens examined: 26½ miles (41 km) west-south-west Koonalda, *A. C. Beauglehole 14910*, 24.ix.1965 (MEL 1012254); Marble Range, Eyre Peninsula, *R. B. Filson 11866*, 24.x.1970 (MEL 1011805); Memory Cove, Cape Catastrophe, *R. B. Filson 11824*, 24.x.1970 (MEL 1012287); Kingscote, Kangaroo Island, *R. D. Seppelt*, 10.xii.1972 (MEL 1012251); Warren Gorge, Flinders Ranges, *R. B. Filson 11972*, 30.x.1970 (MEL 1012294).

Occurs also in Western Australia, Victoria, Tasmania, New South Wales and Queensland.

P. pulla is probably our most common brown *Parmelia*. A similar species, *P. glabrans* Nyl., is a chemical variant of *P. pulla*, having a strong blue-white fluorescence of the medulla in ultraviolet light (Alectoronic acid).

Parmelia pumila Kurokawa and Filson 1975:42.

Thallus terricolous, closely adnate to the substrate, up to 6 cm diam.; lobes up to 1·5 mm wide, imbricate; secondary lobes subterete, coralloid, isidia-like growing up from lobules in the centre of the thallus; upper surface pale yellow-green, smooth, often pruinose on the marginal lobes, older parts becoming rugulose and cracked, without soredia or isidia; lower surface brown at the marginal lobes, progressively darker until black in the centre. *Apothecia* up to 2·5 mm diam.

Reactions: Thallus K−, medulla K+ yellow slowly brown then blackish-red, C−, KC−, P+ yellow becoming orange then red.

Specimens examined: Knowles Cave, Nullarbor Plain, *R. B. Filson 9454*, 5.i.1967 (MEL 25398); vicinity of Koonalda Cave, Nullarbor Plain, *R. B. Filson 9410*, 28.xii.1966 (MEL 25385); "Nullarbor" H.S., *J. H. Willis*, 29.viii.1947 (MEL 6246); Eyre Highway 16 km west of Ivy Shed Tanks, *G. C. Bratt 67/1*[illegible] 4.x.1967 (R.W.R.).

Known only from South Australia.

P. pumila is closely allied to *P. callifolia* and is separated from it by the closer adnation to the substrate, narrower marginal lobes, and the sub-terete, isidia-like secondary lobes.

Parmelia quercina (Willd.) Vain. 1899:279.

Lichen quercina Willd. 1787:353.

Thallus corticolous, firmly attached to the substrate, pale greenish-grey whitish-grey, up to 6 mm diam.; lobes up to 2·5 mm wide, hardly imbricate, ciliate; upper surface convex sometimes pruinose on the marginal lobes, slightly rugulose, without soredia or isidia; lower surface jet black. *Apothecia* up to 6 mm diam.; disk pale brown, sometimes pruinose, flat to slightly concave; margin thin entire; ascospores 12 x 9 μm.

Reactions: Thallus K+ yellow, KC+ orange, medulla K−, C+ blood red, KC−, P−.

Specimens examined: Greenhill, *R. W. Rogers 886*, 15.i.1967 (R.W.R.); near Mount Bold Reservoir, *V. M. Cruikshank*, x.1967 (R.W.R.); The Gap, 31 [illegible] north of Naracoorte, *M. Beek 37*, 15.vii.1973 (MEL 1013823).

Occurs in all States except the Northern Territory.

Parmelia refringens Kurokawa and Filson 1975:43.

Thallus saxicolous, moderately appressed to the substrate, covering patches by regeneration to 15 cm diam., pale yellow-green to straw-yellow; lobes imbricate, up to 3 mm wide; upper surface smooth at the marginal lobes, central lobes becoming rugulose and cracked, not servediose but isidiose; isidia verruculose, inflated at the apices, sometimes almost spherical, apices breaking open but not forming soredia; lower surface black. *Apothecia* up to 6 mm diam.; disk dark brown, deeply concave; margin thick inrolled, lacerate, sometimes heavily isidiose; ascospores 9-10 x 5-6 μm.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming orange.

Specimens examined: Wynbring rocks, c. 1 km north of Wynbring on the East-West Railway Line, *R. B. Filson 11940a*, 28.x.1970 (MEL 1013381).

Known only from South Australia.

P. refringens is part of the "incrustata group" and can be separated from the closely related species *P. globulifera* by the black under surface.

Parmelia reptans Kurokawa apud C. Baker et al. 1973:137.

Thallus forming irregular rosettes on earth, up to 4 cm diam.; lobes irregular to irregular-dichotomous, 0·5-1·5 (−2·0) mm wide; upper surface pale yellow-green, plane to slightly convex, soredia and isidia absent; lower surface pale brown sometimes with a paler zone towards the tips of the lobes. *Apothecia* not seen.

Reactions: Thallus K−, medulla K−, C−, KC−, P+ orange or yellow becoming red-orange.

Figure: Habit, fig. 23A.

Specimens examined: On hill to the south of old dam on western side of Corunna Range, 6·5 km north of Iron Knob, *R. B. Filson 11727*, 21.x.1970 (MEL 1011850); Koonamore Vegetation Reserve, *C. Barnard*, 12.xii.1927 (R.W.R.); 4 miles (6 km) east of Oodla Wirra, *R. W. Rogers 1938*, 2.xi.1971 (R.W.R.).

Occurs also in Western Australia and Victoria.

As with other species in the "amphixantha group" this species is difficult to distinguish in the field as it tends to grade into the other three species. To be sure of determination they must be separated chemically.

Parmelia reticulata Tayl. apud Mack. 1836:148.

Thallus corticolous, loosely attached to the substrate, mineral grey, up to 20 cm diam.; lobes up to 6 mm wide, secondary lobes building up the thallus into a thick mat, ciliate; upper surface heavily maculate in a reticulate pattern so that with ageing the surface of the lobe becomes reticulately cracked, without isidia, submarginally sorediose, becoming capitate; lower surface black, heavily rhizinate with a dark brown bare zone at tips of lobes. *Apothecia* rare up to 8 mm diam.; disk pale to warm brown, concave; margin thick, heavily sorediose, deeply incised; ascospores 13-16 × 9-11 μm.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red to brown to black, C−, KC−, P+ yellow becoming orange-red.

Specimens examined: Monster Mount, 13 km south of Keith, *R. D. Seppelt 2781*, 28.vii.1973 (MEL 1018048); Nixon-Skinner Conservation Park, Myponga. *R. W. Rogers 1709*, 16.vi.1969 (R.W.R.).

Occurs in all States except the Northern Territory.

Parmelia reticulata may be confused with *P.* sp. *nov.* 5 but can easily separated from this species by the bare or moderately rhizinate zone under lobe ends. It differs from *P. perlata* in having a reticulate upper surface.

Parmelia rimalis Kurokawa apud Kurokawa and Filson 1975:43.

Thallus saxicolous, closely appressed to the substrate, up to 15 cm diam., straw-yellow; lobes elongate, up to 2·5 mm wide, moderately imbricate becoming areolate towards the centre of the thallus; upper surface smooth at the margins becoming rugulose and cracked towards the centre, without soredia or isidia; lower surface brown. *Apothecia* up to 5 mm diam.; disk dark brown, concave; margin thick, inrolled, slightly lacerate; ascospores 12-13 × 6-7 μm

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ intense yellow.

Specimens examined: On rocky outcrop by salt lake, 50 km east of Tarcoola, *R. B. Filson 11949*, 28.x.1970 (MEL 1011713); summit of the Wallabyng Range, 21 km north of Kingoonya, *R. B. Filson 11958a*, 28.x.1970 (MEL 1011710); Yudnapinna Station, 28 km west of Hesso, *R. W. Rogers 24*, 22.vi.1965 (R.W.R.); spur to the south-west of Mount Arden, Southern Flinders Ranges, *John Curtis 2*, 23.iv.1967 (MEL 34826); Koonamore Vegetation Reserve, *R. W. Rogers 1309* 21.xi.1967 (R.W.R.); near old gold mine Waukaringa, *R. Rogers 1288*, 9.x.1967 (R.W.R.).

Known also from New South Wales.

Parmelia rutidota Hook.f. and Tayl. 1844:645.

Thallus foliose, corticolous or lignicolous, adnate to the substrate, green or yellow-green, up to 20 cm diam.; lobes irregular 2·0-8·0 mm wide, margins crenulate, imbricate, lobulate; upper surface dull, sometimes slightly shining, more or less rugulose at the margins becoming rugulose towards the centre. isidia and soredia absent; lower surface jet black, sparsely rhizinate; medulla white to cream, sometimes with yellowish patches in the lower part. *Apothec* up to 7 mm diam.; disk cinnamon brown, concave; margin strongly inrolled first becoming less so at maturity; ascospores 55 x 27μm.

Reactions: Thallus K−, medulla K−, C−, KC−, P+ deep orange, yellow patches in the lower medulla K−.

Figures: Habit, plate 12C (MEL 1021191) and fig. 23B.

Specimens examined: On sandhill, 1·6 km west of Barton on the East-West Railway Line. *R. B. Filson 11938*, 27.x.1970 (MEL 1011719); Gum Flat.

Fig. 23. A, *Parmelia reptans*; B, *Parmelia rutidota*; C, *Parmelia tasmanica*; D, *Parmelia tinctina*. Scale in millimetres.

40·25 km north-west of Elliston, Eyre Peninsula, *R. B. Filson 11896*, 25.x.1970 (MEL 1011832); along the track to Memory Cove, Cape Catastrophe, 24 km south-south-west of Port Lincoln, *R. B. Filson 11857*, 24.x.1970 (MEL 1011754); Nixon Skinner Conservation Park, near Myponga, *R.W. Rogers 1708*, 17.vi.1969 (R.W.R.); Hindmarsh Reservoir, Hindmarsh Tiers, Fleurieu Peninsula, *R.W. Rogers 1047*, 25.iv.1967 (R.W.R.); Ferguson Park, Burnside, *R.W. Rogers 1829*, 3.i.1970 (R.W.R.); Naracoorte, *M. Beek 5*, 30.v.1973 (MEL 1012083).

Occurs in all States.

Parmelia rutidota is at its best on dead wood in dry habitats. It may be confused with other species in the "caperata group" particularly with *P. ferax* from which it differs in chemistry. It is easily separated from *P. jeleneckii* in the chemical reactions on the pigment in the lower medulla and in the less divided and flexuose margins to the lobes.

Parmelia scabrosa Tayl. 1847:162.

Thallus moderately loose on the substrate; lobes imbricate up to 5 mm wide; upper surface yellow-blue-green, blackening towards the centre, smooth, shining at marginal lobes becoming dull and cracked on the older portions, soredia lacking, isidiose; isidia cylindric coralloid, up to 1·5 mm tall; lower surface brown to dark brown, blackening at the tips of the lobes. *Apothecia* up to 6·5 mm diam.; disk at first strongly concave becoming flat, dark brown, shining; margin at first inrolled, isidiose; ascospores 8-12 x 5-6 μm.

Reactions: Thallus K−, medulla K−, C−, KC+ pale rose, P−.

Figure: Habit, plate 12D (MEL 1021193).

Specimens examined: Near summit of Mount Bonython, *R.W. Rogers 877*, 15.i.1967 (R.W.R.).

Known also in Western Australia and Victoria.

Parmelia schistaceae Kurokawa and Filson 1975:44.

Thallus foliose, saxicolous, tightly adnate to the substrate, mineral-grey to pale yellowish-grey, up to 4 cm diam.; lobes sublinear elongate, irregularly branched; upper surface dull to slightly shining in parts, convex, smooth, cracked, without isidia, pustulate; pustules not readily forming soredia; lower surface pale brown. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K−, C−, KC−, P−.

Specimen examined: Wilgena Hill, 6·5 km north of Kingoonya, *R.B. Filson 11921*, 26.x.1970 (MEL 1011839).

Known only from South Australia.

Parmelia scotophylla Kurokawa apud Kurokawa and Filson 1975:45.

Thallus foliose, saxicolous, adnate to the substrate, mineral-grey, outside margins of the lobes darkening to a brownish-grey, up to 10 cm diam.; lobes up to 3 mm wide, slightly imbricate; upper surface flat to slightly convex, shining, smooth becoming cracked towards the centre, sparsely isidiose, without soredia; lower surface pale to light brown. *Apothecia* uncommon, substipitate, up to 6 mm diam.; disk pale brown, deeply concave; margin thin, inrolled, isidiose.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming orange.

Specimens examined; Warren Gorge, 17 km north of Quorn, *R. B. Filson 11971*, 30.x.1970 (MEL 1011743); vicinity of Arkaringa Creek, *R. Helms 69*, 25.v.1891 (MEL 6153).

Grows also in New South Wales.

This species may be confused with *P. schistaceae* as it sometimes has a pale yellowish cast to the thallus, it is separated from *P. schistaceae* in the presence of isidia, the larger, flat, more spread out lobes and in the reaction of KOH on the medulla.

Parmelia soredians Nyl. 1872:259.

Thallus corticolous, tightly adnate to to the substrate, up to 8 cm diam.; lobes rotund up to 3 mm wide, imbricate; upper surface yellow-green, smooth, dull to slightly shining, starting at the margins with sorediose bumps becoming heavily ridged with pulvinate soredia towards the centre, soredia granular, without isidia; lower surface black with dark brown zone at tips of lobes. *Apothecia* not seen.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming orange.

Specimens examined: 6 km west of Springton along the High Eden road, *J.A. Elix 2238*, 20.v.1976 (J.A.E.); 1 km east of Hallett Cove, *J. A. Elix 2137*, 13.v.1976 (J.A.E.).

Occurs in Victoria and New South Wales.

Parmelia soredians is a very distinctive yellow-green sorediose lichen found growing on old fence posts. A form with narrower more strongly dissected marginal lobes, less dense soredia and a negative reaction with KOH is also found growing in similar habitats.

Parmelia spodochroa Kurokawa and Filson 1975:46.

Thallus saxicolous, tightly adnate to the substrate, pale grey to ash-coloured, up to 4 cm diam.; lobes irregular, up to 1·5(–2·0) mm wide, sometimes imbricate; upper surface smooth, dull convex, becoming cracked towards the centre, without soredia or isidia; lower surface pale, becoming dark brown to blackish-brown at the margins. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red, C−, KC−, P+ orange.

Specimen examined: Warren Gorge, 17 km north of Quorn, *R. B. Filson 11976*, 30.x.1970 (MEL 1011718).

At present known only from the type collection.

Parmelia spodochroa is allied to *P. schistaceae* and *P. scotophylla* and differs from them in the lack of pustules, soredia or isidia.

Parmelia subalbicans Stirt. 1877-78:254.

Thallus corticolous or lignicolous, adnate to moderately adnate to the substrate, varying in colour from greyish-white to mineral-grey to almost blackish-grey, up to 8 cm diam.; lobes elongate, up to 2·5 (−3·0) mm wide crenulate, margins blackish-grey and sometimes pruinose, not ciliate; upper surface dull to slightly shining, smooth, flat, becoming pseudocyphellate, without soredia or isidia; lower surface pale to light brown. *Apothecia* common, stipitate, crowded into the central parts of the thallus, up to 6 mm diam.; disk pale brown to very dark brown, concave to almost flat; margin thin, crenulate, persistent; ascospores ellipsoidal, 15-16 × 8-10 μm.

Reactions: Thallus K+ yellow, medulla K−, C+ red, P−.

Specimens examined: On sandhill 1·5 km west of Barton on the East-West Railway Line, *R. B. Filson 11939*, 27.x.1970 (MEL 1011729); 35 km east of Refuge Rockholes, 40 km west of Whyalla, *N. N. Donner 2199 (in part)* 28.viii.1967 (MEL 1018046); Stuart Highway, c. 43 km north of Hesso, *R. W. Rogers 11*, 2.iv.1965 (MEL 1011853, AD); Koonamore Vegetation Reserve, *R. W. Rogers 1316*, 1.xii.1967 (R.W.R.); Ferguson Park, Burnside, *R. W. Rogers 1830*, 5.i.1970 (R.W.R.).

Occurs in Western Australia, Victoria, Tasmania and New South Wales.

Parmelia subalbicans is a very common lichen on old fence posts and post and rail fences where it is often found in association with *P. rutidota*.

Parmelia subcaperata Kremp. 1873:10.

Thallus corticolous, lignicolous or occasionally saxicolous, loosely attached to the substrate, pale grey to buff, up to 15 cm diam.; lobes up to 15 mm wide, margins black, heavily ciliate; cilia up to 3 mm long, often branched; upper surface smooth, shining, strongly maculate becoming cracked on the older parts of the thallus, without soredia or isidia; lower surface brown to dark brown. *Apothecia* up to 20 mm diam., stipitate; disk light brown with a perforation in the centre; margin thin deeply incised; ascospores 15 × 9-10 μm.

Reactions: Thallus K+ yellow, medulla K− yellow becoming red to blackish-red, C−, KC−, P+ yellow becoming orange.

Specimens examined: Kapunda, 70 km north-north-east of Adelaide, *G. Hazel*, ix.1965 (MEL 1011798, AD); top of The Bluff, Victor Harbor, *R. W. Rogers 1888*, ix.1970 (R.W.R.).

Occurs in Victoria and Tasmania.

Parmelia subcaperata might be confused with two chemically identical species, *P. tenuirima* and *P. reticulata*. It differs from *P. tenuirima* in having long marginal cilia and from *P. reticulata* in not having reticulate maculae on the upper surface and in the lack of soredia.

Parmelia subdistorta Kurokawa 1969:212.

Thallus, terricolous or saxicolous on pebbles on the ground, mostly adnate to the substrate, pale yellow-green, up to 10 cm diam.; lobes at the margins sublinear-elongate, up to 1·0 mm wide, imbricate; secondary lobes overgrowing the centre of the thallus, narrower than the marginal lobes, revolute, dichotomous, 0·3-0·5 (−0·7) mm wide; upper surface minutely rugulose, flat strongly convex, without soredia or isidia; lower surface pale, darkening to greyish-brown at the lobe ends. *Apothecia* rare up to 3 mm diam.; disk pale to dark brown; margin thick revolute; ascospores 10 × 7 μm.

Reactions: Thallus K−, medulla K−, C−, KC+ rose, P−.

Figure: Ascospores, fig. 21C.

Specimens examined: Kimba to Cowell road, 18 km north-west of Cowell, *R. B. Filson 11780,* 22.x.1970 (MEL 1011818); "Cariewerloo" Station, 50 km west-north-west of Port Augusta on the road to Hesso, *R. W. Rogers 1934,* 25.iii.1965 (R.W.R.); alongside a secondary road, c. 3 km north-west of Quorn, *R. B. Filson 11964,* 29.x.1970 (MEL 1011744); "Baratta" H. S., 65 km east of Hawker, *N. N. Donner 5037,* 10.vii.1974 (AD); Oodla Wirra, *R. D. Seppelt,* 1.v.1971 (R.W.R.).

Occurs also in Western Australia and Victoria.

This species may be confused with some forms of *P. australiensis* which is chemically similar. However it differs in having narrower revolute lobes and is usually rosette forming rather than being loose and scattered on the substrate.

Parmelia subrudecta Nyl. 1888:26.

Thallus corticolous, loosely attached to the substrate, mineral-grey to pale tan, up to 15 cm diam.; lobes up to 6 mm wide, without cilia; upper surface, dull, flat, without isidia, heavily pseudocyphellate; pseudocyphellae on the older lobes sometimes developing into soredia; soredia mainly marginal; lower surface smooth to rugulose, pale to pale brown. *Apothecia* rare up to 4 mm diam.; disk pale brown to tan, deeply concave; margin at first inrolled, pseudocyphellate becoming sorediose; ascospores 16-18 × 9-15 μm.

Reactions: Thallus K+ yellow, medulla K−, C+ blood-red, KC+ red, P−.

Figure: Habit, plate 13A (MEL 1021209).

Specimens examined: Warren Gorge, 18 km north of Quorn, *R. B. Filson 11969,* 30.x.1970 (MEL 1011738); Comaum, 17 km north-east of Penola, *K. Alcock,* 21.vii.1972 (MEL 1011852).

Occurs in all States except the Northern Territory.

Parmelia subverrucella Essl. 1977:133.

Thallus foliose, saxicolous, tightly adnate, up to 3 cm diam.; lobes up to 1·5 (-3) mm broad, short, rounded, contiguous, subimbricate; upper surface olive-brown to dark brown, smooth to weakly wrinkled, without soredia, isidia subglobose, at times becoming lobulate, sometimes almost black; lower surface pale tan, moderately rhizinate. *Apothecia* not seen.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimen examined: Summit of Wallabyng Range, 21 km north of Kingoonya, *R. B. Filson 11960*, 28.x.1970 (MEL 1012292).

At present known only from South Australia.

Parmelia tasmanica Hook. and Tayl. 1844:644.

Thallus foliose, saxicolous, loosely attached to the substrate; lobes numerous, densely imbricate, 2·5-5·0 mm wide with masses of secondary lobes building up the thallus into a thick mat; upper surface yellow-green to yellow-blue-green, shining, soredia and isidia absent; lower surface jet black with narrow cinnamon brown zone at the lobe ends. *Apothecia* up to 15 mm diam., deeply cup-shaped; disk reddish-brown, shining; margins inrolled; ascospores 10 × 6 μm.

Reactions: Thallus K−, medulla K+ yellow becoming red to brownish-red, C−, KC−, P+ yellow becoming brick red.

Figures: Habit, plate 13B (MEL 1021208) and fig. 23C.

Specimens examined: Podinna rock, 24 km north of Minnipa, *R. B. Filson 11901b*, 25.x.1970 (MEL 1011863); south side of Carappee Hill, Eyre Peninsula, *R. B. Filson 11764*, 22.x.1970 (MEL 1011814); Hawker to Marree road, 21 km south of Copley, *A C. Beauglehole 28186*, 2.viii.1968 (MEL 1011700); rocky hillside, "Olive Grove" Station, 14 km south of Quorn, *R. B. Filson 12000*, 30.x.1970 (MEL 1011733); 5 km up River Torrens past Cudlee Creek, *R. W. Rogers 1260*, 20.vii.1967 (R.W.R.); Hindmarsh Falls, *R. B. Filson 15480*, 13.xi.1975 (MEL 1015122).

Occurs in Victoria, Tasmania and New South Wales.

Parmelia tasmanica is very common on rock in open situations.

Parmelia tenuirima Hook. and Tayl. 1844:645.

Thallus saxicolous rarely corticolous, loosely attached to the substrate, pale whitish-grey to mineral-grey, sometimes becoming pale brown in the centre of the thallus, up to 30 cm diam.; lobes up to 10 mm wide, strongly imbricate, secondary lobes building up the thallus into a thick mat, without cilia; upper surface dull, flat, heavily pseudocyphellate, but the pseudocyphellae never forming soredia, without isidia; lower surface jet black with a brown zone at the ends of the lobes. *Apothecia* up to 25 mm diam., sessile; disk rugulose, warm brown to dark brown, concave at first, becoming flat and undulating then distorted; margin thin, hardly revolute, crenulate, deeply incised and lacerate, sometimes right to the centre; ascospores 14-16 × 8-9 μm.

Reactions: Thallus K+ yellow, medulla K+ yellow becoming red to blackish-red, C−, KC−, P+ yellow becoming orange.

Figure: Habit, plate 13C (MEL 1021192).

Specimens examined: Near the summit of Mount Lofty, *R. W. Rogers 1838,* x.1969 (R.W.R.).

Occurs in Victoria, Tasmania, New South Wales and Queensland.

Parmelia tenuirima may be confused with two chemically similar species; it can be separated from *P. subcaperata* in the lack of marginal cilia and from *P. reticulata* by the lack of soredia.

Parmelia sp. *nov.* 6

Thallus terricolous, or lignicolous on small debris twigs, loosely attached to the substrate, pale yellow-green, in loose disjointed patches up to 5 cm diam., lobes elongate, revolute to convolute, up to 1·0 mm wide growing over and under one another, secondary lobes narrower, 0·3-0·5 mm wide over growing the other lobes; upper surface dull, smooth to slightly rugulose, convex, without soredia or isidia; lower surface pale to light brown. *Apothecia* up to 2 mm diam., adnate to the thallus; disk brown, smooth, concave; margin thick, crenulate; ascospores 8-10 x 6 μm.

Reactions: Thallus K−, medulla K+ yellow becoming red, C−, KC−, P+ yellow becoming orange.

Specimens examined: Near Owen, *J. B. Cleland,* 28.x.1966 (R.W.R.); Weary Paddock, "Quondong" Station, *R. W. Rogers 1291,* 1.xi.1967 (R.W.R.).

Known also from Victoria.

This species is part of the "callifolia group" differing from *P. callifolia* in the pale underside and from *P. subdistorta* in chemistry and the non-rosette forming habit.

Parmelia tinctina Maheu and Gillet 1925:860.

Thallus saxicolous, adnate to the substrate, yellow-green to yellow-blue-green, becoming blackish-green in the centre, up to 10 cm diam., lobes strongly imbricate, up to 3 mm wide, secondary lobes narrower overlaying the centre of the thallus, without soredia; isidia short, subglobose but occasionally cylindrical; upper surface smooth, shining, flat to slightly convex; lower surface jet black. *Apothecia* not seen.

Reactions: Thallus K−, medulla K+ yellow becoming red to blackish-red, C−, KC−, P+ yellow becoming orange.

Figure: Habit, fig. 23D.

Specimens examined: Memory Cove, Cape Catastrophe, Eyre Peninsula, *R. B. Filson 11831,* 24.x.1970 (MEL 1011800); by waterhole in Frome River, 6 km north of "Evans O.S.", 40 km east-south-east of Copley, *R. B. Filson 15610,* 19.xi.1975 (MEL 1014744); rocks just above high tide mark on The Bluff, Victor Harbor, *R. W. Rogers 1940,* 27.viii.1971 (R.W.R.).

Occurs also in Victoria.

Parmelia tinctina is morphologically similar to *P. mexicana* and *P. plittii* but differs from both of those species in having a black under surface.

Parmelia ustulata Kurokawa and Filson 1975:46.

Thallus saxicolous, moderately adnate to the substrate, yellow-green at the margins to blackish-green in the centre of the thallus, without soredia or isidia; lobes elongate, up to 4 mm wide, imbricate, flexuose; upper surface mainly dull but the marginal lobes are sometimes shining, smooth at the margins becoming cracked on the older lobes; lower surface pale brown, margins pale greyish-brown. *Apothecia* adnate, up to 10 mm diam.; disk dark brown to blackish-brown, concave; margin thick, crenulate, incised; ascospores 10 x 5-6 μm.

Reactions: Thallus K−, medulla K−, C−, KC−, P−.

Specimens examined: Memory Cove, Cape Catastrophe, Eyre Peninsula, *R. B. Filson 11834*, 24.x.1970 (MEL 1011807); on rocky hillside, "Olive Grove" Station, 14·5 km south of Quorn, *R. B. Filson 11997*, 30.x.1970 (MEL 1011734).

Known only from South Australia.

Parmelia ustulata may be confused with *P. flavescentireagens* as both are morphologically similar however it is more tightly appressed to the substrate and the marginal lobes are wider. *P. flavescentireagens* also has a positive reaction with C and KC on the medulla.

Parmelia verrucella Esslinger 1977:132.

Thallus saxicolous or terricolous, moderately to loosely adnate, up to 6 cm diam., yellowish-brown to dark-brown; lobes up to 2·5 mm wide, flat, imbricate or entangled; upper surface wrinkled in part, dull or slightly shining at the lobe ends, sometimes lightly pruinose, without soredia, isidia sometimes dense, cylindrical, simple or branched; lower surface black. *Apothecia* up to 2·0 mm diam.; disk concave to flattening: margin entire or sparsely isidiose; ascospores 8-9 x 5-6 μm.

Reactions: Medulla K−, C−, KC− or KC− faint rose, P−.

Specimens examined: Along road to "Artimore" (ruins) 2 km. from Narrina Creek, 20 km north-east of Blinman, *R. B. Filson 15571*, 17.xi.1975 (MEL 1014505).

Occurs also in Victoria.

Parmelia verrucella is very similar to *P. subverrucella* differing in the colour of the underside. It may be confused with *P. incantata* but the KC reaction of that species is usually more stronger.

Parmelia sp. *nov.* 7

Thallus terricolous, loose to lightly attached to the substrate; lobes elongate, irregularly branched 1·0-2·5 mm wide; upper surface plane to slightly convex, maculate, isidia and soredia absent; lower surface concolourous with the upper surface, plane to canaliculate, rhizines infrequent. *Apothecia* not seen.

Reactions: Thallus K−, medulla K+ faint gold, C−, KC−, P+ faint yellow becoming orange then red.

Specimens examined: Eyre Highway, 11 miles (18 km) east of Koonalda, Nullarbor Plain, *J. H. Willis*, 18.x.1961 (MEL 17651); vicinity of Koonalda Cave, Nullarbor Plain, *R. B. Filson 9420b*, 28.xii.1966 (MEL 1013686).

Occurs in Western Australia, Victoria and Tasmania.

60. PARMELIELLA Müll. Arg. 1862:376.

Thallus squamulose to subfoliose, attached to the substrate by a dark prothallus or rhizoids; upper surface corticate, mineral-grey; lower surface ecorticate. *Apothecia* laminal; disk reddish-brown to brown; margin prominent; ascospores eight in ascus, simple, hyaline; phycobiont *Nostoc*.

Figure: Ascospores, fig. 21D.

No records of this genus are known from South Australia but it is likely to be found amongst mosses on bark or earth in the wetter areas.

61. PELTIGERA Willd. 1787:347.

Literature: Kurokawa et. al. 1966, Thomson 1950.

Thallus foliose, large, more or less lobed, loosely attached to the substrate, differentiated into a well-developed cellular upper cortex, a distinct algal layer and a medullary layer, upper surface smooth, sometimes tomentose; lower surface ecorticate, more or less veined; rhizines fasciculate. *Apothecia* on the upper surface at the margins of the lobes; disk reddish-brown sometimes revolute; margin concolourous with the thallus; ascospores eight in ascus, hyaline to brown, fusiform to acicular, 3 to 8-celled.

Peltigera spuria (Ach.) DC. ex Lam. et DC. 1805:406.

Lichen spurius Ach. 1798:159.

Thallus brownish-grey, of scattered lobes each 0·5-1·5 cm wide, adnate to the substrate by long white rhizines; upper surface finely tomentose, occasionally with orbicular laminal soralia, non-isidiose; under surface very pale tan with slightly darker veins. *Apothecia* digitate.

Figure: Ascus containing spores and one free ascospore, fig. 21E.

Specimens examined: Mount Compass, *R. W. Rogers 1882*, 29.vii.1970 (R.W.R.); Meningie, *L. D. Williams 1938*, 6.viii.1964 (L.D.W.); Fairview Reserve, c. 35 km west Naracoorte, *T. Roach 18*, 10.v.1970 (AD).

Occurs also in Victoria.

Peltigera spuria is often found on compacted soil in wetter areas.

62. PELTULA Nyl. 1853:316.

Literature: Wetmore 1970.

Thallus areolate, squamulose, peltate or sub-fruticose, attached by a small group of rhizines or umbilicus. *Apothecia* immersed in thallus; disk usually open; ascospores many in ascus, hyaline, simple.

Figure: Ascospores, fig. 21F.

ARTIFICIAL KEY TO SPECIES

1. Thallus saxicolous 2
1. Thallus terricolous .... *P. australiensis*
  2. Thallus sorediose 3
  2. Thallus non sorediose .... *P. omphaliza*
3. Thallus squamulose, margins of squamules down-rolled, soredia blue-grey to brown .... *P. euploca*
3. Thallus areolate, margins of thallus placodiform, margins of areoles slightly raised, soredia brown to black .... *P. placodizans*

Peltula australiensis (Müll. Arg.) R. B. Filson

Heppia australiensis Müll. Arg. 1892:193.

Thallus squamulose, terricolous, up to 2·5 mm diam., deeply concave or flat; margins smooth, entire or lobed, usually thickened and upturned; upper surface rugulose, olive, sometimes appearing yellow-pruinose; lower surface covered with pale brown rhizinae which penetrate the substrate. *Apothecia* usually one per squamule (sometimes up to three), up to 1·5 mm diam., immersed; disk flat to convex, pale red to brown; margin sometimes prominent sometimes absent; ascospores numerous in asci, globose up to 5 µm diam.

Figure: Habit, fig. 22C.

Specimens examined: Arcoellinna well, Everard Ranges, *R. Helms 35*, 28.v.1891 (MEL 5780); by side of Everard road, 26 km west of Stuart Highway, *R. B. Filson 15641a*, 23.xi.1975 (MEL 1018606); Wilgena Hill, 6·5 km north of Kingoonya-Tarcoola road, 67 km west of Kingoonya, *R. B. Filson 11929a*, 26.x.1970 (MEL 1018619); Koonamore Vegetation Reserve, *R. W. Rogers 1725*, 4.viii.1969 (MEL 1011695).

Occurs in Victoria.

Peltula euploca (Ach.) Wetmore, 1970:184.

Lichen euplocus Ach. 1798:141.

Heppia euploca (Ach.) Vain. 1921:14.

Thallus saxicolous, squamulose, peltate, irregularly round, up to 10 mm diam.; margins smooth, entire, lobed or slightly lacerate, usually thickened and downturned, sorediose; upper surface olive to brown to almost black, smooth, rugulose, cracked in older specimens, sometimes with soredia along older cracks sometimes with soralia; soredia farinose, blue-grey to greenish-brown. *Apothecia* not seen.

Figure: Habit, fig. 18B.

Specimens examined: Murrawijinnie Cave No. 2, 6 miles (10 km) north of Eyre Highway, *D. S. Kemsley*, 7.i.1952 (MEL 1011697); rocky outcrop 100 m north of Ernabella road, 6 km west of "Kenmore Park", Musgrave Ranges, *R. B. Filson 15698*, 26.xi.1975 (MEL 1018604); Illbillie area, Everard Ranges, *A. C. Beauglehole 13579*, 24.vi.1965 (MEL 1018634); 3 km north of Kokatha on Poochera-Kingoonya road, *R. B. Filson 11911*, 26.x.1970 (MEL 1018621); Waukaringa mines near Koonamore road, *R. W. Rogers 1822*, 18.xii.1969 (MEL 1011686).

Occurs in Victoria, New South Wales and Northern Territory.

Peltula omphaliza (Nyl. in Eckf.) Wetmore, 1970:194.

Heppia omphaliza Nyl. in Eckf. 1889:106.

Thallus saxicolous, squamulose, peltate, irregularly round, up to 2 mm diam., flat to slightly convex; margins smooth, entire or slightly lobed; upper surface olive to pale brown with dark brown border, smooth, dull or occasionally slightly shining. *Apothecia* several per squamule, immersed, disk punctiform; ascospores ellipsoid, 3-6 μm diam.

Specimen examined: Big Rock, 8 km east of Teeta Bore, Everard Ranges, *R. B. Filson 15659*, 24.xi.1975 (MEL 1018612).

Peltula placodizans (Zahlbr.) Wetmore, 1970:196.

Heppia placodizans Zahlbr. 1908:299.

Thallus saxicolous, areolate, varying from small rosette up to 1 cm diam. to covering patches along cracks several centimetres long, margins lobate, placodiform; marginal lobes 0·2-0·5 mm wide, up to 1·5 mm long, flat to convex; central areoles irregularly round, up to 0·6 mm diam., flat, convex to hemispheric, margin smooth, incised, flexuose; upper surface olive, sometimes appearing pruinose, soredia dark brown to black in capitate soralia. *Apothecia* one per areole, immersed; disk up to 0·3 mm diam., flat, pale red; ascospores globose to subglobose 4-5 × 4-6 μm.

Specimen examined: Wynbring Rocks, 1·2 km north of Wynbring on East-West Railway Line, *R. B. Filson 11946*, 28.x.1970 (MEL 1018626).

Occurs in Victoria and in the Northern Territory.

63. PERTUSARIA DC. ex Lam. et DC. 1805:319.

Literature: Oshio 1968.

Thallus crustose, with or without an upper cortex; medulla of interwoven hyphae. *Apothecia* immersed in wart-like structures on the upper surface, opening through pores; ascospores one to eight in ascus, hyaline, ellipsoid, simple, usually large.

Figures: Habit, fig. 20B; ascospore, fig. 21G.

Pertusaria is a large genus and the South Australian material not reliably determined. The most useful characters in separating species are—the number of ascospores in the ascus; the number of layers in the wall of the ascospore; the presence or absence and degree of ornamentation in the ascospore walls; and colour reactions of the thallus with the chemical reagents. Gross thallus morphology is apparently very plastic.

64. PHAEOGRAPHINA Müll. Arg. 1882:398.

Literature: Wirth and Hale 1963.

Thallus crustose, epi- or endophloic, ecorticate or with a rudimentary cortex. *Apothecia* immersed to adnate or sessile, generally elongate, simple or sparingly branched, often contorted; disk narrow and slit-like; margin sometimes carbonaceous; ascospores one to three in ascus, brown, muriform; paraphyses unbranched.

Figure: Ascospore, fig. 21H.

At present this genus has not been recorded in South Australia but it is likely to occur on bark.

65. PHAEOGRAPHIS Müll. Arg. 1882:336.

Literature: Wirth and Hale 1963.

Thallus crustose, ecorticate or with a rudimentary cortex, epi- or endophloic. *Apothecia* immersed, adnate or sessile, generally elongate, simple or branched often contorted; disk narrow and slit-like; margin sometimes carbonaceous; asci clavate to oblong; ascospores one to eight in ascus, brown, one- to many-celled, with transverse septa; paraphyses unbranched.

Figure: Ascospore, fig. 21I.

There are no records of this genus for South Australia, but collections are likely to be made on wood or bark.

66. PHYSCIA (Schreb. in L.) Th.Fr. em Vain 1890a:138.

Lichen Secn *Physcia* Schreb. in L. 1791:768.

Literature: Thomson 1963.

Thallus foliose, mainly attached to the substrate by rhizines; lobes flat to convex, corticate, sometimes ciliate or fibrillose; upper cortex densely paraplectenchymatous; medulla plectenchymatous; lower cortex densely plectenchymatous or paraplectenchymatous. *Apothecia* lecanorine, laminal.

sessile or shortly stalked; margin concolourous with the thallus; disk brown or black, sometimes white or red pruinose; ascospores eight in ascus, brown two-celled. *Pycnidiospores* 2-3 μm long, straight.

ARTIFICIAL KEY TO SPECIES

1. Lobes with long ascending marginal cilia 2
1. Lobes without marginal cilia 3
2. Ends of the lobes inflated, open underneath, open parts thus exposed sorediose . . . . *P. adscendens*
2. Ends of the lobes not inflated, soredia in terminal soralia . . . . . *P. tenella*
3. Thallus without soredia 4
3. Thallus sorediose 6
4. Thallus maculose on the upper surface . . . . *P. aipolia*
4. Thallus emaculose, upper surface uniformly coloured 5
5. Medulla K+ yellow . . . . *P. alba*
5. Medulla K− . . . . *P. stellaris*
6. Soredia laminal, capitate 7
6. Soredia marginal 8
7. Thallus maculose, lobes cartilaginous . . . . *P. caesia*
7. Thallus emaculose, lobes soft . . . . *P. tribacoides*
8. Medulla K+ yellow or yellow becoming red 9
8. Medulla K− . . . . *P. tribacia*
9. Medulla P+ yellow . . . . *Anaptychia sp.*
9. Medulla P− . . . . *P. albicans*

Physcia adscendens (Fr.) Oliv. em Bitt. 1901b:431.

Parmelia stellaris var. *adscendens* Fr. 1846:105.

Thallus pale to dark grey, forming isolated rosettes, sometimes coalescing; lobes long and narrow, up to 1 mm wide, inflated to globose at the ends with long marginal cilia; loosely attached to the substrate by rhizines; lower surface white, sorediose under open inflated ends. *Apothecia* not seen.

Reactions: Thallus K+ yellow, medulla K−, P−

Specimens examined: Seppeltsfield, *R. D. Seppelt*, 25.v.1969 (R.W.R.); Mount Lofty, *R. W. Rogers 1836*, 28.viii.1970 (R.W.R.); "between Coorong and sea", south of Meningie, *A. C. Beauglehole 15089*, 2.x.1965 (MEL 23023).

Recorded for Victoria, Tasmania, New South Wales and Queensland.

Physcia adscendens is rarely fertile; it occurs on bark and rarely on rock in the wetter parts of the state.

Physcia aipolia (Ehrh. in Humb.) Hampe in Fürnr. 1838:249.

Lichen aipolius Ehrh. in Humb. 1793:19.

Thallus blue-grey to whitish-grey, maculate, forming rosettes, adnate to the substrate; lobes up to 1·5 mm wide, soredia and isidia absent; lower surface pale brown. *Apothecia* sessile up to 1·7 mm diam.; disk black, often heavily pruinose; margin prominent, concolourous with the thallus; ascospores 27-31 x 12-14 µm, two-celled, brown.

Reactions: Thallus K+ yellow, medulla K+ yellow, P−.

Figure: Habit, fig. 22D; ascospores, pycnidiospores, fig. 25A.

Specimens examined: "Colona" Station, Yalata Aboriginal Reserve, *J. H. Willis*, 27.viii.1947 (MEL 26324); Spur to south-west of Mount Arden, Southern Flinders Ranges, *John Curtis 1a*, 23.iv.1967 (MEL 26293); Seppeltsfield, *R. F. Seppelt*, 1.vi.1969 (R.W.R.); Comaum Forest Headquarters, *K. Alcoc*, 26.viii.1973 (MEL 1012141).

Grows in Victoria, Tasmania, New South Wales and Queensland.

This is a widespread but apparently uncommon species found growing on bark.

Physcia alba (Fée) Müll. Arg. 1887:136.

Parmelia alba Fée 1824:125.

Thallus pale bluish-grey, forming distinct rosettes up to 12 cm diam., close adnate to the substrate; lobes up to 3 mm wide, soredia and isidia absent; lower surface pale. *Apothecia* sessile; disk black, usually pruinose; margin prominent.

Reactions: Thallus K+ yellow, P+ yellow, medulla K+ yellow, P+ yellow.

Figure: Habit, fig. 24B.

Specimens examined: Iron Knob, *R. W. Rogers 555*, 1.x.1966 (R.W.R.); Hamley Bridge, *R. W. Rogers 1325*, 18.xi.1967 (R.W.R.); Kuitpo Forest, *R. W. Rogers 1444*, 29.vii.1968 (R.W.R.); Salt Creek, *G. C. Bratt 67/130a*, 30.ix.1967 (R.W.R.); Naracoorte, *D. Hunt*, 1962 (AD).

Occurs in Victoria.

This species is widespread and common on bark.

Physcia albicans (Pers.) Thoms. 1963:88.

Parmelia albicans Pers. 1811:17.

Thallus bluish-grey to olive, forming distinct rosettes several centimetres across, closely attached to the substrate; lobes up to 4 mm wide, contiguous, margins more or less ascending; soralia labriform; lower surface pale becoming dark towards the centre. *Apothecia* rare.

Reactions: Thallus K+ yellow becoming red, P−, medulla K+ yellow becoming red, P−.

Figure: Habit, fig. 24A.

Specimen examined: Middleback Station, *R. W. Rogers 1807*, 5.xi.1969 (R.W.R.); Koonamore Vegetation Reserve, *R. W. Rogers 1784*, 20.xi.1967

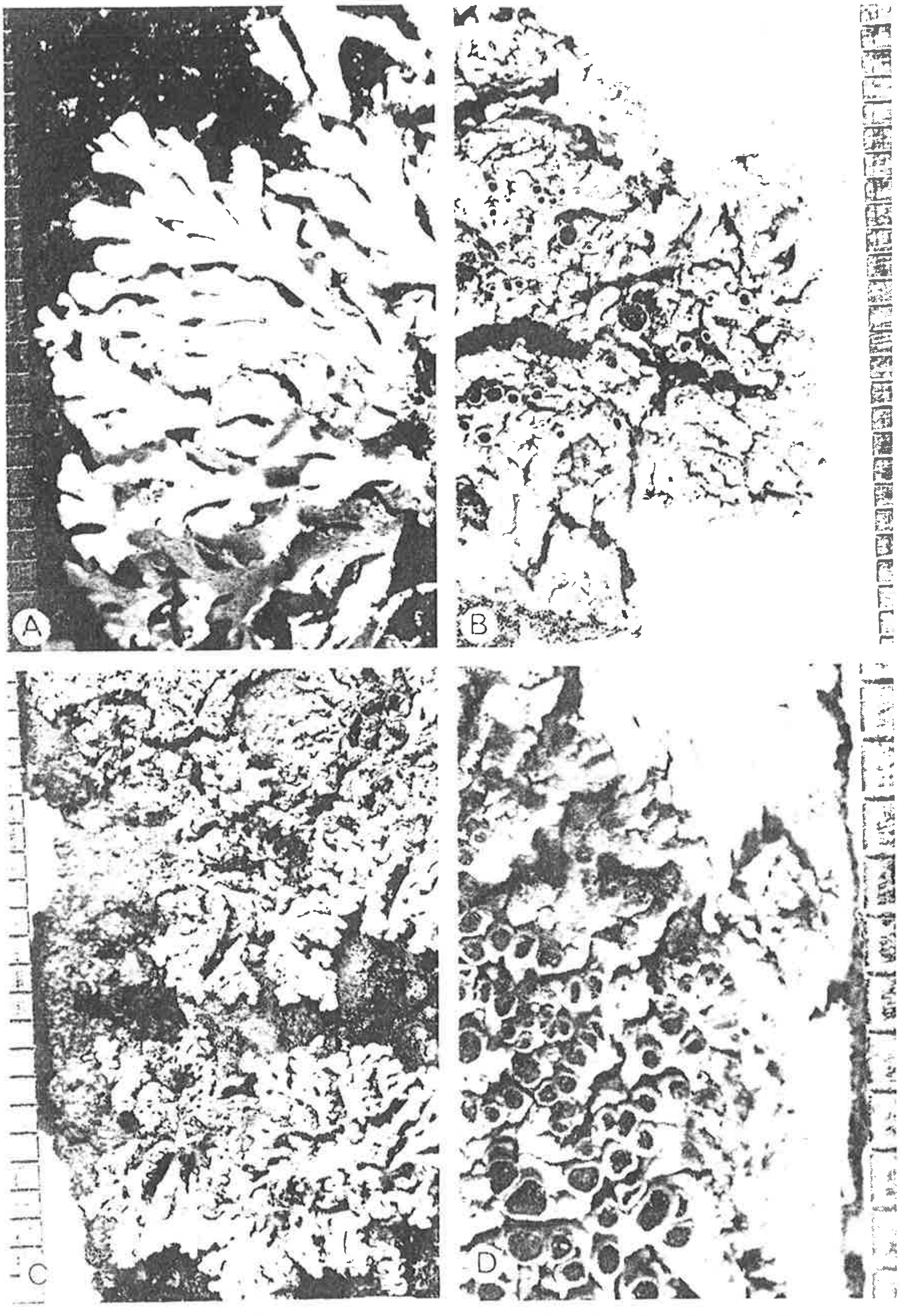

Fig. 24. A, *Physcia albicans*; B, *Physcia alba*; C, *Physcia tribacea*; D, *Physciopsis syncolla*. Scale in millimetres.

(R.W.R.); City of Adelaide, *R. W. Rogers 1422*, 29.vi.1968 (R.W.R.); Victor Harbor, *R. W. Rogers 1883*, 28.vii.1970 (R.W.R.).

Also in Victoria, New South Wales and Queensland.

A widespread and common species occurring on bark and occasionally on rock.

Physcia caesia (Hoffm.) Hampe in Fürnr. 1839:250.

Lichen caesius Hoffm. 1784:65.

Thallus blue-grey or grey, forming small rosettes up to 2 cm diam., sometimes coalescing; lobes appressed, 0·5-1·0 mm wide, maculate on the ends, without isidia; soralia laminal, capitate; soredia coarsely granular; lower surface pale to brown. *Apothecia* rare.

Reactions: Thallus K+ yellow, P+ slowly yellow, medulla K+ yellow, P+ yellow.

Specimens examined: Chilpitty Rock, near Minnipa, *Purdie*, 29.ix.1969 (R.W.R.); Mount Whyalla, *R. W. Rogers 1805*, 5.xi. 1969 (R.W.R.); Keith, *R. L. Specht*, 18.ii.1972 (R.W.R.); Victor Harbor, *R. W. Rogers 1885*, 28.viii.197 (R.W.R.)

Grows in Victoria and Tasmania.

A rarely collected species growing on granitic rocks. It is likely that the South Australian populations of this species constitute a chemical race as Thomson (1963:75) obtained a negative reaction of Pd on the medulla.

Physcia stellaris (L.) Nyl. 1856:307.

Lichen stellaris L. 1753:1144.

Thallus bluish-grey or greyish-white, forming patches up to 4 cm across, sometimes coalescing, not closely appressed to the substrate; lobes up to 1·5 mm wide, soredia and isidia absent; lower surface pale. *Apothecia* up to 1·5 mm diam.; disk reddish-brown becoming black at maturity, sometimes heavily pruinose; margin prominent, persistent, concolourous with the thallus; ascospores 21-22 × 9-13 μm, at first grey becoming brown.

Reactions: Thallus K+ yellow, P−, medulla K−, P+ yellow-brown.

Figure: Ascus containing spores and two free ascospores, fig. 25B.

Specimens examined: Everard Ranges, *R. Helms 59*, 31.v.1891 (MEL 6332); Lock, *N. N. Donner 2363*, (AD); Koonamore Vegetation Reserve, *R. W. Rogers 1322*, 20.xi.1967 (R.W.R.)

Physcia stellaris is restricted to bark and not often collected. South Australian representatives have been from dry habitats, unlike the distribution in North America and Europe. It is morphologically similar to *P. alba*, and may have been overlooked in the wetter parts of the state.

Physcia tenella (Scop.) DC. em Bitt. 1901b:431.

Lichen tenellus Scop. 1772:394.

Thallus bluish-grey forming small rosettes; lobes up to 1 mm wide with long marginal cilia, soralia labriform, terminal on the ends of the lobes; lower surface white. *Apothecia* rare.

Reactions: Thallus K+ yellow, P− yellow, medulla K−, P−.

Specimen examined: Belair National Park, *R.D. Seppelt,* 5.vii.1970 (R.W.R.).

Occurs also in Victoria.

A rare species which Thomson (1963:39) suggests may only be a sporadic variant of *P. adscendens.* It differs only in the form of the soralia, which are labriform and terminal. The lobe ends are reflexed, rather than inflated and globose.

Physcia tribacia (Ach.) Nyl. 1874:307.

Lecanora tribacia Ach. 1810:415.

Thallus pale grey to lead-grey, forming rosettes up to 2 cm across, loosely attached to the substrate; lobes up to 1 mm wide, tips broadening, fan-shaped; margins becoming sorediose; lower surface pale. *Apothecia* not known.

Reactions: Thallus K+ yellow, P−, medulla K−, P−.

Figure: Habit, fig. 24C.

Specimen examined: Mount Whyalla, *R.W. Rogers 1806,* 5.xi.1969 (R.W.R.).

The only South Australian collection examined by the authors was collected on rock. According to Thomson, the medulla of *P. tribacia* is K−, however he believes that this material is best referred to this species.

Physcia tribacoides Nyl. 1869a:322.

Thallus light grey, forming scattered groups of lobes or small rosettes, closely appressed to the substrate; lobes broadening to the tips, up to 2·5 mm wide, with laminal, capitate soralia; lower surface pale. *Apothecia* not seen.

Reactions: Thallus K+ yellow, P−, medulla K+ yellow, P−.

Specimen examined: City of Adelaide , *R. D. Seppelt,* 25.vi.1970 (R.W.R.).

Apparently a rare species in South Australia; only one collection has been cited and this from the bark of an elm tree in the centre of the city.

67. PHYSCIOPSIS Choisy 1950:20.

Literature: Poelt 1965b.

Thallus foliose, closely appressed to the substrate; lobes flattened, corticate, layered; upper cortex densely paraplectenchymatous; medulla plectenchymatous; lower surface densely plectenchymatous or paraplectenchymatous.

Apothecia laminal, sessile or shortly stalked; disk brown or black; margin prominent, concolourous with the thallus; ascospores eight in ascus, brown, two-celled. *Pycnidiospores* 10-15 μm long.

ARTIFICIAL KEY TO SPECIES

1. Thallus esorediose, lobes 1 mm wide .... *P. syncolla*
1. Thallus sorediose, lobes 0·2-0·5 mm wide .... *P. elaeina*

Physciopsis elaeina (Sm. in Sm. and Sow.) Poelt 1965b:30.

Lichen elaeinus Sm. in Sm. and Sow. 1810:2158.

Physcia elaeina (Sm.) A.L.Sm. 1918:244.

Thallus dull grey-green to grey-brown, of isolated lobes or forming extensive patches many centimetres across, closely attached to the substrate; lobes 0·2-0·5 mm wide with laminal soralia, non-isidiose; under surface pale around the margins, darkening towards the centre. *Apothecia* small, 0·5-0·8 mm diam., disk dark brown to black, concave; margin thick prominent, strongly inrolled; ascospores 16-22 x 6-12 μm grey at first becoming brown, thick walled, two-celled.

Reactions: Thallus K−, medulla K−, P−.

Figure: Ascospores, pycnidiospores, fig. 21J.

Specimens examined: Burnside, *R.W. Rogers 1826*, 3.i.1970 (R.W.R.); Victor Harbor, *R.W. Rogers 1858*, 15.i.1970 (R.W.R.).

Probably occurs in all States.

This is an obscure species merging with the bark of trees, and therefore it is not often collected.

Physciopsis syncolla (Tuck.) Poelt 1965b:30.

Physcia syncolla Tuck. *in* Nyl. 1858:428.

Thallus brown, often forming extensive patches, closely attached to the substrate; lobes closely contiguous, up to 1 mm wide, without soredia or isidia; under surface dark. *Apothecia* up to 1·5 mm diam.; disk concave at first becoming strongly convex, matt, dark brown to black, sometimes pruinose; ascospores grey at first becoming brown at maturity, thick walled, two-celled, 12-21 x 6-7 μm.

Reactions: Thallus K−, medulla K−, P−.

Figure: Habit, fig. 24D.

Specimens examined; 6 km west of "Kenmore Park" H.S., Musgrave Ranges, *R. B. Filson 15686*, 26.xi.1975 (MEL 1018663); Everard Ranges, *R. Helms*, 28.v.1891 (AD); Oodla Wirra, *R.W. Rogers 1744*, 18.vi.1969 (R.W.R.); Koonamore Vegetation Reserve, *R.W. Rogers 1639*, 19.iv.1969 (R.W.R.).

This species has not often been collected. All South Australian gatherings have been from bark in the dry areas.

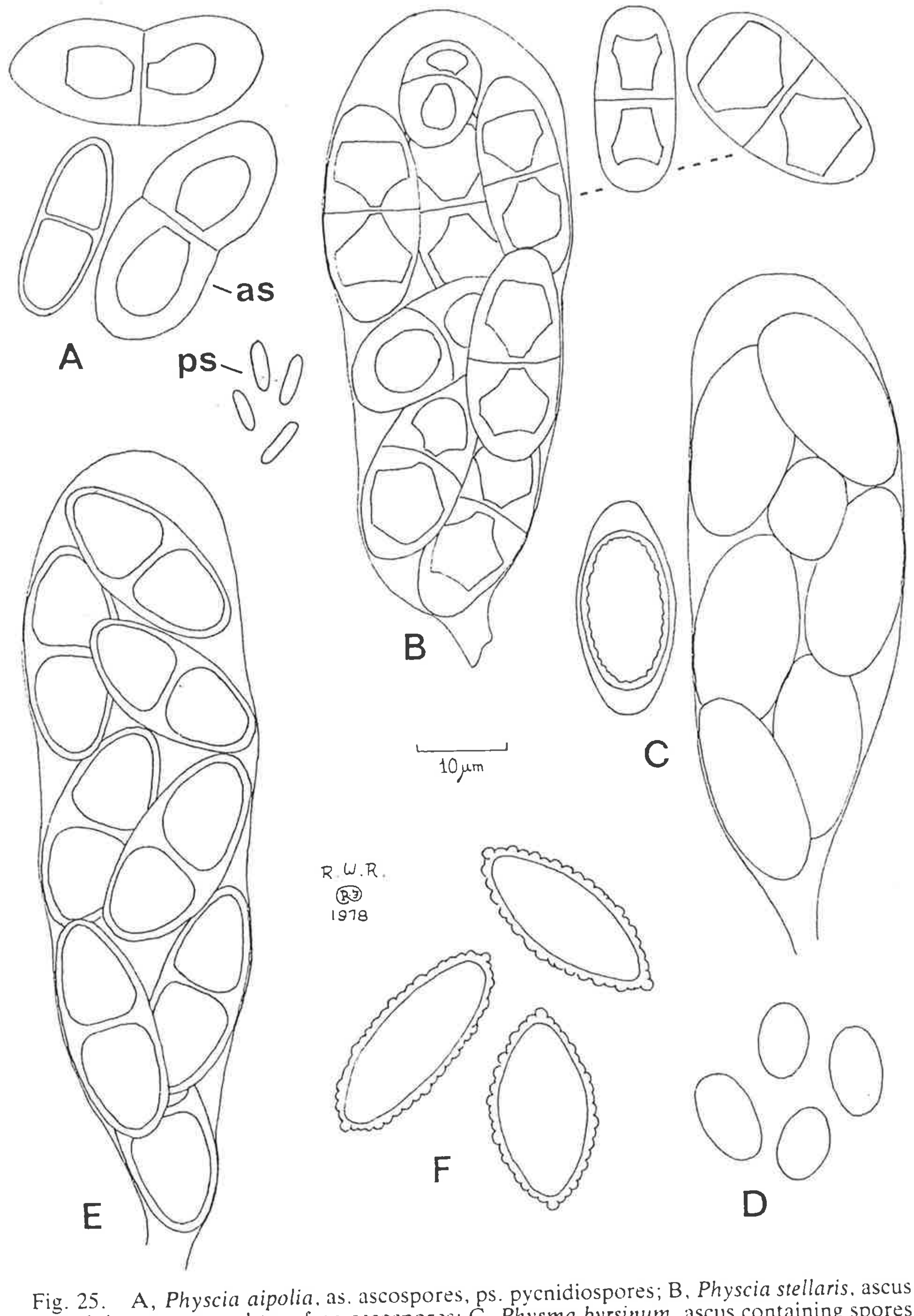

Fig. 25. A, *Physcia aipolia*, as. ascospores, ps. pycnidiospores; B, *Physcia stellaris*, ascus containing spores and two free ascospores; C, *Physma byrsinum*, ascus containing spores and one free ascospore; D, *Porocyphus lichinelloides*, ascospores; E, *Pseudocyphellaria australiensis*, ascus containing spores; F, *Psoroma sphinctrinum*, ascospores.

68. PHYSMA Mass. 1854:6.

Thallus foliose, over a spongy hypothallus, ecorticate, algae scattered in the medulla, hyphae lax. *Apothecia* sessile; disk reddish-brown to black, lecanorine; margin prominent; ascospores eight in ascus, simple, hyaline, ellipsoid.

Physma byrsinum (Ach.) Müll. Arg. 1885:531.

Parmelia byrsina Ach. 1803:222.

Thallus olive, forming patches up to 8 cm across, adnate to the substrate; lobes discrete, radiating, up to 4 mm wide; lower surface spongy, black. *Apothecia* common up to 5 mm diam., disk deeply concave, reddish-brown.

Figure: Ascus containing spores and one free ascospore, fig. 25C.

Occurs in Queensland, New South Wales and Victoria.

Not known from South Australia but likely to occur on the bark of trees (especially *Callitris* sp.) throughout the State.

69. POLYBLASTIOPSIS Zahlbr. 1903:67.

Thallus crustose, ecorticate, endo- or epi-phloic. *Pseudothecia* perithecium-like, sessile to more or less immersed in the thallus; ascospores eight in ascus, hyaline, muriform; paraphyses reticulately branched and anastomosing.

No records of this genus are known from South Australia, but collections are likely to be made on bark.

70. POROCYPHUS Körb. 1855:425.

Literature: Henssen 1963.

Thallus crustose, granulose or minutely fruticose, devoid of differentiation. *Apothecia* terminal, minute, immersed or sessile; disk concave, closed or open; margin indistinct, concolourous with the disk, surrounded by a thicker, irregular thalloid margin; ascospores 8-16 in ascus, simple, hyaline.

Porocyphus lichinelloides A. Henssen 1963:68.

Thallus fruticose, pulvinate, dark olive-green to black, of narrow terete upright branched filaments, less than 0·1 mm diam., up to 3 mm tall. *Apothecia* terminal, up to 0·2 mm diam.; disk concave red-brown; ascospores eight in ascus, hyaline, ellipsoidal, 8-10 × 5·5-6 µm.

Figure: Ascospores, fig. 25D.

No specimens from South Australia have been positively referred to this genus, however it has been recorded on granite outcrops in the dry areas of both Victoria and Western Australia.

71. PSEUDOCYPHELLARIA Wainio 1890a:182.

Literature: Magnusson 1940.

Thallus foliose, loosely attached to the substrate, smooth to rugulose, differentiated into a thick, well developed plechtenchymatous upper cortex, distinct algal layer, loosely woven medullary layer and a well developed lower cortex broken by pseudocyphellae. *Apothecia* lecanorine, adnate to substipitate, marginal or laminal; disk concave to convex; ascospores eight in ascus, hyaline to brown, oblong, ovoid to fusiform, two- to four- celled.

ARTIFICIAL KEY TO SPECIES

1. Lobes with small, flattened isidia or lobules, often broken off giving the appearance of soredia .... *P. australiensis*
1. Lobes with marginal and laminal soredia .... *P. crocata*

Pseudocyphellaria australiensis Magn. 1940:9.

Thallus pale to dark brown, up to 12 cm diam., or forming an extensive mat, loosely attached to the substrate; lobes 1·0-4·0 cm wide; upper surface densely ridged, without soredia; margins densely isidiose and lobulate; isidia often broken at the apex and appearing sorediose; lower surface pale to dark brown, densely tomentose with yellow pseudocyphellae; medulla deep yellow. *Apothecia* up to 2·0 mm diam., ascospores eight in ascus, 23-29 × 9-12 μm, two-celled, brown.

Figures: Habit, plate 14A (MEL 1022007) and fig. 26A; ascus containing ascospores, fig. 25E.

Specimens examined: Angaston, *R. W. Rogers 1346,* 31.xii.1967 (R.W.R.); Sellicks Hill, 50 km south of Adelaide, *R. B. Filson 15497,* 14.xi.1975 (MEL 1018656); Belair, *H. B. S. Womersley,* 27.vi.1943 (ADU); Kuitpo, *V. Cruikshank,* 20.v.1967 (R.W.R.); Hindmarsh Falls, *R. W. Rogers 1054,* 30.iv.1967 (R.W.R.).

Known also from Victoria, New South Wales and Tasmania.

This species is common over rocks in the wetter parts of the State where it favours exposed sunny positions.

Pseudocyphellaria crocata (L.) Wainio 1898:36.

Lichen crocatus L. 1791:310.

Thallus brown, loosely attached to the substrate, forming rosettes 5·0-7·0 cm diam.; lobes 0·5-1·5 cm wide, densely reticulately ridged; ridges often with warts which burst into yellow soredia; lower surface dark, densely tomentose with yellow pseudocyphellae; medulla grey or pale yellow. *Apothecia* rare 1·5-2·5 mm diam.

Specimen examined: Angaston, *R. W. Rogers 1350,* 31.vii.1967 (R.W.R.).

Reported from Victoria.

This species has been found only once on the bark of a eucalypt, but it is likely to occur on rock and bark throughout the wetter parts of the State.

72. PSOROMA Nyl. 1855b:175.

Thallus squamulose to foliose with a well differentiated cellular cortex, indistinct algal and medullary layers, thin lower cortex of interwoven hyphae with few rhizoids. *Apothecia* lecanorine, adnate to sessile; disk concave to flat, red or brownish-red; ascospores eight in ascus, hyaline, ellipsoid to spherical, simple.

Figure: Psoroma sphinctrinum, habit, fig. 26B: ascospores, fig. 25F.

P. crawfordii Müll. Arg. is the only species that has been recorded for South Australia. Although the precise locality is not known it is likely to be in the Mount Lofty Ranges or the South-East of the State. Another species, *P. sphinctrinum* (Mont.) Nyl., although not recorded is also likely to be found in these areas.

73. PYRENOPSIDIUM Forss. 1885:39, and 59.

Thallus crustose, granular to warty, continuous or areolate attached to the substrate by hyphae. *Apothecia* lecanorine, the margin almost closing the narrow disk; asci oblong to almost globose; ascospores eight in ascus, hyaline, simple; paraphyses distinct and unbranched. Phycobiont *Chroococcus*.

There is no definite record of this genus being collected in South Australia.

Pyrenopsidium decorticans Müll. Arg. 1892:191 is possibly a species of *Peltula*.

74. RAMALEA Nyl. 1866c:289.

Thallus of yellowish-brown granules or squamules, often densely packed, forming extensive patches; squamules 1·0-2·0 mm wide; podetia up to 10 mm tall, arising from basal squamules. *Apothecia* terminal; ascospores eight in ascus, hyaline, simple.

Ramalea cochleata Müll. Arg. 1896:89.

Primary thallus greyish-brown to olive-green, granular or squamulos squamules 1·0-2·0 mm diam.; podetia up to 15 mm tall but usually short granular often twisted and distorted, expanding towards the top. *Apothec* terminal, clustered; ascospores eight in ascus, hyaline, simple, sometim appearing two-celled, 9 x 4 μm.

This species may be confused with *Thysanothecium* but is easily distinguished by the subfoliose primary thallus and the clustered apothecia terminal on the podetium. It is not yet known in South Australia though it has been found on the acid soils in heathlands in Victoria and Western Australia.

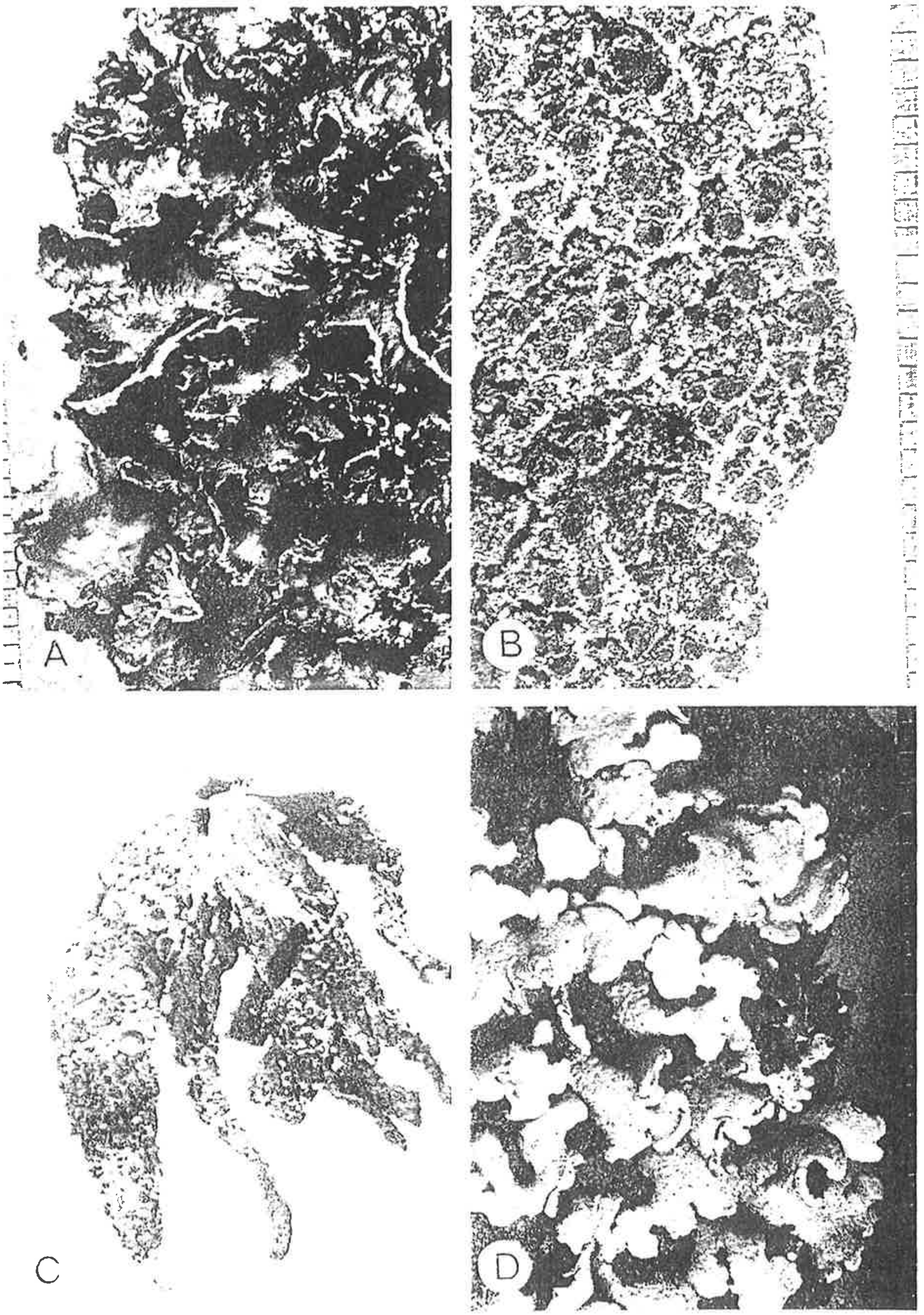

Fig. 26. A, *Pseudocyphellaria australiensis*; B, *Psoroma sphinctrinum*; C, *Ramalina ecklonii*; D, *Siphula coriacea*. Scale in millimetres.

75. RAMALINA Ach. 1810:122.

Thallus fruticose, erect or pendulous; lobes flattened and strap-like or hollow and inflated, differentiated into a cortical layer of closely interwoven longitudinal hyphae, an algal layer and a medulla of loosely interwoven hyphae. *Apothecia* laminal, lateral or terminal, sessile or pedicellate; disk concave to convex, buff or greenish-yellow; margin concolourous with the thallus usually prominent; ascospores eight in ascus, hyaline, oblong-ellipsoid, two-celled.

This genus is poorly understood, and the Australian entities are in need of investigation.

ARTIFICIAL KEY TO SPECIES

1. Thallus inflated and fistulate or hollow, usually less than 2 cm tall 2
1. Thallus flat and leaf-like, neither fistulate nor hollow, usually several centimetres long 3
    2. Thallus fistulous, horny in texture, of stout construction .... *R. pusilla*
    2. Thallus hollow, with small or larger openings into the hollow lobes, of a light, tissue-paper like construction .... *R. geniculata*
3. With numerous laminal apothecia, few lobes per thallus, little branched .... *R. ecklonii*
3. With few terminal apothecia, many lobes forming a shrubby thallus, lobes much branched .... *R. fastigiata*

Ramalina ecklonii (Spreng.) Meyen et Flotow 1843:213.

Parmelia ecklonii Spreng. 1827:328.

Thallus greenish-yellow, forming a tuft of erect or pendulous lobes, up to 8 cm long, attached to the substrate by a small holdfast; lobes longitudinally striate, up to 1 cm wide, isidia and soredia absent. *Apothecia* common, laminal, 2·0-3·0 mm diam.; disk yellow-green; margin prominent sometimes disappearing; ascospores hyaline, slightly curved or straight, two-celled, 13-15 6·0-6·5 μm.

Reactions: Medulla K−, C−, KC−, P−.

Figure: Habit, fig. 26C; ascospores, fig. 27A.

Specimens examined: Cape Jervis, *R. W. Rogers 1458*, 1.ix.1968 (R.W.R.); Hope Valley, *R. W. Rogers 1572*, 11.xi.1968 (R.W.R.); Seppeltsfield, *R. D. Seppelt*, 1.vi.1969 (R.W.R.) Oodla Wirra, *R. W. Rogers 1623*, 27.ii.1969 (R.W.R.).

Reported from all States except the Northern Territory.

Ramalina ecklonii is a very variable and widespread species found on twigs and bark.

Ramalina fastigiata (Pers.) Ach. 1810:603.

Lichen fastigiatus Pers. 1794:156.

Thallus thin somewhat translucent, greenish-yellow, forming an erect shrubby clump up to 4 cm high, attached to the substrate by a small basal holdfast; lobes

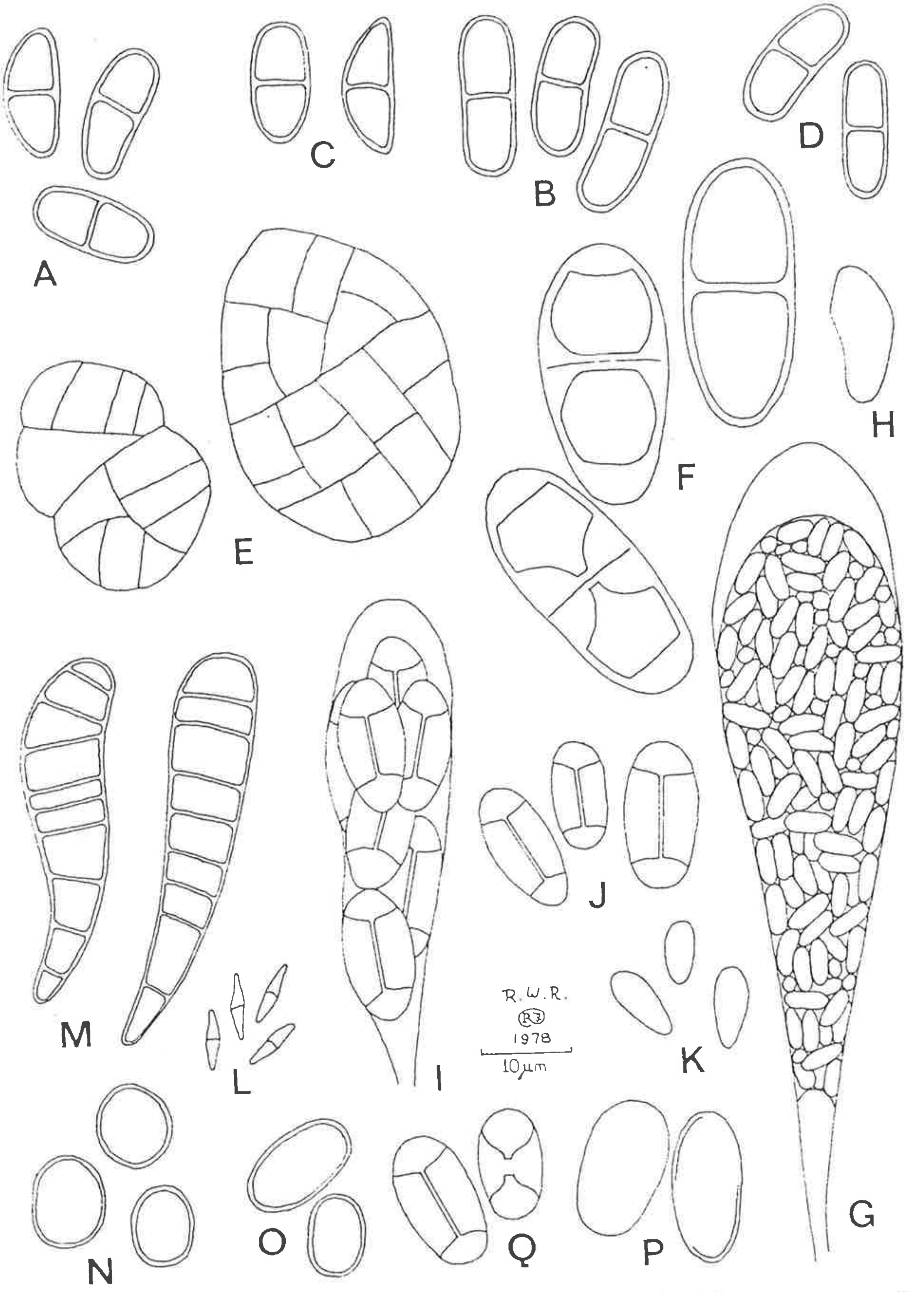

Fig. 27. A, *Ramalina ecklonii*, ascospores; B, *Ramalina fastigiata*, ascospores; C, *Ramalina geniculata*, ascospores; D, *Ramalina pusilla*, ascospores; E, *Rhizocarpon tinei*, ascospores; F, *Rinodina australiensis*, ascospores; G, *Sarcogyne pruinosa*, ascus containing spores; H, *Synalissa symphorea*, ascospore; I, *Teloschistes chrysophthalmus*, ascus containing spores; J, *Teloschistes velifer*, ascospores; K, *Thysanothecium hyalinum*, ascospores; L, *Toninia caeruleonigricans*, ascospores; M, *Trypethelium eluteriae*, ascospores; N, *Usnea ramulosissima*, ascospores; O, *Usnea scabrida*, ascospores; P, *Verrucaria microsporoides*, ascospores; Q, *Xanthoria ectanea*, ascospores.

up to 1 cm wide, longitudinally striate, isidia and soredia absent. *Apothecia* terminal or sub-terminal, up to 3 mm diam.; disk concave becoming flat; margin prominent; ascospores hyaline, slightly curved or straight, two-celled, long ellipsoid, 15-19 × 6·0-6·5 µm.

Reactions: Medulla K−, C−, KC−, P−.

Figure: Habit, fig. 20C; ascospores, fig. 27B.

Specimens examined: Point Drummond, *R. B. Filson 11878*, 25.x.1970 (MEL 1018640); Cape Jervis, *R. W. Rogers 1456*, 1.ix.1968 (R.W.R.); Millbrook, *R. W. Rogers 1780*, 20.ix.1969 (R.W.R.); Kuitpo, *R. W. Rogers 1442*, 29.vii.1968 (R.W.R.); Murray Bridge, *R. W. Rogers 392*, 11.v.1966 (R.W.R.); Penola, *K. Alcock*, 25.vii.1972 (R.W.R.).

Reported also from Tasmania.

This species is common on bark in the wetter areas. It is likely that a number of different taxa key out to this species. *Ramalina sinensis* is a similar species but it tends to have broader lobes. Chemical variation is also likely to occur.

Ramalina geniculata Hook.f. & Tayl. 1844:655.

Thallus of a light, papery texture, greenish-yellow, forming a small erect shrubby clump, up to 2 cm tall, attached to the substrate by a small basal holdfast; lobes inflated to the tips, with distinct openings to the central cavity, isidia and soredia absent. *Apothecia* subterminal, up to 4·0 mm diam.; disk concave, becoming plain, smooth at first becoming rugulose; margin prominent disappearing at maturity; ascospores hyaline, long ellipsoidal, two-celled, straight, 13-15 × 6·0-6·5 µm.

Reactions: Medulla K−, C−, KC−, P−.

Figure: Ascospores, fig. 27C.

Specimens examined: Gum Flat, 25 miles (40 km) north-west of Elliston, *R. B. Filson 11887*, 25.x.1970 (MEL 1018639); Memory Cove, Cape Catastrophe, *R. B. Filson 11841*, 24.x.1970 (MEL 1018638); Kuitpo, *R. W. Rogers 1443*, 29.vii.1968 (R.W.R.); Kersbrook, *V. M. Cruikshank*, 10.iv.1966 (R.W.R.).

Occurs in Queensland, New South Wales, Victoria and Tasmania.

Ramalina pusilla le Prev. in Duby 1830:614.

Thallus greenish-yellow, forming a small erect, shrubby clump up to 2 cm tall, attached to the substrate by a small basal holdfast; lobes inflated, sometimes appearing globose, longitudinally fistulate, soredia and isidia absent. *Apothecia* terminal, 1-2 mm diam.; disk concave; margin prominent smooth; ascospores hyaline, straight or curved, two-celled, 14-15 × 5·0-6·5 µm.

Reactions: Medulla K−, C−, KC−, P−.

Figure: Habit, fig. 20D; ascospores, fig. 27D.

Specimens examined: Iron Knob, *R. W. Rogers 556*, 1.x.1966 (R.W.R.); Minlaton, *R. W. Rogers 1898*, 2.i.1971 (R.W.R.); Cudlee Creek, *R. W. Rogers 1419*, 10.vi.1968 (R.W.R.); Oodla Wirra, *R. W. Rogers 1622*, 27.ii.1969 (R.W.R.); Bagdad near Millicent, *R. D. Seppelt*, 1971 (R.W.R.).

Ramalina pusilla grows on dead wood and fine twigs. It is a very common and widespread species in Victoria and South Australia.

76. RHIZOCARPON Lam. apud Lam. & DC. 1805:365.

Literature: Runemark 1956.

Thallus crustose to squamulose, areolate, not well differentiated. *Apothecia* lecideine, immersed to sessile; disk flat to convex, black; margin concolourous with the disk, disappearing; ascospores eight in ascus, hyaline or brown, transversely septate or muriform.

Rhizocarpon tinei (Tornab.) Runemark 1956:118.

Lecidea tinei Tornab. 1848:17.

Thallus crustose forming bright yellow patches; hypothallus distinct, bordering the thallus and showing between the areolae. *Apothecia* small, numerous, immersed to adnate; ascospores eight in ascus, at first grey becoming dark brown, muriform, 20-40 × 10-22 μm.

Figure: Habit, plate 14C (MEL 1021196); ascospores, fig 27E.

Specimen examined: Angaston, *R. W. Rogers 1359*, 31.xii.1967 (R.W.R.).

This lichen forms large brilliant yellow patches over exposed rocks throughout the Mount Lofty Ranges and in Victoria. There are a number of grey and greyish-brown crustose lichens found on rocks which also belong in this genus, but the taxonomy is very confused and the species occurring in South Australia lack reliable determination.

77. RINODINA (Ach.) S. F. Gray 1821:448.

Literature: Sheard 1967.

Thallus crustose, granulose to areolate or squamulose, with a poorly developed cortex and more or less differentiated algal and medullary layers. *Apothecia* lecanorine, immersed, adnate to sessile; disk flat to convex, brown to black, sometimes pruinose; margin usually raised, concolourous with the thallus; ascospores eight (rarely 16-24) in ascus, brown, two-celled.

Figure: Rinodina australiensis, ascospores, fig. 27F.

There are no collections of *Rinodina* known from South Australia however Victorian records indicate that *R. pachyspora* Müll. Arg. is likely to be found on rocks, and *R. australiensis* Müll. Arg. on bark. Both of these species are small, forming patches 1-2 cm across, with small black apothecia.

78. SARCOGYNE Flot. 1851:753 and 759.

Thallus crustose, weakly developed or disappearing, ecorticate, or with a rudimentary cortex. *Apothecia* circular, adnate to sessile or shortly stipitate; margin concolourous with the disk; ascospores many in ascus, hyaline simple; paraphyses simple.

Figure: Ascus containing ascospores, fig. 27G.

Specimens referable to this genus have been collected from arid soils in north-western Victoria and in Western Australia. It is also likely to occur in South Australia in similar situations.

79. SIPHULA Fr. 1825:238.

Thallus fruticose, sparingly branched; cortex of closely packed, longitudinally extending hyphae; medulla loosely packed. *Apothecia* unknown.

Siphula coriacea Tayl. ex Nyl. 1860:263.

Thallus fruticose, forming rosettes up to 5·0 cm diam.; lobes mineral grey to pale bluish-grey at the tips, fan-shaped, up to 10 mm tall and 2·0-3·0 mm wide above the soil surface, cylindrical and bearing an extensive rhizoid system below the surface.

Figure: Habit, plate 14B (MEL 1021214) and fig. 26D.

Specimens examined: South side of Carappee Hill, Eyre Peninsula, *R. B. Filson 11771*, 22.x.1970 (MEL 1018625); Jamestown, *R. W. Rogers 689*, 3.x.1966 (R.W.R.); Hamley Bridge, *R. W. Rogers 667*, 23.x.1966 (R.W.R.); Mount Pleasant, *V. M. Cruikshank*, 30.vii.1967 (R.W.R.); Tintinara, *R. W. Rogers 1880*, 12.viii.1970 (R.W.R.)

Also in New South Wales, Victoria, Tasmania and Western Australia. A very widespread species on bare soils.

80. SYNALISSA Fr. 1825:297

Thallus fruticose, erect, much branched; branches cylindrical, clavate, coralloid, devoid of differentiation into layers, attached to the substrate by rhizoids. *Apothecia* terminal; disk open or closed, margin thick, concolourous with the thallus; ascospores 8-32 in ascus, hyaline, ellipsoid to spherical, simple

Synalissa symphorea (Ach.) Nyl. 1856:264.

Lichen symphoreus Ach. 1798:135.

Thallus dark olive-green to black, clumped together into patches up 3 cm diam., the individual thalli up to 2·0 (-3·0) mm high and less than 1·0 mm diam., attached to the substrate by basal rhizoids; thallus branched, lobes tightly packed, somewhat nodulose. Apothecia up to 0·2 mm diam., terminal, but sometimes appearing immersed in the lobes; disk reddish brown; margin inrolled, concolourous with the thallus; ascospores eight in ascus, hyaline, irregular ellipsoid, 15 × 17 µm.

Figure: Ascospores, fig. 27H.

Specimens examined: Whalers Way Fence, Fishery Bay, Eyre Peninsula, *R. B. Filson 11808,* 23.x.1970 (MEL 1018641); 25 km north of Mount Dutton Railway Siding, Marree-Oodnadatta road, *R. B. Filson 15627,* 21.xi.1975 (MEL 1018610); Tarcoola, *R. W. Rogers 215,* 23.ii.1966 (AD); Koonamore Vegetation Reserve, *R. W. Rogers 1318,* 20.xi.1967 (R.W.R.); Yunta, *R. W. Rogers 117,* date ? (AD); Swan Reach, *R. W. Rogers 150* (AD).

Recorded also from Western Australia, Victoria and New South Wales.

An inconspicuous species on desert soils; forming small black plaques, or in small tufts growing amongst other lichens, or randomly distributed as isolated individuals.

81. TELOSCHISTES Norm. 1853:228

Literature: Filson 1969.

Thallus fruticose to subfoliose, prostrate or ascending; lobes terete or flattened; cortex of longitudinally arranged conglutinate hyphae; medulla loosely interwoven. *Apothecia* lateral, terminal or scattered, sessile to subsessile; disk concave to flat, yellow or orange; margin concolourous with the thallus, entire or crenulate, often ciliate; ascospores eight in ascus, hyaline, oblong-ellipsoid, polaribilocular.

ARTIFICIAL KEY TO SPECIES

1. Lobes narrow, fruticose beset with fine rhizines or cilia 2
1. Lobes broadly flattened, subfoliose, without fine rhizines or cilia 5
    2. Mature lobes slightly hooded, with soredia on the lower surface under open ends .... *T. velifer*
    2. Mature lobes not hooded 3
3. Thallus lobes with isidia-like nodules or soredia on the margins *T. spinosus*
3. Thallus lobes without isidia-like nodules or soredia on the margins 4
    4. Apothecia mostly pedicillate, the margin strongly ciliate .... *T. chrysophthalmus*
    4. Apothecia more or less sessile, the margin eciliate but the underside of the apothecium often with scattered cilia .... *T. sieberianus*
5. Lobes ascending, slightly hooded, soredia on lower surface under open ends .... *T. velifer*
5. Lobes appressed, neither hooded nor somediose .... *Xanthoria sp.*

Teloschistes chrysophthalmus (L.) Th. Fr. 1861*a*:51.

Lichen chrysophthalmus L. 1771:311.

Thallus orange to greyish-orange, forming a fruticose to subfoliose clump up to 2 cm diam., lobes 0·5-2·5 mm wide with long marginal fibrils, without soredia or isidia. *Apothecia* terminal, pedicillate, up to 6 mm diam.; disk light chrome-yellow to orange; margin prominent, with numerous spinulous fibrils: ascospores eight in ascus, 15-16 × 7-8 μm polaribilocular.

Figure: Habit plate 15A; portion of thallus, fig. 28F; section through thallus lobe, fig. 28H; section through apothecium, fig. 28J; ascus containing spores, fig. 27I.

Specimens examined: Stuart Highway 24 miles north of Port Augusta, *J. H. Willis* 3.vii.1966 (MEL 17313); Gawler Ranges, *Tietkins,* c.1880 (MEL 7595); Waterfall Gully, *A. C. Beauglehole 15072,* 30.ix.1965 (MEL 23027); Meningie, *L. D. Williams 2747,* 16.ii.1966 (L.D.W.); Bool Lagoon, c. 20 km south of Naracoorte, *D. Hunt,* iii.1962 (AD).

Reported from all States except the Northern Territory.

Teloschistes chrysophthalmus is common on bark and twigs in the wetter parts of the State.

Teloschistes sieberianus (Laur.) Hillman 1930:315.

Parmelia sieberiana Laur. 1827:38.

Thallus golden orange, up to 6 cm diam.; lobes flat, radiating, appressed to ascending 0·3-1·0 mm wide; margins fibrilate up to 3·0 mm long, isidia and soredia absent. *Apothecia* sessile, up to 5 mm diam., with fibrils on the lower surface but not on the margin; ascospores 12-16 × 7-9 μm.

Figure: Habit, plate 15B (MEL 1021852).

Specimens examined: Wilpena Pound, *R. G. Gray,* 31.viii.1952 (MEL 7452); Cape Jervis, *R. W. Rogers 1455,* 1.ix.1968 (R.W.R.); East Payneham, c. 6 km north-east of Adelaide, *J. G. O. Tepper.* 28.i.1893 (AD); Kersbrook, *V. M. Cruikshank.* 10.iv.1966 (R.W.R.); Kuitpo, *V. M. Cruikshank,* 8.vii.1967 (R.W.R.).

In all States except the Northern Territory.

This species is common on twigs and bark in the wetter parts of the state.

Teloschistes spinosus (Hook. f. & Tayl.) J. Murray 1960:205.

Parmelia spinosa Hook. f. & Tayl. 1844:644.

Thallus golden orange, up to 3 cm diam., sometimes forming small cushions: lobes flat, radiately appressed to ascending, 0·3-0·8 mm wide, with fine fibrils on the upper surface; margins granular sorediose, or with isidia-like nodules, fibrilose. *Apothecia* up to 4 mm diam., sessile, nodular or sorediose below: ascospores 12-16 × 8-9 μm.

Figure: Thallus lobe, fig. 28G.

Specimens examined: Whyalla, *R. W. Rogers 1749,* 10.viii.1969 (R.W.R.); Mount Brown, c. 17 km north-west of Wilmington, *J. D. Curtis,* 27.v.1967

(MEL 32123); Two Wells, *R. W. Rogers 1580,* 12.xi.1968 (R.W.R.); Coonalpyn, *L. D. Williams 3114*, 20.viii.1967 (L.D.W.).

Found in Victoria, Tasmania and New South Wales.

Teloschistes spinosus is both corticolous and saxicolous and is widespread but not common, it is found in the wet and dry areas.

Teloschistes velifer F. Wils. 1889:69.

Thallus yellow-orange to golden-orange, of scattered lobes or forming patches 2-4 cm diam.; lobes subfruticose, up to 5 mm wide and 10 mm long, slightly hooded at the apex, open underneath, the open part thus exposed, ecorticate, sorediose, attached to the substrate by rhizoids. *Apothecia* up to 3 mm diam., without fibrils; ascospores 12-16 × 6-8 μm.

Figure: Habit, plate 15C (MEL 1021851); ascospores, fig. 27J.

Specimens examined: Tent Hill, near Deep Creek, Fleurieu Peninsula *R. W. Rogers 1460,* 3.ix.1968 (R.W.R.); Kuitpo Forest, *R. W. Rogers 1435,* 10.viii.1968 (R.W.R.).

Also in New South Wales, Victoria and Tasmania.

This species is not often collected. It grows on thin twigs sometimes in association with *Ramalina sp.*

82. THYREA Mass. 1856b:210

Thallus fruticose or subfoliose, lobed or branched, adnate or ascending, attached to the substrate by a holdfast. *Apothecia* immersed or adnate, lecanorine; disk open or closed, sometimes deeply concave. Ascospores 8-10 in ascus, simple, hyaline; paraphyses simple.

As yet not recorded in South Australia, but specimens referable to this genus have been collected in western New South Wales and the Northern Territory. It could occur in damp places on granite outcrops in the drier parts of the State.

83. THYSANOTHECIUM Mont. & Berk. 1846:257.

Primary thallus granular or squamulose; upper surface corticate; lower surface without rhizines; pseudopodetia erect, unbranched or little branched, solid, expanded towards the apices. *Apothecia* terminal on lateral surface of the pseudopodetia, round or lobed; disk pale to dark brown; ascospores eight in ascus, hyaline, ellipsoid, simple or two-celled.

Thysanothecium hyalinum (Tayl.) Nyl. 1857:94.

Baeomyces hyalinus Tayl. 1847:187.

Thallus finely granular, sometimes almost indiscernible, yellow-green to brownish-green; pseudopodetia up to 1·5 (-2·0) cm tall. *Apothecia* terminal, solitary, up to 7 mm diam.; disk pale yellow-green, sometimes lightly pruinose; margin prominent, crenulate, concolourous with the thallus; ascospores hyaline, long ellipsoid, 7-10 × 3-5 µm.

Figure: Habit, plate 16A (MEL 1022011); ascospores, fig. 27K.

Specimens examined: hundred of Blesing, *N. N. Donner 2335*, 6.x.1967 (AD 97528235); Millbrook, *R. W. Rogers 1779*, 20.ix.1969 (R.W.R.); Mount Lofty, *R. W. Rogers 1874*, 3.viii.1970 (R.W.R.); Cape Jervis, *R. W. Rogers 1471*, 1.ix. 1968 (R.W.R.).

In all States except the Northern Territory.

Thysanothecium hyalinum is a common lichen on burnt wood in eucalypt forest. If found growing on the ground or earth banks careful examination will reveal that it is attached to small pieces of charcoal.

84. TONINIA Mass. 1852a:107.

Thallus crustose or squamulose with an indistinctly cellular upper cortex, algal and medullary layers. *Apothecia* lecideine, adnate or sessile; disk flat to convex, usually black; margin concolourous with the disk, sometimes disappearing; ascospores eight in ascus, hyaline, ellipsoid to fusiform, two-to many-celled.

Toninia caeruleonigricans (Lightf.) Th. Fr. 1874:336.

Lichen caeruleonigricans Lightf. 1777:805.

Thallus of irregular, inflated dark grey to brown squamules, up to 1 mm diam., usually reticulately cracked, densely white to bluish-white pruinose. *Apothecia* up to 2 mm diam.; disk flat, black, sometimes pruinose; margin black or pruinose; ascospores fusiform, two-celled.

Figure: Ascospores, fig. 27L.

Specimens examined: Top of the cliffs, Great Australian Bight, 12 miles (19 km) south of "Koonalda" H. S., *R. B. Filson 9432*, 29.xii.1966 (MEL 25393); Kingoonya, *R. W. Rogers 492*, 7.ix.1966 (AD); Port Augusta, *R. W. Rogers 1149*, 22.v.1967 (AD); Kadina, *R. W. Rogers 941*, 9.ii.1967 (AD); Morgan, *R. W. Rogers 1058*, 17.v.1967 (AD); Pinnaroo, *R. W. Rogers 324*, 9.iii.1966 (AD).

Occurs in Western Australia, Victoria and New South Wales.

A very common lichen found on calcareous rocks, pebbles or sandy soils.

85. TRAPELIA Choisy 1949:112.

Literature: Hertel 1969a.

Thallus crustose to squamulose, upper surface corticate. *Apothecia* lecideine, adnate to immersed; ascospores eight in ascus, hyaline, simple; paraphyses reticulately branched and anastomosing.

Trapelia coarctata (Turn. ex Sm. & Sow.) Choisy in Wern. 1932:160.

Lichen coarctatus Turn. ex Sm. & Sow. 1799:534.

Thallus of small white to greyish-white, bullate squamules, up to 2 mm diam., crowded or scattered. *Apothecia* 0·2-0·4 mm diam., immersed to erumpent or sessile; disk pale to black; ascospores simple, eight per ascus.

Specimens examined: "Roopena" Station, Eyre Peninsula, *R. W. Rogers 1758,* 10.viii.1969 (R.W.R.); Tarlee, *R. W. Rogers 1511,* 29.x.1968 (AD 97733168); Barossa Reservoir, *R. W. Rogers 1479,* 30.x.1968 (AD 97733170); Kanmantoo, *R. W. Rogers 1528,* 5.xi.1968 (AD 97733171).

Reported from Western Australia, New South Wales and Victoria.

Trapelia coarctata is common on dry, compacted soils.

86. TRYPETHELIUM Spreng. 1805:309.

Thallus crustose, epi- or endophloic, ecorticate or with a thin cartilaginous cortex. *Pseudothecia* perithecium-like immersed in stromatic bodies on the upper surface, one to many in each stroma; ascospores eight in ascus, hyaline, transversely septate, 3-17 celled.

Figure: Trypethelium eluteriae ascospores fig. 27M.

No collections of this genus are known for South Australia but specimens are likely to be found on bark.

87. USNEA (Hill.) Wigg. 1780:90.

Literature: Motyka 1936-38.

Thallus fruticose, filamentous, erect, pendulous or prostrate, branched; branches thinning towards the apex, terete, angled, smooth, foveolate, verrucose, tuberculate or spinulose; attached to the substrate by a holdfast; cortex coriaceous or spongy of densely woven vertical hyphae; medulla variable in thickness, with a chondroid axis of longitudinal hyphae, usually very solid, sometimes hollow. *Apothecia* lecanorine, lateral, subterminal or terminal; ascospores simple, hyaline, ellipsoidal.

All of the South Australian material examined has been of the short, subpendulous or erect species, the filaments being less than 5 cm long. No long, pendulous species, nor any species with coloured medulla or hollow axis have been found.

ARTIFICIAL KEY TO SPECIES

1. With neither isidia nor soredia, usually fertile, main branches densely covered with short branchlets or spinules 2
1. Sorediose or isidiose, usually sterile, sometimes the isidia growing into spinules 3

2. Medulla K+ yellow becoming reddish-orange .... *U. ramulosissima*
2. Medulla K− .... *U. scabrida*
3. Branches densely covered with isidia growing into spinules 5
3. Branches without isidiate spinules, rarely constricted or articulate, main branches with fibrils 4
4. Medulla K+ red .... *U. arida*
4. Medulla K− .... *U. angulosa*
5. Branches constricted and articulate at the base .... *U. sp.*
5. Branches not constricted and articulate at the base .... *U. inermis*

Usnea angulosa (Müll. Arg.) Mot. 1937:512

Usnea dasypogoides var. *angulosa* Müll. Arg. 1886:254.

Thallus of yellowish-green terete to angular-terete branches, 1·0-5·0 cm long, more or less pendant, frequently branched, without distinct articulations at the joints; main branches 0·1-0·5 mm thick, beset with soredia and fibrils in discrete patches; medulla of loosely woven hyphae. *Apothecia* not seen.

Reactions: Medulla K−, C−, KC−, P−.

Specimens examined: Mount Bonython, *R. W. Rogers 880,* 15.i.1967 (R.W.R.); Mount Pleasant, *V. M. Cruikshank*, 30.vii.1967 (R.W.R.); Hindmarsh Valley, *R. W. Rogers 1048*, 25.x.1967 (R.W.R.); Angaston, *R. W. Rogers 1355,* 31.xii.1967 (R.W.R.); Bagdad Station near Millicent, *R. D. Seppelt,* ? 1971 (R.W.R.).

This is a common species on trees and rocks in the wetter areas. It differs from *U. arida* in reaction of KOH on the medulla and in the angular ridges on the branches.

Usnea arida Mot. 1937:492.

Thallus of yellowish-green terete branches 1·0-5·0 cm long, more or less pendant, frequently branched, without distinct articulations at the joints; main branches 0·1-0·5 mm thick, fibrillose, sorediose; medulla of loosely woven hyphae. *Apothecia* not seen.

Reactions: Medulla K+ orange-brown, C−, KC−, P−.

Figure: Habit plate 16B (MEL 1021189).

Specimens examined: Kuitpo, *R. W. Rogers 1430*, 21.vii.1968 (R.W.R.); Hindmarsh Valley, *R. W. Rogers 1051*, 30.iv.1967 (R.W.R.).

Known from Queensland, New South Wales, Victoria and Tasmania.

Usnea arida is common on trees in the wetter areas.

Usnea inermis Mot. 1937:109.

Thallus of yellowish-green terete branches 1·0-5·0 cm long, erect or subpendant, frequently branched, without distinct articulations at the joints;

main branches densely beset with isidia which often grow out into spinules; medulla loosely woven. *Apothecia* not seen.

Reactions: Medulla K−, C−, KC−, P−.

Known from Victoria and New South Wales.

No specimens of this species have been seen from South Australia, however it is recorded for this State in Weber and Wetmore (1972:118).

Usnea ramulosissima Stevens and Rogers 1978:45.

Thallus yellowish-green of terete branches 1·0-5·0 cm long, erect, branched, without distinct articulations at the joints; main branches 1·0-2·0 mm thick, very densely beset with fibrils, isidia and soredia absent; medulla of loosely woven hyphae. *Apothecia* lateral, up to 10 mm diam.; disk greenish-yellow; margin flexuose, fibrilose; ascospores hyaline, broad-ellipsoid to subspherical, 7-10 × 8-9 μm.

Reactions: Medulla K+ yellow becoming orange, C−, KC−, P+.

Figure: Habit, plate 16C (MEL 1021188); ascospores, fig. 27N.

Specimens examined: Verdun, *R. D. Seppelt*, 17.v.1969 (R.W.R.); Mylor, *R. D. Seppelt*, 25.vii.1971 (AD); Murray Bridge, *V. M. Cruikshank*, 1965 (AD); Karoonda, *R. W. Rogers 390a*, 11.v.1966 (R.W.R.).

Known from Queensland, New South Wales, Victoria and Tasmania.

This species differs from *U. scabrida* in being more branched and having coarse papillae amongst the fibrils. The apothecia are lateral and the marginal cilia often initiate new branches.

Usnea scabrida Tayl. 1844:1095.

Thallus yellowish-green of terete branches 1·0-5·0 cm long erect, commonly branched, without distinct articulations at the joints; main branches 1·0-2·0 mm thick, very densely beset with fibrils, isidia and soredia absent; medulla of loosely woven hyphae. *Apothecia* terminal, up to 10 mm diam.; disk greenish-yellow sometimes pruinose, margin prominent, flexuose, densely fibrilose; ascospores hyaline, broad-ellipsoid to subspherical, 9-13 × 7-8 μm.

Reactions: Medulla K−, C−, KC−, P−.

Figure: Ascospores, fig. 27O.

Specimens examined: Wudinna, *A. Bailey*, ix.1967 (R.W.R.); Whyalla, *R. W. Rogers 1746*, 8.viii.1969 (R.W.R.); Kersbrook, *V. M. Cruikshank*, 10.iv.1966 (R.W.R.); Karoonda, *R. W. Rogers 390b*, 11.v.1966 (AD).

Reported also from Victoria and Tasmania.

Usnea scabrida is a common species on bark on old wooden fence posts in the subarid areas. It differs from *U. ramulosissma* in being less spinulose and having terminal apothecia.

Usnea sp.

Thallus of yellow-green terete branches up to 5·0 cm long, erect, branched; branches 1·0-2·0 mm diam., with distinct arthropod-like articulations at the joints, densely beset with spinules and isidia which grow out into spinules; medulla of loosely woven hyphae. *Apothecia* not seen.

Reactions: Medulla K+ yellow becoming orange-brown, C−, KC−, P−.

Specimens examined: Myponga, *R. W. Rogers 1715*, 16.vi.1968 (R.W.R.); Penola, *K. Alcock*, vi.1971 (R.W.R.).

Known also from Victoria.

88. VERRUCARIA Wigg. 1780:85.

Thallus crustose to endophloic or endolithic, smooth or areolate, ecorticate. *Perithecia* sessile, immersed in the thallus or in thalline warts; ascospores eight in ascus, simple, hyaline; paraphyses soon dissolve into mucilage.

Figure: Verrucaria microsporoides, ascospores, fig. 27P.

Verrucaria is a very large and difficult genus. Two species reported for South Australia are *V. maura* Wahlenb. ex Ach. growing on sandstone rocks in the maritime splash zone and *V. calciseda* DC. in Lam. et DC. growing on calcareous pebbles in arid areas. The common species found growing on the coastal dune limestones below high water mark is referable to *V. microsporoides* Nyl. apud Crouan.

89. XANTHORIA Th. Fr. 1861b:166.

Literature: Filson 1969.

Thallus foliose, radiate, dorsiventral, with a distinct pseudoparenchymatous upper and lower cortex formed from vertical hyphae; medulla of loosely woven hyphae. *Apothecia* lecanorine, sessile or shortly stipitate; disk concave becoming convex at maturity; margin prominent, concolourous with the thallus; ascospores eight in ascus, hyaline, polaribilocular.

Reactions: Thallus and apothecia K− claret.

ARTIFICIAL KEY TO SPECIES

1. Lobes thin, rugulose, ultimate lobes concave with a slightly raised flexuose margin .... *X. parietina*
1. Lobes thick, smooth, ultimate lobes slightly convex and appressed to the substrate .... *X. ectanea*

Xanthoria ectanea (Ach.) Räs. ex R. Filson 1969:83.

Parmelia parietina var. *ectanea* Ach. 1810:464.

Thallus forming a yellow to deep golden-orange rosette, up to 8·0 cm diam., adnate to the substrate; lobes smooth, up to 2·5 mm wide, margins slightly

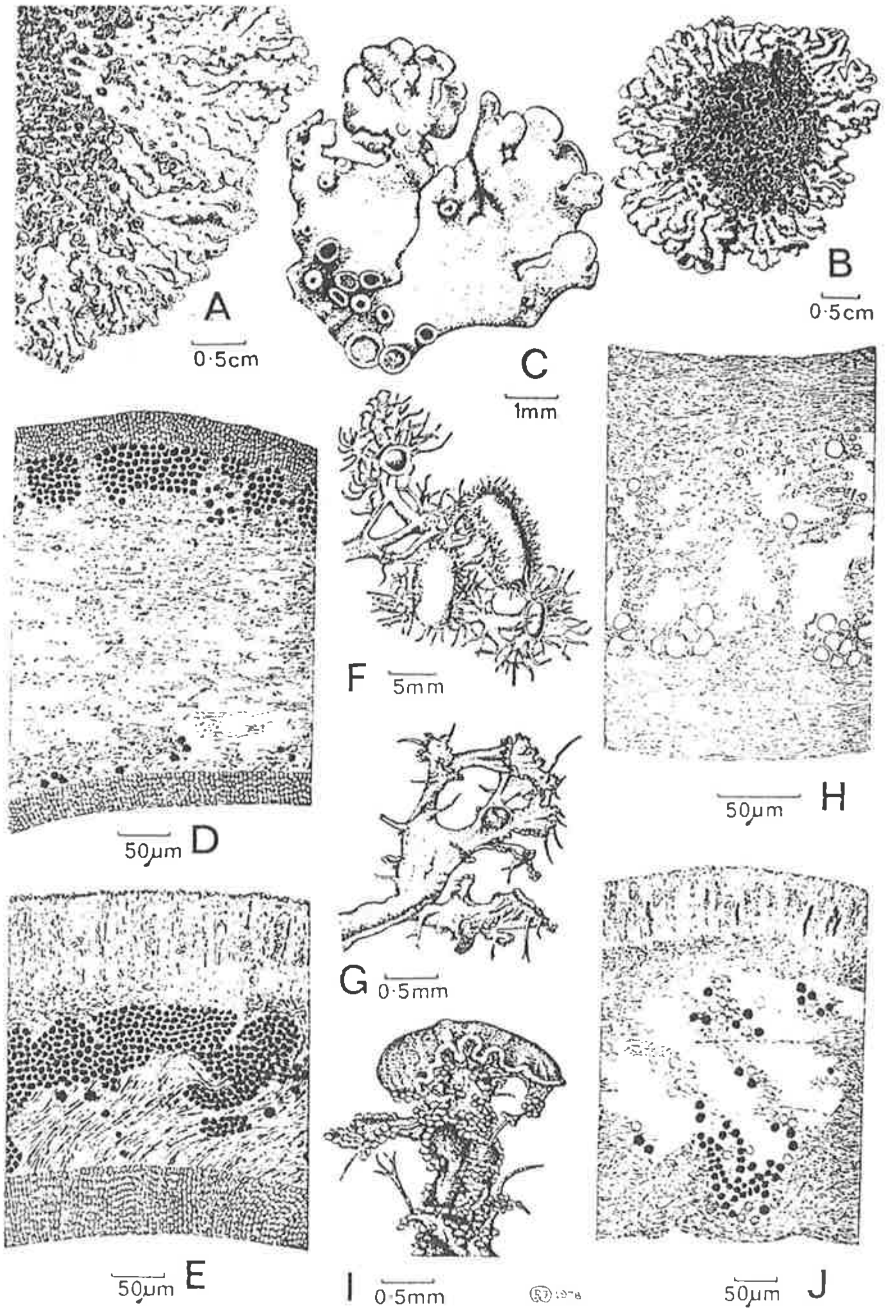

Fig. 28. A, *Xanthoria parietina*, portion of thallus; B, *Xanthoria ectanea*, typical thallus; C, *Xanthoria ectanea*, portion of thallus lobe showing apothecia in various stages of development, D, *Xanthoria ectanea*, section through thallus lobe showing structure of upper and lower cortex; E, *Xanthoria ectanea*, section through apothecium; F, *Teloschistes chrysophthalmus*, portion of thallus showing apothecia in various stages of development; G, *Teloschistes spinosus*, thallus lobe showing pycnidia and granular soredia; H, *Teloschistes chrysophthalmus*, section through thallus lobe showing structure of upper and lower cortex; I, apothecium, spinules and granules; J, *Teloschistes chrysophthalmus*, section through portion of apothecium. After Filson 1969.

raised then deflexed, isidia and soredia absent. *Apothecia* clustered into the centre of the thallus up to 2·5 mm diam.; ascospores hyaline, polaribilocular, canal sometimes absent, 14-16 × 6-8 μm.

Figure: Habit, plate 16D; typical thallus, fig. 28B; section through thallus Lobe, fig. 28D; section through apothecium, fig. 28E; ascospores, fig. 27Q.

Specimens examined: "Koonalda" Station, Nullarbor Plain, *D. S. Kemsley*, 9.i.1952 (MEL 7462); "Colona" Station, Yalata Aboriginal Reserve, *J. H. Willis*, 27.viii.1947 (MEL 7435); 24 miles (38 km) north-west of Port Augusta, *J. H. Willis*, 3.viii.1966 (MEL 17314); Middle River, Kangaroo Island, *S. J. Edmonds*, v.1952 (MEL 7490); Kings Beach Cliffs near Victor Harbor, *R. W. Rogers 1889*, 31.i.1966 (MEL 16196).

Reported for all States except Queensland and the Northern Territory.

Xanthoria parietina (L.) Beltr. 1858:102.

Lichen parietinus L. 1753:1143.

Thallus forming a yellow to deep golden-orange rosette up to 10 cm diam., adnate to the substrate; lobes rugulose, up to 5 mm wide, margins slightly reflexed and flexuose, isidia and soredia absent. *Apothecia* on the older parts of the thallus, up to 3 mm diam.; ascospores hyaline, polari-bilocular, canal mostly present, 12-15 × 7-10 μm.

Figure: Portion of thallus, fig. 28A.

Specimens examined: Koonalda Cave, Nullarbor Plain, *R. B. Filson 9419*, 28.xii.1966 (MEL 25277); Fowlers Bay, *R. B. Filson 9492*, 12.i.1967 (MEL 25276); River Torrens Gorge, *N. N. Donner 1307*, 13.iii.1965 (MEL 9117); Princes Highway, 7 miles (11 km) east of Murray Bridge, *R. T. M. Pescott*, 26.vi.1966 (MEL 17335).

In all States except Queensland and the Northern Territory.

Xanthoria parietina occurs only in the settled areas and is especially common on introduced trees. It may be an introduction.

GLOSSARY

Acicular: long and needle-shaped.
Adnate: closely attached, the thallus close to the substrate, or the apothecium flat on the thallus.
Aggregated: apothecia arranged one upon the other like a pile of dishes.
Algal layer: the band of gonidia (phycobiont) in the lichen thallus.
Anastomosing: with numerous cross-connections.
Apex (pl. *Apices):* tip.
Apical: situated at the tip.
Apothecium (pl. *Apothecia):* the disk-shaped fruiting body (ascocarp) of an ascomycete, (see Fig. 2D).
Appressed: closely adhering to the substrate.
Arachnoid: cobweb-like in structure.
Areole: a small part of a lichen thallus separated from the rest of the thallus by minute cracks.
Areolate: consisting of a mosaic of areoles.
Articulate: thallus constricted and jointed thus appearing like a crustacean's leg.
Ascending: rising from the substrate.
Ascocarp: the sporocarp of an ascomycete lichen producing asci and ascospores, i.e. apothecium, perithecium, pseudothecium.
Ascospore: a spore produced by an ascus.
Ascostroma: a stroma bearing asci.
Ascus (pl. *Asci):* sac containing spores.
Axil: the angle between branches or lobes.
Axis (pl. *Axes):* the main stem of a branched lichen, or in *Usnea*, the central cartilaginous core.

Bullate: expanded like a bubble.

C±: calcium hypochlorite ($Ca(ClO)_2$) used as a reagent colour test (see Chemical Tests in the Introduction).
Canaliculate: grooved or channelled.
Capitate: shaped like a head—usually with reference to more or less globular soralia.
Cartilaginous: of firm dense tissue like mammalian cartilage.
Cerebriform: having an irregular brain-like appearance.
Cephalodia: a tubercle containing blue-green algal cells, which is sometimes found in or on a thallus containing a green phycobiont.
Chondroid axis: the elastic, cartilaginous central core in the genus *Usnea*.
Cilium (pl. *Cilia):* a hair-like growth on the margins or upper surface of lobes; or on the margins or lower surface of apothecia.
Clathrate: net-like.
Clavate: club-shaped.
Coralloid: coral-like.
Coriaceous: leathery.
Cortex: the outermost layer of the thallus, consisting of compacted hyphae which may appear either fibrous or cellular.

Corticolous: growing on bark.
Crenate: with a wavy or notched margin.
Crustose: thallus type, forming a closely adnate, strongly adherent crust over the substrate; without a lower cortex or rhizines.
Cyphella (pl. *Cyphellae):* a pore in the lower surface, lined with pseudo-cortex.

Digitate: finger-like.
Dilated: become larger, opening out.
Disk: the upper surface of the apothecium, (see Fig. 2D)
Dorsiventral: with distinct differences between the upper and lower surfaces.

Ecorticate: without a cortex.
Effigurate: having a defined outline.
Emarginate: without a margin (e.g. the apothecial margin).
Endolithic: immersed in rock or stone.
Endophloedal: immersed in wood or bark.
Entire: smooth and unbroken, without notches.
Epithecium: the surface of the apothecial disk, the top-most layer of the hymenium (see Fig. 2F).
Erect: rising vertically from the substrate.
Evanescent: soon disappearing.
Exciple: the layer surrounding the hymenium which sometimes develops into a distinct margin. A proper exciple has no algal component and is derived from apothecial tissue, a thalloid exciple has an algal component and is derived from the vegetative thallus.

Farinose: fine, floury, powdery, usually with reference to soredia.
Fasciculate: in bundles or clusters.
Fenestrate: with small perforations.
Fertile: with apothecia or perithecia.
Fibril: short, thin lateral branches, especially in *Usnea*.
Fibrillose: having fibrils.
Filamentous: hair or thread-like.
Fistulate: hollow and pipe-like with gaping mouths.
Foliose: thallus type, usually with upper and lower cortices, dorsiventral, flat and somewhat leaf-like.
Foveolate: pitted, with grooves and depressions.
Fruticose: thallus type, usually erect and uprising or pendulous, commonly radially symmetrical but sometimes dorsiventral.
Fusiform: spindle shaped.

Gelatinous: jelly-like.
Gonidial: algal layer (see phycobiont).
Granulose: with granules or coarse grains. Usually with reference to soredia or some crustose thalli.

Heteromerous: a thallus form in which more or less distinct tissues are present.
Holdfast: a disk-like base by which some lichens are attached to the substrate.

Homiomerous: a thallus form in which the algal and fungal components are uniformly dispersed.
Hymenium: that part of the ascocarp composed of asci and paraphyses, (see Fig. 2F).
Hypha (pl. *hyphae):* a filament of fungal cells.
Hypothallus: a growth of undifferentiated hyphae upon which a differentiated thallus develops. Sometimes present as a distinct layer below or around a thallus.
Hypothecium: the tissue in the ascocarp from which the paraphyses and asci initiate, (see Fig. 2F).

Imbricate: overlapping like roofing tiles.
Immersed: sunken into the thallus.
Inflated: expanded, often hollow.
Isidium (pl. *isidia):* an outgrowth from the thallus with a cortex.

K±: 10% potassium hydroxide (caustic potash) solution used as a colour test, (see Chemical Tests in the Introduction).

Labriform: lip-like.
Lacerate: irregularly cut or torn.
Laminal: on the surface.
Lecanorine: referring to an apothecium like that of *Lecanora,* with a thalline margin around the disk, (see Fig. 2E).
Lecideine: referring to an apothecium like that of *Lecidea* with a proper exciple around the disk, (see Fig. 2E).
Leprose: entirely sorediose.
Lignicolous: growing on wood.
Linear: narrow and uniform in width.
Lirelliform: having a shape rather like the characters of Chinese writing.
Lobe: a segment of a branched thallus.
Lobule: a small lobe on the margin or upper surface of a larger lobe.

Maculose: spotted; submacroscopic white spots showing on the upper surface caused by breaks in the algal layer.
Marginal: on the edge or margin rather than on the upper or lower surface.
Marginate: with a distinct margin (with reference to apothecia).
Mazaedium (pl. *mazaedia):* a fruiting body in which ascus walls break down to form an amorphous spore mass.
Medulla: an internal layer of loosely woven hyphae, between the algal layer and lower cortex, (see Fig. 2F).
Muriform: resembling bricks in a wall—with reference to spores with both longitudinal and cross septa, (see Fig. 16C, D, E & F).
Mycelial: made up of mycelium or intertwined strands of hyphae.
Mycobiont: the fungal component of a lichen.

Nodule: a small lump or knot.

Orbicular: more or less round.

Ostiole: a pore-like opening at the apex of a perithecium through which the spores escape.

Papilla (pl. *papillae):* a small wart-like outgrowth from the thallus.

Paraphysis (pl. *paraphyses):* a specialised hyphal form, either simple or branched, in the hymenium.

Paraplectenchymatous: a fungal tissue with a cellular structure.

P±: an alcoholic solution of paraphenylenediamine used for colour testing, (see Chemical Tests in the Introduction).

Pedicellate: on a pedicel or short stalk.

Peltate: like a shield on a central stalk.

Pendulous: hanging.

Perforate: with holes through the thallus or into a central cavity.

*Perithecium (*pl. *perithecia):* a flask-shaped fruiting body immersed in the thallus with a single, terminal opening, (see Fig. 2G).

Phycobiont: the algal component of a lichen.

Placodiform: a crustose thallus having effigurate lobes tightly appressed to the substrate.

Plectenchyma: parenchyma-like tissue of tightly packed hyphae.

Podetium (pl. *podetia):* an erect portion of a thallus derived from tissue of apothecial origin, rising from a primary thallus.

Polar: referring to two-celled spores in which the cells are at opposite ends of the spore, separated by a very thick wall.

Polaribilocular: referring to spores which are non-septate, but in which the wall thickens almost dividing the cell into two polar compartments.

Proper margin: an exciple formed from tissue of apothecial origin—without algae in the rim.

Prosoplechtenchymatous: fungal tissue of fibrous or indistinctly cellular appearance.

Pruina: a white or bluish coating or bloom on the surface.

Pruinose: with pruina.

Pseudocyphella (pl. *pseudocyphellae):* areas of the thallus where the upper or lower cortex is perforated or split and medullary hyphae come to the surface.

Pseudoparenchymatous: having the appearance of parenchyma—i.e., isodiametric cells.

Pseudopodetium (pl. *pseudopodetia):* a podetium-like structure that has its origin in vegetative rather than reproductive tissue.

Pseudothecium (pl. *pseudothecia):* term used for the fruiting structures in pyrenocarpous lichens with bitunicate asci.

Pubescent: clothed with soft hair or down.

Punctiform: dot-like.

Pustular: having slight elevations like blisters.

Pycnidium (pl. *pycnidia):* a flask-shaped structure producing pycnidiospores.

Pycnidiospores: the spore type produced in a pycnidium.

Radiate: with lobes arranged in a radial manner.

Recumbent: lying upon the substrate.

Reflexed: turned up at the margin.
Reticulate: with a network of ridges, lines or cracks on the surface.
Rhizine (pl. *rhizines):* hyphal structures on the lower surface anchoring the thallus.
Rhizoid: a short branch of the thallus resembling a root.
Rosulate: with a crustose effigurate rosette.
Rugulose: with a wrinkled surface.

Saxicolous: growing on rock.
Scrobiculate: marked by shallow depressions.
Septate: divided by a septum or wall.
Sessile: without a stem or stipe, sitting on the surface.
Soralium (pl. *soralia):* a patch of soredia.
Soredium (pl. *soredia):* microscopic powdery structures containing a group of algal cells and hyphae, but lacking a cortex.
Spinule: a small spine.
Squamule: a small scale-like thallus segment, usually lacking a lower cortex.
Squamulose: a growth form composed of squamules.
Stipe: a stalk that supports a fruiting body.
Stipitate: elevated on a stipe.
Stoloniferous: having an underground stem system.
Striate: with parallel stripes.
Stroma (pl. *stromata):* a compact mass of fungal tissue in which fruits are formed.
Substrate: the material on which an organism is living.

Terete: circular in cross-section.
Terminal: ending the structure, or on the end.
Terricolous: growing on soil.
Thalline margin: an exciple in which part of the vegetative thallus has grown up around the apothecium so that algae occur in the margin.
Thallus (pl. *thalli):* the lichen body, both alga and fungus.
Tomentum: a dense woolly covering of hyphae.
Tubercle: A small wart-like outgrowth through the cortex.
Type (specimen): the type of a family, genus, species or subspecies; the single element of a taxon to which the name is attached; the original specimen from which the description was drawn up.

Umbilicus: a point attachment at the centre of a thallus.

INDEX TO AUTHORS AND THEIR ABBREVIATION

Ach.: Acharius, E.
Adans.: Adanson, M.
Anzi, M.
Arn.: Arnold, F. C. G.

Bab.: Babington, C.
Baker, C.
Beltr.: Beltramini de Casati, F.
Berk.: Berkeley, M. J.
Bibby, P. N. S.
Bitt.: Bitter, F. A. G.
Borr.: Borrer, W.

C.A.Ag.: Agardh, C. A.
Choisy, M.
Cohn, F. J.
Cromb.: Crombie, J. M

DC.: De Candolle, A. P.
Degelius, G.
Del.: Delise, D. F.
de Not.: Notaris, de G.
Dicks.: Dickson, J.
Duby, J. E.

Eckf.: Eckfeldt, J. W.
Ehrh.: Ehrhart, F.
Elix, J. A.
Eschw.: Eschweiler, F. G.
Esslinger, T. L.
Evans, A. W.

Fée, A. L. A.
Filson, R. B.
Flörke, H. G.
Flot.: Flotow,
J. C. G. U. G. G. A. E. F. von
Forss.: Forssell, K. B. J.
F. Muell.: Mueller, F.
Fr.: Fries, E. M.
Furnr.: Furnrohr, A. E.
F. Wils.: Wilson, F. R. M.

Gams, H.
Gaudich.: Gaudichaud-Beaupré, C.
Gillet, A.
Gray, S. F.
Gyel.: Gyelnik, V. K.

Hale, M. E.
Hampe, G. E. L.
Hawksworth, D. L.
Hedw.: Hedwig, J.
Henssen, A.
Hepp, P.
Hill, J.
Hillman, J.
H. Magn.: Magnusson, A. H.
Hoffm.: Hoffmann, G. F.
Hook.f.: Hooker, J. D.
Huds.: Hudson, W.
Hue, A. M. Abbe
Humb.: Humboldt, F. H. A. von

Körb.: Körber, G. W.
Kremp.: Krempelhuber, A. von
Kurokawa, S.

L.: Linnaeus, C.
Lam.: Lamarck, J. B. A. P. M. de
Lamy.: Lamy de la Chapelle, P. M. E.
le Prev.: Le Prevost, A.
Lett.: Lettau, G.
Lightf.: Lightfoot, J.
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Mack.: Mackay, J. T.
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Mont.: Montagne, J. P. F. C.
Mot.: Motyka, J.
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Müll. Arg.: Müller Argoviensis, J.
Murray, J.

Naeg.: Nägeli, C. W. von
Norm.: Norman, J. M.
Nyl.: Nylander, W.

Oliv.: Olivier, P. H.

Pers.: Persoon, C. H.
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Räs.: Räsänen, V.
Rassad.: Rassadina, K. A.
Rich.: Richard, M. A.
Rogers, R. W.
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Sant.: Santesson, R.
Sato, M.
Schaer.: Schaerer, L. E.
Schrad.: Schrader, H. A.
Scop.: Scopoli, J. A.
Sm.: Smith, J. E.
Smith, A. L.
Sommerf.: Sommerfelt, S. C.
Spreng.: Sprengel, K. P. J.
Stein, J.

Stevens, N. C.
Stiz.: Stizenberger, E.
Sw.: Swartz, O P.

Tayl.: Taylor, T.
Th. Fr.: Fries, T. M.
Thomson, J. W.
Thunb.: Thunberg, C. P. P.
Tornab.: Tornabene, F.
Trev.: Trevisan de St.-Leon
Tuck.: Tuckerman, E.

Vain.: Vainio, E. A.
Verseghy, K.
Vill.: Villars, D.

Wahlenb.: Wahlenberg, G.
Wainio.: Vainio E. A.
Web.: Weber, G. H.
Wern.: Werner, R. G.
Wetmore, C. M.
Wigg.: Wiggers, F. H.
Willd.: Willdenow, C. L.
Wilson, F. R. M.

Yoshimura, I.

Zahlbr.: Zahlbruckner, A.

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(LICHENIZED FUNGI)

Roderick W. Rogers

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TO NAOMI
who watched
and asked
and encouraged

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This account could not have been prepared at all had not the Interim Council of the Australian Biological Resources Study funded a survey of the lichens in the Brisbane area which necessitated gathering most of the information contained in this volume.

Introduction

This account of the genera of lichen forming fungi in Australia has been prepared so that the naturalist anywhere in Australia can name a lichen to genus. References have been provided to the scattered literature which will allow species determinations in many genera.

There is no extensive account of lichen biology in this book. Those who wish to study lichens are referred to the introductory accounts in Filson and Rogers' *Lichens of South Australia* or to the fuller accounts in Hale's *The Biology of Lichens.* The reading of such an account will greatly facilitate use of this set of keys and descriptions. The glossary is full, refers to a number of illustrations, and certainly should be sufficient for those with some knowledge of the fungi.

The Nature of Lichens

A lichen is probably best regarded not as an organism but as a tightly integrated biological community. A lichen always consists of at least one species of alga (represented by numerous individuals) and one species of fungus (possibly representing more than one individual). There are a number of lichens which are reported to characteristically posses two algal species either as alternatives or simultaneously, especially as cephalodia.

Such a complex community cannot be given a species name under the International Code of Botanical Nomenclature, but perhaps it could within a phytosociological framework.

The International Code of Botanical Nomenclature is quite clear that the name given to a lichen applies only to its fungal component: "For nomenclatural purposes the names given to Lichens shall be considered as applying to their fungal symbionts" (Article 13d).

The state of knowledge of lichens is not, however, so well advanced as to allow a full integration of the lichen classification with that of the other fungi. With some exceptions lichenization is taken as a character to separating fungal orders.

Sources of Information

The genera included in this account are those listed for the region by Weber and Wetmore (1972), Wetmore (1963) or reported in the literature or communicated personally by various workers. Those genera in the latter categories are listed elsewhere.

A convenient starting point in the accumulation of descriptions of the genera was the account prepared by Zahlbruckner (1903). That account provided a preliminary description for almost all of the genera. A second major source was Santesson (1952) which summarized all the foliicolous genera, and commented on related genera in a most helpful manner. Recourse has been taken also to a wide range of check lists and regional floras to ensure that genera have been used in a currently acceptable sense. Not all genera, however, are currently treated in a like manner by all writers. A particularly difficult group is the genus *Parmelia sensu lato*, which has been split into a large number of segregates each with genus status by Mason Hale (1974a,b,c) and Theodore Esslinger (1978a). In this arrangement I have followed Hale and Esslinger, not because I am convinced that all the segregates are good genera, but because at least some are. This arrangement makes a maximum of information available.

In recent times there has been a great deal of work done on the delimitation of the genera of crustose lichens. In particular the large genera *Lecanora* and *Lecidea* together with the other superficially similar genera, have been reviewed. As a result many old genera have been reinstated for use, and many new genera proposed. Our knowledge of the crustose lichens of Australia is very scant indeed, and it is not possible to be sure which of these many genera do occur in Australia. A conservative approach to the taxonomy of the crustose lichens has therefore been taken: perhaps at some time in the future a critical review like that of the British lichen flora by Hawksworth, James and Coppins (1980) will be possible in Australia.

Extra information for most genera has been drawn from the account of families prepared by Poelt (1973), providing information which will not normally be used in identifying material (for example, nature of ascus wall) but which does help make the arrangement into families more clear.

It is doubtful if very much significance can be attached to the description of fulcrum form in pycnidia, but the form of pycnospore has been used to separate genera, notably in division of the old genus *Physcia*. The information has therefore been provided for all genera possible.

Other pieces of information have been gleaned from diverse literature sources over a number of years — in some cases without record of the sources being retained. Original literature sources are therefore not normally acknowledged.

Information on the chemistry of genera has been compiled in the first instance from the accounts by Culberson (1969, 1970) and Culberson *et al.* (1977). In a number of cases, however, revisional studies have either superseded or supplemented their information.

Species number in each genus is based usually on the figure given by Poelt (1973), but figures from revisional studies have sometimes been used instead. Australian distributions are based on the information in Weber and Wetmore (1972) and Wetmore (1963), supplemented by revisional studies, personal communications and the author's field knowledge.

Many pieces of information have been gleaned from diverse sources over a period of years, and a debt is owned to a great many lichenologists whom it is no longer possible to acknowledge directly.

Notes on the Use of Keys

Users are reminded that there are seven separate keys. Some genera occur in more than one key, for the criteria separating the form groups are not clear cut. Some genera will be found treated in sections to which they strictly do not belong, but to which a casual examination will suggest they do. The keys are designed not to reflect taxonomy, but simply to facilitate naming.

The keys to the fruticose and foliose genera have been designed to allow determination of a specimen when sterile as far as is practicable — and many species will be found only in the sterile condition. The keys to other groups could not be so arranged. It is simply not possible to key out a sterile crustose or squamulose lichen at this time. We do not have sufficient information, and it seems unlikely that we ever will.

To key out to genus a crustose or squamulose lichen requires fertile material, and access to a microscope. Such determinations can only be made in a laboratory, not in the field.

The wording of the keys is deliberate. Users must read both of the choices offered in these strictly dichotomous keys before deciding which is the appropriate one, and must consider all of the information included. Until the user is familiar with the usage of words in the keys, free use should be made of the glossary. When a genus name has been arrived at from the key, the specimen should be carefully compared with the description, for a key cannot always provide the right answer even if the user has made the correct choice at every step — and since incorrect choices are possible, to do so is even more important. Further, comparison with reliably named material in a herbarium is most desirable.

Genera New for Australia

The following genera were not listed for Australia in the catalogues produced by Wetmore (1963) for Tasmania and Weber and Wetmore (1972) for Australia excluding Tasmania, but are now known for the region.

Those marked * are the result of entirely new records, and the others are genera segregated out of those indicated.

*_Arctomia_
Bulbothrix (Parmelia)
*_Candelariella_
*_Cetrelia_
Chrysothrix (Lepraria)
Cladina (Cladonia)
Coccotrema (Perforaria)
*_Conotremopsis_
*_Cystocoleus_
Diploicia (Buellia)
Dirinaria (Physcia)
Fistulariella (Ramalina)
Heterodermia (Anaptychia)
Hypotrachyna (Parmelia)
Mallotium (Leptogium)
*_Mastodia_
Melanelia (Parmelia)
Neofuscelia (Parmelia)
Pannoparmelia (Anzia)
Parmelina (Parmelia)
Parmotrema (Parmelia)
Phaeophyscia (Physcia)
Physciopsis (Physcia)
*_Placynthium_
*_Polycaulonia_
Protoblastenia (Lecidea)
Pseudoparmelia (Parmelia)
Psora (Lecidea)
*_Psoromaria_
Relicina (Parmelia)
*_Sagenidium_
*_Spilonema_
Squamarina (Lecanora)
*_Thelidium_
*_Thyrea_
*_Trimmatothele_
Xanthoparmelia (Parmelia)
*_Xylographa_

Classification

This outline classification of the genera of lichen forming fungi reported from Australia is based on Poelt (1973).

DIVISION EUMYCOTA
SUBDIVISION ASCOMYCOTINA

ORDER ARTHONIALES
ARTHONIACEAE
Arthonia
Arthothelium
Gymnographa
OPEGRAPHACEAE
Chiodecton
Enterodictyon
Enterographa
Mazosia
Opegrapha
LECANACTIDACEAE
Catinaria
Lecanactis
Melampydium
Schismatomma
ROCELLACEAE
Dirina
Dirinastrum
Rocella
Sagenidium
CHRYSOTHRICACEAE
Chrysothrix

ORDER DOTHIDALES
PLEOSPORACEAE
Arthopyrenia
Dermatina
Microthelia
Mycoporellum
Polyblastiopsis
Tomasellia

ORDER VERRUCARIALES
VERRUCARIACEAE
Dermatocarpon
Endocarpon
Mastodia
Thelidium
Trimmatothele
Verrucaria

ORDER PYRENULALES
PYRENULACEAE
Anthracothecium
Asteroporum
Parathelium
Parmentaria
Pleurotheliopsis
Pseudopyrenula
Pyrenula
TRYPETHELIACEAE
Melanotheca
Trypethelium
LAURERACEAE
Bottaria
Campylothecium
Laurera
STRIGULACEAE
Aspidothelium
Pleurotrema
Strigula
CLATHROPORINACEAE
Clathroporina
Porina
Tricothelium

ORDER CALICIALES
MYCOCALICIACEAE
Stenocybe
CALICIACEAE
Calicium
Chaenotheca
Coniocybe
Cyphelium
Pyrgillus
Tylophoron
SPHAEROPHORACEAE
Sphaerophorus

ORDER OSTROPALES
THELOTREMACEAE
Conotremopsis
Diploschistes
Leptotrema
Ocellularia
Phaeotrema
Thelotrema
Tremotylium

ORDER GRAPHIDALES
GRAPHIDACEAE
Aulaxina
Diplogramma
Glyphis
Graphina
Graphis
Helminthocarpon
Medusulina
Phaeographina
Phaeographis
Sarcographa
Sarcographina
MELASPILEACEAE
Melaspilea
ASTROTHYRIACEAE
Echinoplaca
Gyalectidium
Sagiolechia
Tricharia
GYALECTACEAE
Coenogonium
Dimerella
Gyalecta

ORDER LECANORALES
LICHINACEAE
Ephebe
Lempholemma
Lichina
Peccania
Porocyphus
Pyrenopsidium
Pyrenopsis
Synalissa
Thyrea
HEPPIACEAE
Heppia
Peltula
PLACYNTHIACEAE
Placynthium
Psoroma
Psoromaria
PELTIGERACEAE
Peltigera
NEPHROMIACEAE
Nephroma
LOBARIACEAE
Lobaria
Pseudocyphellaria
Sticta
COLLEMATACEAE
Collema
Leptogium
Mallotium
Physma
COCCCOCARPIACEAE
Coccocarpia
Spilonema
PANNARIACEAE
Erioderma
Pannaria
Parmeliella
ARCTOMIACEAE
Arctomia
LECIDEACEAE
Bacidia
Bombyliospora
Byssoloma
Catillaria
Crocynia
Lecidea
Lopadium
Megalospora
Phylctella
Phyllopsora
Psora
Rhizocarpon
Sporopodium
Tapellaria
Toninia

LECANORACEAE
Haematomma
Lecania
Lecanora
Squamarina
ASPICILIACEAE
Aspicilia
Placopsis
HYPOGYMNIACEAE
Hypogymnia
Menegazzia
Pseudevernia
PARMELIACEAE
Bulbothrix
Cetraria
Cetrelia
Chondropsis
Hypotrachyna
Pannoparmelia
Parmelia
Parmelina
Parmeliopsis
Parmotrema
Pseudoparmelia
Relicina
Xanthoparmelia
USNEACEAE
Alectoria
Coelocaulon
Evernia
Neuropogon
Usnea
RAMALINACEAE
Fistulariella
Ramalina
ANZIACEAE
Anzia
STEREOCAULACEAE
Pilophorus
Stereocaulon
CLADONIACEAE
Cladia
Cladina
Cladonia
Gymnoderma
Ramalea
Thysanothecium
HETERODEACEAE
Heterodea
BAEOMYCETACEAE
Baeomyces
SIPHULACEAE
Siphula
Thamnolia
UMBILICARIACEAE
Umbilicaria
ACAROSPORACEAE
Acarospora
Biatorella
Maronea
Sarcogyne
Sporastatia
PERTUSARIACEAE
Coccotrema
Ochrolechia
Pertusaria
CANDELARIACEAE
Candelaria
Candelariella
TELOSCHISTACEAE
Caloplaca
Fulgensia
Polycaulonia
Protoblastenia
Teloschistes
Xanthoria
PHYSCIACEAE
Anaptychia
Buellia
Diploicia
Dirinaria
Heterodermia
Phaeophyscia
Physcia
Physciopsis
Pyxine
Rinodina
MICAREACEAE
Micarea
TRAPELIACEAE
Placopsis
Trapelia
AGYRACEAE
Xylographa

SUBDIVISION BASIDIOMYCOTINA
ORDER APHYLLOPHORALES
DICTYONEMATACEAE
Dictyonema
Herpothallon

SUBDIVISION DEUTEROMYCOTINA
Cystocoleus
Dendriscocaulon
Leparia
Leprocaulon
Normandina

Keys to the Genera of Lichens in Australia

A series of seven artificial keys to genera are presented:

Fruticose thalli page 13
Foliose thalli page 16
Squamulose thalli page 21
Crustose thalli page 23
Filamentous thalli page 33
Leprose thalli page 34
Basidiolichens page 35

In some cases it has not been possible to provide key characters for genera. These are a few genera of crustose or squamulose lichens which are not known to form fruiting bodies, the basis for the key to those groups. These genera are listed in the end of the relevant key.

Fruticose thalli

1.	Thallus filamentous or terete, regular	2
1.	Thallus flattened or irregular and of unequal thickness	9
2.	With a resistant chondroid axis	3
2.	Without a chondroid axis	4
3.	Branches light yellow at the base, shading to black in the upper regions, disk black or dark	*Neuropogon*
3.	Branches yellow-green to grey or red, disk pale	*Usnea*
4.	Thallus hollow, or with perforations through the cortex to the central medullary regions	43
4.	Thallus solid, imperforate	5
5.	Thallus yellow-green to grey or pink	45
5.	Thallus brown or black (at least near the tips)	6
6.	Without pseudocyphellae, thallus black (at least at the tips)	7
6.	With pseudocyphellae, thallus brown	47
7.	Thallus of blue-green algal filaments (*Stigonema*) with hyphae ramifying through the gelatinous sheath	8
7.	Thallus with a well developed fungal cortex enclosing the green alga *Trebouxia* or the blue-green alga *Nostoc*	48
8.	Apothecia immersed in swellings	*Ephebe*
8.	Apothecia terminal on lobes	*Spilonema*
9.	Thallus gelatinous when wet	10
9.	Thallus not gelatinous when wet	14
10.	Thallus a loose weft of prostrate filaments	11
10.	Thallus not of prostrate filaments	12
11.	Apothecia immersed in swellings	*Ephebe*
11.	Apothecia terminal on lobes	*Spilonema*
12.	On rocks in the marine splash zone, apothecia in urceolate swellings	*Lichina*
12.	Not in marine splash zone, apothecia not in urceolate swellings	13
13.	Thallus of thin ascending branches (usually on granites)	*Porocyphus*
13.	Thallus branches as thick as they are tall, aggregated to form a crust-like plaque (usually on calcareous substrates)	*Synalissa*

14. Crustose primary thallus bearing minutely stipitate fruiting bodies (less than 2 mm tall)	15
14. Thallus entirely fruticose, or the primary thallus bearing podetia or pseudopodetia more than 2 mm tall	18
15. Spores simple	16
15. Spores septate	17
16. Spores pale (hyaline to yellow)	*Coniocybe*
16. Spores dark (brown)	*Chaenotheca*
17. Spores once septate	*Calicium*
17. Spores 3-7 septate	*Stenocybe*
18. Thallus hollow	19
18. Thallus solid	23
19. Thallus vermiform, white or pale grey, alpine	*Thamnolia*
19. Thallus not vermiform, variously coloured and distributed	20
20. On twigs, bark or wood	*Fistulariella*
20. On soil or rocks, or among mosses and litter	21
21. Medulla stained yellow with usnic acid, on acid heath soils	*Ramalea*
21. Medulla not yellow from usnic acid	22
22. Walls perforate to the hollow centre or rather lax medulla	*Cladia*
22. Axils sometimes perforate, but not the lateral walls	*Cladonia*
23. Spores free in a mazaedium at maturity	*Sphaerophorus*
23. Spores retained in an ascus at maturity	24
24. Branches with a strong central chondroid axis	25
24. Branches without a strong central chondroid axis	26
25. Branches light yellow at the base becoming black at the tips	*Neuropogon*
25. Branches yellow-green to grey or red	*Usnea*
26. Apothecia lateral on the expanded top of the flattened podetia	*Thysanothecium*
26. Apothecia not on expanded, flattened podetia	27
27. Thallus of well developed basal squamules bearing marginal podetia	28
27 Thallus not of squamules bearing marginal podetia, but cylindrical, irregular or strap-like	29
28. On acid heathland soils, podetia a few millimetres tall	*Ramalea*
28. On trees in wet forests, podetia to 10 millimetres tall	*Gymnoderma*
29. Thallus more or less cylindrical or irregular in cross-section	30
29. Thallus bilaterally flattened, strap-like	34
30. Thallus of anastomosing prostrate pseudocyphellae, rather rope-like strands on calcareous arid soils	*Aspicilia*
30. Thallus erect, not on arid soils	31
31. Lobes with phyllocladia	*Stereocaulon*
31. Lobes without phyllocladia, but may be sorediate	32

32. Thallus golden at least in parts, without a crustose primary thallus	33
32. Thallus never golden, with a primary crustose thallus	40
33. Thallus of recumbent lobes usually 1 cm or more long with lateral apothecia	*Teloschistes*
33. Thallus of short (few millimetres) long lobes with terminal apothecia	*Polycaulonia*
34. Thallus gold, apothecia K+ purple (with parietin)	35
34. Thallus not gold, apothecia not K+ purple (no parietin)	36
35. Thallus of recumbent lobes usually 1 cm or more long with lateral apothecia	*Teloschistes*
35. Thallus of short (few millimetres) long lobes with terminal apothecia	*Polycaulonia*
36. On mangroves on tropical coasts	37
36. Not on tropical mangroves	38
37. Thallus white or grey	*Rocella*
37. Thallus straw-yellow to green	*Ramalina*
38. Thallus straw-yellow to green	*Ramalina*
38. Thallus white to silver grey or brown	39
39. Thallus esorediate	40
39. Thallus sorediate	*Evernia*
40. Apothecia immersed in terminal swellings	*Sphaerophorus*
40. Apothecia not immersed	41
41. On maritime rocks, apothecia adnate	*Sagenidium*
41. On alpine rocks, peat or on soil or twigs	42
42. Thallus less than 2 cm tall, base of lobes immersed in soil or peat	46
42. Thallus larger, loosely adnate on rocks, soil or twigs	*Cetraria*
43. Thallus perforate	*Cladia*
43. Thallus imperforate	44
44. Apothecia naked, in terminal cymes, apices nodding	*Cladina*
44. Apothecia immersed in terminal swellings, apices erect	*Sphaerophorus*
45. Apothecia sessile or shortly stipitate, with a distinct margin	*Ramalina*
45. Apothecia on erect podetia, often inflated and emarginate	*Baeomyces*
46. Thallus brown, usually with black apothecia	*Toninia*
46. Thallus white or grey, always sterile	*Siphula*
47. Phycobiont green, thallus little branched	*Coelocaulon*
47. Phycobiont blue-green, thallus much branched	*Dendriscocaulon*
48. Phycobiont green, thallus cylindrical or terete	*Alectoria*
48. Phycobiont blue-green, thallus irregular	*Dendriscocaulon*

Foliose thalli

1.	Lower surface with well developed rhizines	2
1.	Lower surface apparently devoid of rhizines, sparsely rhizinate at the margins only, naked or tomentose	44
2.	Lobes 1 cm or more wide	3
2.	Lobes less than 1 cm wide	15
3.	Lower cortex with cyphellae or pseudocyphellae	4
3.	Lower cortex with neither cyphellae nor pseudocyphellae	5
4.	Lower cortex truly cyphellate	*Sticta*
4.	Lower cortex pseudocyphellate	*Pseudocyphellaria*
5.	Lower surface with vein-like markings, apothecia on the upper side of marginal projections	*Peltigera*
5.	Not as above	6
6.	Upper cortex yellow-gold, K+ purple (parietin)	*Xanthoria*
6.	Upper cortex brown, grey or straw-yellow to green, never K+ purple (no parietin)	7
7.	Thallus brown	70
7.	Thallus grey or straw-yellow to green, apothecia on the upper surface	8
8.	Upper cortex pseudocyphellate or reticulately cracked on young lobes	9
8.	Upper cortex not pseudocyphellate nor reticulately cracked except on very old lobes	10
9.	Pseudocyphellae minute (less than 0.1 mm diameter) ovoid	*Cetrelia*
9.	Pseudocyphellae larger, effigurate	*Parmelia*
10.	On rocks or soil, thallus straw-yellow to green (usnic acid)	*Xanthoparmelia*
10.	On any substrate, but if on rocks or soil not straw-yellow to yellow-green (without usnic acid)	11
11.	Rhizines dichotomously branched	*Hypotrachyna*
11.	Rhizines simple or squarrosely branched	12
12.	Thallus with marginal cilia	13
12.	Thallus without marginal cilia	14
13.	Lobes apically truncate, rhizines to the lobe tips	*Parmelina*
13.	Lobes broadly rotund at the tip, rhizines absent from a broad zone below the tips of lobes	*Parmotrema*

14. Lobes apically truncate, rhizines present to the lobe tips	*Pseudoparmelia*
14. Lobes broadly rotund at the tips, rhizines absent from a broad zone below the tips of the lobes	*Parmotrema*
15. Margin of the thallus ciliate	16
15. Margin of the thallus eciliate	25
16. Cilia bulbate at the base	17
16. Cilia not bulbate	18
17. Thallus grey (atranorin)	*Bulbothrix*
17. Thallus straw-yellow to yellow-green (usnic acid)	*Relicina*
18. Upper cortex brown	*Phaeophyscia*
18. Upper cortex white, grey or straw yellow to green	19
19. Upper cortex of young lobes reticulately cracked or pseudocyphellate	*Parmelia*
19. Upper cortex of young lobes neither reticulately cracked nor pseudocyphellate	20
20. Rhizines dichotomously branched	21
20. Rhizines simple or squarrose	23
21. Upper cortex of longitudinally oriented hyphae, giving the thallus a waxy appearance	22
21. Upper cortex of plectenchyma, giving the thallus a dull surface	*Hypotrachyna*
22. Spores with blastidia, thallus normally adnate	*Heterodermia*
22. Spores with two locules only, thallus normally ascending	*Anaptychia*
23. Spores two celled, lobes usually 2 mm or less wide	*Physcia*
23. Spores simple, lobes usually more than 2 mm wide	24
24. Lobe tips truncate, rhizines right to the tips of lobes	*Parmelina*
24. Lobe tips broadly rotund, rhizines absent from a broad marginal zone	*Parmotrema*
25. Upper surface bright yellow or yellow gold	26
25. Upper surface, white, grey, brown or straw-yellow to yellow-green	27
26. Thallus K+ purple (parietin), lobes more than 2 mm wide	*Xanthoria*
26. Thallus K− (without parietin), lobes less than 1 mm broad	*Candelaria*
27. Thallus brown or olive	28
27. Thallus white, grey or straw-yellow to yellow-green	31
28. Spores simple	29
28. Spores septate	30
29. Upper cortex of interwoven hyphae	*Parmeliopsis*
29. Upper cortex plectenchymatous	74
30. Pycnospores spherical (lobes usually about 2 mm broad)	*Phaeophyscia*
30. Pycnospores acicular (lobes often less than 1 mm broad)	*Physciopsis*
31. Thallus on rocks or soil and straw-yellow to yellow-green	*Xanthoparmelia*
31. Thallus white or grey, or if straw-yellow to yellow-green not on rocks or soil	32

32. Upper cortex of young lobes reticulately cracked or pseudocyphellate	33
32. Upper cortex of young lobes neither reticulately cracked nor pseudocyphellate	35
33. Lobes more than 2 mm wide	34
33. Lobes less than 2 mm wide	*Pyxine*
34. Pseudocyphellae minute (less than 0.1 mm diameter) ovoid	*Cetrelia*
34. Pseudocyphellae effigurate	*Parmelia*
35. Rhizines dichotomously branched	*Hypotrachyna*
35. Rhizines simple or squarrose	36
36. Upper cortex of interwoven hyphae	37
36. Upper cortex plectenchymatous	39
37. Spores simple	*Parmeliopsis*
37. Spores septate	38
38. Spores with blastidia, thallus normally adnate	*Heterodermia*
38. Spores without blastidia, thallus commonly ascending	*Anaptychia*
39. Spores simple	40
39. Spores septate	41
40. Lobes broadly rotund at the tips, rhizines absent from a broad naked zone near the lobe tips	*Parmotrema*
40. Lobes truncate at the tips, rhizines present right up to the tips of lobes	*Pseudoparmelia*
41. Apothecium with a proper exciple only	*Pyxine*
41. Apothecium with a thalloid exciple	42
42. Hypothecium hyaline	*Physcia*
42. Hypothecium dark	43
43. Thallus K+ yellow (atranorin)	*Dirinaria*
43. Thallus K− (no atranorin)	*Pyxine*
44. Rhizines present but restricted to the thallus margin	45
44. Rhizines absent	46
45. Spores with blastidia, thallus normally adnate	*Heterodermia*
45. Spores two celled only, thallus normally ascending	*Anaptychia*
46. Thallus umbilicate	47
46. Thallus not umbilicate	49
47. Thallus not gelatinous when wet	*Umbilicaria*
47. Thallus gelatinous when wet	48
48. Phycobiont *Scytonema*	*Porocyphus*
48. Phycobiont *Xanthocapsa*	*Thyrea*
49. Thallus on a tomentum	50
49. Thallus naked below	54
50. Upper surface of the thallus scrobiculate	*Lobaria*
50. Upper surface smooth or slightly irregular	51

51.	Thallus with green algae	52
51.	Thallus with blue-green algae	53
52.	Lobes less than 2 mm broad	71
52.	Lobes more than 2 mm broad	*Heterodea*
53.	Phycobiont *Scytonema*	76
53.	Phycobiont *Nostoc*	72
54.	Phycobiont green	55
54.	Phycobiont blue-green	62
55.	Thallus inflated, hollow, or the medulla thick, often loose and cobweb-like	56
55.	Thallus not inflated, solid, the medulla thin	57
56.	Upper cortex pierced by holes to the centre of the thallus	*Menegazzia*
56.	Upper cortex not pierced by holes	*Hypogymnia*
57.	Thallus free or loosely attached to the soil	58
57.	Thallus adnate on rock wood or bark	59
58.	With cyphella-like pores below, apothecia marginal	*Heterodea*
58.	Lower surface without cyphella-like pores, apothecia laminal	73
59.	Upper cortex densely tomentose	*Erioderma*
59.	Upper cortex naked	60
60.	Thallus brown or olive	67
60.	Thallus grey	61
61.	Thallus closely adnate, medulla thin	*Dirinaria*
61.	Thallus loosely adnate, medulla thick	69
62.	Spores with a thick wall and slime coating	*Physma*
62.	Spores with thin walls without slime	63
63.	Thallus of hyphae wholly embedded in the algae	*Lempholemma*
63.	Thallus with a developed cortex	64
64.	Spores non-septate, thallus heteromerous	65
64.	Spores septate, thallus homeomerous	66
65.	Apothecia with a proper exciple	*Parmeliella*
65.	Apothecia with a thalloid exciple	*Pannaria*
66.	Upper cortex of interwoven hyphae	*Collema*
66.	Upper cortex cellular	*Leptogium*
67.	Thallus ascending, attached only by a holdfast	*Cetraria*
67.	Thallus closely adnate, attached by the lower surface	68
68.	Thallus with cephalodia	*Placopsis*
68.	Thallus without cephalodia	*Physciopsis*
69.	Lower surface black, thallus inflated	*Hypogymnia*
69.	Lower surface pale, thallus compressed	*Cetraria*
70.	Apothecia on upper surface of thallus	74
70.	Apothecia on lower surface of thallus	*Nephroma*

71. Thallus white or grey, spores many per ascus *Anzia*
71. Thallus brown or green, spores eight per ascus *Pannoparmelia*

    72. Upper cortex a single cell layer, thallus gelatinous, tomentum short *Mallotium*
    72. Upper cortex several cell layers, thallus not gelatinous, tomentum often long 75

73. Thallus rolling into a ball when dry, pale below *Chondropsis*
73. Thallus often markedly channelled, but not rolling into a ball, dark below *Pseudevernia*

    74. Thallus blue with HNO_3, with neither isidia nor soredia *Neofuscelia*
    74. Thallus HNO_3^- or HNO_3 red, usually with isidia or sorediate isidia *Melanelia*

75. Spores thin walled *Pannaria*
75. Spores thick walled *Physma*

    76. Upper cortex smooth, striate *Coccocarpia*
    76. Upper cortex shaggy *Erioderma*

Squamulose thalli

1.	Fruiting bodies markedly stipitate (with a secondary thallus)	2
1.	Fruiting bodies sessile to immersed	8
2.	Secondary thallus hollow	3
2.	Secondary thallus solid	4
3.	Hypothecium pale, apothecium flat or convex	*Cladonia*
3.	Hypothecium dark, apothecium conical or globose	*Pilophorus*
4.	Apothecia lateral on the tips of flattened podetia	*Thysanothecium*
4.	Apothecia terminal on more or less cylindrical podetia	5
5.	Medulla with usnic acid	*Ramalea*
5.	Medulla without usnic acid	6
6.	Spores septate	27
6.	Spores simple	7
7.	Primary thallus corticate, paraphyses reticulate	*Gymnoderma*
7.	Primary thallus ecorticate, paraphyses unbranched	*Pilophorus*
8.	Asci immersed in fruiting bodies opening by a pore	9
8.	Asci in open disk	11
9.	Spores simple	10
9.	Spores septate	*Endocarpon*
10.	Thallus ecorticate, of loosely woven hyphae	*Mastodia*
10.	Thallus corticate above, paraplectenchymatous	*Dermatocarpon*
11.	Spores simple	12
11.	Spores septate	24
12.	Asci polysporous	13
12.	Asci with 1-16 spores	15
13.	Thallus with a thick upper cortex	14
13.	Thallus ecorticate	*Pyrenopsis*
14.	Phycobiont blue-green	*Peltula*
14.	Phycobiont green	*Acarospora*
15.	Thallus ecorticate	*Pyrenopsis*
15.	Thallus with a developed cortex	16
16.	Apothecia immersed	17
16.	Apothecia sessile or adnate	18

17. Phycobiont blue-green	*Heppia*
17. Phycobiont green	*Trapelia*
18. Apothecia with a thalloid exciple	19
18. Apothecia with a proper exciple	21
19. Phycobiont *Nostoc*	*Pannaria*
19. Phycobiont green	20
20. Lower surface sparingly rhizinate	*Psoroma*
20. Lower surface without rhizines	*Squamarina*
21. Phycobiont blue-green	22
21. Phycobiont green	23
22. Upper surface with fine longitudinal striae, phycobiont *Scytonema*	*Coccocarpia*
22. Upper surface not striate, phycobiont *Nostoc*	*Parmeliella*
23. Squamules finely lacerate	*Phyllopsora*
23. Squamules not lacerate	29
24. Spores brown	25
24. Spores hyaline	26
25. Apothecia with thalloid exciple at maturity	*Rinodina*
25. Apothecia with proper exciple at maturity	*Diploicia*
26. Spores polarilocular	*Caloplaca*
26. Spores septate	28
27. Disk pink	*Baeomyces*
27. Disk black	*Toninia*
28. Phycobiont green *(Trebouxia)*	*Toninia*
28. Phycobiont blue-green *(Dichotrix)*	*Placynthium*
29. Lower surface sparingly rhizinate	*Psoromaria*
29. Lower surface without rhizines	*Psora*

The genus *Normandina* is never fertile.
Cladonia squamules are commonly found sterile.

8. Paraphyses soon gelatinizing	*Thelidium*
8. Paraphyses permanent	*Pleurotrema*
9. Fruiting body an apothecium immersed in warts	*Ocellularia*
9. Fruiting body a perithecium	10
10. Thallus obligately foliicolous, always subcuticular (alga *Cephaleuros*)	*Strigula*
10. Thallus not obligately foliicolous, but if on leaves supracuticular (alga *Trentepohlia* or *Phycopeltis*)	*Porina*
11. The opening of the perithecium ornamented with a star-shaped disk	*Asteroporum*
11. The opening of the perithecium simple or slit-like	12
12. Fruiting structure compounded from several hymenia opening by an irregular pore or slit	*Mycoporellum*
12. Fruiting body with a single hymenium, opening by a pore	13
13. Spore walls unequally thickened, resulting in lenticular locules	*Pyrenula*
13. Spore walls evenly thickened, locules cylindrical	*Microthelia*
14. Spores transversely septate only	15
14. Spores muriform	27
15. Spores hyaline	16
15. Spores brown	25
16. Fruiting body an apothecium immersed in thalline warts	*Ocellularia*
16. Fruiting body a perithecium, or group of perithecia, sometimes immersed in thalline warts	17
17. Fruiting body with several hymenia, opening by an irregular pore or by a slit	*Mycoporellum*
17. Perithecium with a single hymenium opening by a pore	18
18. Perithecia immersed singly or in groups in stromatic tissue	19
18. Perithecia not aggregated in stromatic tissue	20
19. Spore walls unequally thickened, resulting in lenticular loculi	*Trypethelium*
19. Spore walls of even thickness, locules cylindrical	*Tomasellia*
20. Paraphyses branched and anastomosing	21
20. Paraphyses simple or forked towards the tips, but not anastomosing	23
21. Spore walls unequally thickened, resulting in lenticular locules	*Pseudopyrenula*
21. Spore walls evenly thickened, locules cylindrical	22
22. Ostiolar canal markedly oblique or prostrate	*Pleurotrema*
22. Ostiolar canal erect	*Arthopyrenia*
23. Spore walls unequally thickened to produce lenticular locules, thallus not normally foliicolous	*Pyrenula*
23. Spore walls thin, locules cylindrical	24
24. Perithecia with a corona of spreading bristles	*Trichothelium*
24. Perithecia without a corona of spreading bristles	38

5. Spores 3-7 septate	*Stenocybe*
5. Spores 1 septate	*Calicium*

Key to genera of Group C: fruiting structures open, spores simple

1. Fruiting bodies stipitate on podetia or pseudopodetia	2
1. Fruiting bodies sessile to immersed, but not stipitate	6
2. Podetia flattened laterally towards the top, apothecia facial on the flattened area	*Thysanothecium*
2. Podetia not laterally flattened toward the top	3
3. Apothecia terminal, conical or globose, hypothecium dark, podetia imperforate, rarely branched	4
3. Apothecia terminal or lateral, never globose, hypothecium pale or if dark on much branched perforate pseudopodetia	5
4. Primary thallus granular	*Pilophorus*
4. Primary thallus isidiate	*Gymnoderma*
5. Podetia richly di- or tri-chotomously branched	*Cladina*
5. Podetia little branched	*Cladonia*
6. Phycobiont blue-green	7
6. Phycobiont green	10
7. Thallus of discrete, short, thick, erect cylindrical lobes	*Peccania & Synalissa*
7. Thallus granular	8
8. Phycobiont filamentous *(Scytonema)*	*Porocyphus*
8. Phycobiont coccoid	9
9. Phycobiont *Gloeocapsa* (several cells clumped together)	*Pyrenopsis*
9. Phycobiont *Chroococcus* (cells single or in pairs)	*Pyrenopsidium*
10. Spores 32 or more per ascus	11
10. Spores usually eight, but sometimes 1-16 per ascus	16
11. Thallus yellow or orange-yellow	12
11. Thallus other colours	13
12. Apothecia sessile or adnate	*Candelariella*
12. Apothecia immersed	*Acarospora*
13. Apothecia with a thalloid exciple	14
13. Apothecia with a proper exciple	15
14. Apothecia immersed	*Acarospora*
14. Apothecia sessile to adnate	*Maronea*
15. Exciple pale and soft	*Biatorella*
15. Exciple black and hard	*Sarcogyne*
16. Apothecia pierced by a well defined central pore	*Coccotrema*
16. Apothecia not pierced by a central pore	17
17. Spores brown	*Cyphelium*
17. Spores hyaline	18

Crustose thalli

Key to the artificial groups

1. Asci in fruiting structures which open by a pore (for example, perithecia)	Group A (page 23)
1. Asci in open fruiting structures, not opening by a pore (for example, apothecia)	2
2. Spores free in a mazaedium (not contained in asci) at maturity	Group B (page 25)
2. Spores retained in the ascus at maturity	3
3. Spores simple	Group C (page 26)
3. Spores septate or polarilocular	4
4. Spores once septate or polarilocular	Group D (page 27)
4. Spores more than once septate	5
5. Spores transversely septate only	Group E (page 28)
5. Spores muriform	Group F (page 31)

Key to genera of Group A: Fruiting structures opening by a pore

1. Spores simple	2
1. Spores septate	4
2. Fruiting structure an apothecium	*Pertusaria*
2. Fruiting structure a perithecium or perithecium-like structure	3
3. Asci with 1-8 spores	*Verrucaria*
3. Asci with many spores	*Trimmatothele*
4. Spores once septate	5
4. Spores more than once septate	14
5. Spores hyaline	6
5. Spores brown	11
6. Paraphyses absent or reticulately branched	7
6. Paraphyses simple or forked, but not reticulately branched	9
7. Fruiting structure usually compounded from several hymenia, opening by an irregular pore or slit	*Mycoporellum*
7. Fruiting structure of discrete perithecia, sometimes several immersed in thalline warts	8

25.	Fruiting structure usually compounded from several hymenia opening by an irregular pore or slit	*Mycoporellum*
25.	Fruiting structure with a single hymenium, opening by an ostiole	26
26.	Perithecia usually aggregated, immersed in stromatic tissue	*Melanotheca*
26.	Perithecia single, not immersed in stromatic tissue	*Parathelium & Pyrenula*
27.	Spores hyaline	28
27.	Spores brown	33
28.	Fruiting structure usually compounded from several hymenia, opening by an irregular pore or slit	*Dermatina*
28.	Fruiting structure with a single hymenium opening by an ostiole	29
29.	Paraphyses neither gelatinizing nor reticulately branched and anastomosing	30
29.	Paraphyses gelatinizing or reticulately branched	31
30.	Perithecium bearing a broad convex disk about the ostiole	*Aspidothelium*
30.	Perithecium with an unornamented ostiole	*Clathroporina*
31.	Perithecia immersed in stromatic tissue	*Laurera*
31.	Perithecia not immersed in stromatic tissue	32
32.	Ostiole extended into an oblique canal	*Campylothecium*
32.	Ostiole straight, punctiform	*Polyblastiopsis*
33.	Fruiting body usually compounded from several hymenia, opening by an irregular pore or slit	*Dermatina*
33.	Fruiting body with a single hymenium, opening by a pore	34
34.	Paraphyses simple, unbranched	35
34.	Paraphyses reticulately branched and anastomosing	36
35.	Perithecia grouped and immersed in stromatic tissue	*Bottaria*
35.	Perithecia single, not immersed in stromatic tissue	*Anthracothecium*
36.	Ostiolar canals erect	*Bottaria*
36.	Ostiolar canals horizontal or oblique	37
37.	Spores with lenticular or spherical locules	*Parmentaria*
37.	Spores with cubical locules	*Pleurotheliopsis*
38.	Thallus subcuticular	*Strigula*
38.	Thallus supracuticular	*Porina*

Key to genera of Group B: spores free in a mazaedium at maturity

1.	Spores simple	2
1.	Spores septate	3
2.	Spores pale (hyaline or yellow)	*Coniocybe*
2.	Spores dark (brown)	*Chaenotheca*
3.	Fruiting bodies sessile	4
3.	Fruiting bodies at least shortly stipitate	5
4.	Apothecium with a thalline margin	*Tylophoron*
4.	Apothecium with a proper margin only	*Pyrgillus*

18. Apothecia immersed in warts	*Pertusaria*
18. Apothecia immersed or sessile on the thallus	19
19. Thallus and/or apothecia yellow or orange-yellow	20
19. Thallus and apothecia not yellow or orange-yellow	22
20. Thallus or apothecia K + purple (parietin)	21
20. Thallus and apothecia not K + purple (without parietin)	*Candelariella*
21. Thallus with distinct marginal lobes	*Fulgensia*
21. Thallus uniform	*Protoblastenia*
22. Paraphyses reticulate	23
22. Paraphyses simple, branched or dissolving	24
23. Apothecia immarginate	*Micarea*
23. Apothecia with a developed thalline exciple	*Ochrolechia*
24. Apothecia with a proper exciple	25
24. Apothecia with a thalline exciple	27
25. Thallus corticate or absent, not a loose hyphal weft	29
25. Thallus a loose weft of hyphae	26
26. Thallus with a thick black hypothallus	*Crocynia*
26. Thallus without a distinctive hypothallus	*Coenogonium*
27. Thallus with external cephalodia	*Placopsis*
27. Thallus without cephalodia	28
28. Apothecia immersed	*Aspicilia*
28. Apothecia sessile	*Lecanora*
29. Apothecia well developed, round	*Lecidea*
29. Apothecia without an exciple or exciple poorly developed, irregular, minute.	*Xylographa*

Key to genera of Group D: fruiting structures open, spores once septate or polarilocular

1. Spores hyaline	2
1. Spores brown	21
2. Fruiting bodies raised on podetia	3
2. Fruiting bodies sessile or immersed	4
3. Apothecia terminal at maturity	*Baeomyces*
3. Apothecia lateral on flattened podetia at maturity	*Thysanothecium*
4. Spores polarilocular	5
4. Spores truly septate	6
5. Thallus sometimes areolate, apothecia laminal	*Caloplaca*
5. Thallus of areoles produced vertically to become minutely fruticose, apothecia terminal	*Polycaulonia*
6. Paraphyses reticulate	7
6. Paraphyses unbranched or branched but not reticulate	11
7. Hymenium elongate, between developed labia	*Opegrapha*
7. Hymenium irregular or ovoid but not with labia	8

8. Asci globose	*Arthonia*
8. Asci clavate-cylindrical	9
9. Thallus with algae restricted to discrete minute warts or goniocysts	*Micarea*
9. Thallus with a more or less continuous algal layer	10
10. Hypothecium pale	*Megalospora*
10. Hypothecium dark	*Catinaria*
11. Spore walls unequally thickened, locules lenticular	12
11. Spore walls evenly thickened, locules cylindrical	13
12. Apothecia with well developed proper and thalloid margins	*Ocellularia*
12. Apothecia with poorly developed margins	*Phlyctella*
13. Apothecia with a thalloid margin at maturity	13
13. Apothecia with a proper margin at maturity	16
14. Thallus bright yellow or orange-yellow	*Candelariella*
14. Thallus of other colours	14
15. Spores 32 or more per ascus	*Maronea*
15. Spores 1-16 per ascus	*Phylctella*
16. Disk surrounded by a cobweb-like hyphal veil	*Byssoloma*
16. Disk without a veil	17
17. Margin of disk orange	*Dimerella*
17. Margin of disk not orange	18
18. Disk and margin pink	*Baeomyces*
18. Disk and margin pale or dark but not pink	19
19. Thallus thick, corticate	*Toninia*
19. Thallus thin, ecorticate	20
20. Spores small (less than 30μm long) with a thin septum	*Catillaria*
20. Spores large (more than 30 μm long) with a thick septum	*Megalospora*
21. Apothecia elongate, or minute and irregular	22
21. Apothecia more or less round	23
22. Spore walls unequally thickened, locules lenticular	*Phaeotrema*
22. Spore walls evenly thickened, locules cylindrical	*Melaspilea*
23. Apothecia with a thalloid margin at maturity	*Rinodina*
23. Apothecia with a proper margin at maturity	*Buellia*

Key to genera of Group E: fruiting structure open, spores transversely two or more septate

1. Spores brown	2
1. Spores hyaline	9
2. Apothecia round, well developed and not immersed in stromatic tissue	3
2. Apothecia elongate, stellate, irregular and immersed in stromatic tissue or rudimentary	4
3. Apothecia with a thalloid margin at maturity	*Rinodina*
3. Apothecia without a thalloid margin at maturity	*Buellia*

4.	Apothecia immersed in stromatic tissue	5
4.	Apothecia not immersed in stromatic tissue	6
5.	Apothecia one per stromatic wart	*Phaeotrema*
5.	Apothecia commonly several per stromatic wart	*Sarcographa*
6.	Apothecia more or less closed by a proper margin which disintegrates to leave a thalloid margin only	*Phaeotrema*
6.	Apothecia rudimentary or with a persistent proper margin	7
7.	Apothecia only rudimentary, spore walls evenly thickened, spore locules cylindrical	*Gymnographa*
7.	Apothecia with a well developed proper margin, and sometimes a thalloid margin also, spore walls unequally thickened to produce lenticular locules, or wall uniformly thin	8
8.	Exciple of distinct labia, not entire	*Phaeographis*
8.	Exciple continuous, entire	*Dirinastrum*
9.	Fruiting bodies stipitate	10
9.	Fruiting bodies sessile to immersed	11
10.	Spores 1-3 septate, elongate	*Baeomyces*
10.	Spores up to 100 septate, filiform	*Gomphyllus*
11.	Apothecia grouped in stromatic tissue	12
11.	Apothecia not grouped in stromatic tissue	15
12.	Paraphyses simple, spore walls even in thickness, spore locules cylindrical	*Glyphis*
12.	Paraphyses branched and anastomosing, spore walls unevenly thickened to form lenticular loculi	13
13.	Thallus foliicolous, alga *Phycopeltis*	*Mazosia*
13.	Thallus not foliicolous, alga *Trentepohlia*	*14*
14.	Hypothecium pale	*Enterographa*
14.	Hypothecium dark	*Chiodecton*
15.	Apothecia elongate or stellately irregular; if ovoid, exciple poorly developed or absent	16
15.	Apothecia round, exciple usually well developed	18
16.	Twin hymenia parallel to the axis of the apothecium	*Diplogramma*
16.	Single hymenium only	17
17.	Paraphyses reticulately branched and anastomosing	18
17.	Paraphyses simple or forked, but not anastomosing	20
18.	Apothecia with a well developed margin	19
18.	Apothecia without a margin	21
19.	Spore walls unequally thickened to produce lenticular locules	*Helminthocarpon*
19.	Spore walls of even thickness, locules cylindrical	25
20.	Spore walls of even thickness, locules cylindrical	23
20.	Spore walls unequally thickened, locules lenticular	*Graphis*
21.	Thallus foliicolous	47
21.	Thallus not foliicolous	22

22.	Spores with asymmetric locules	*Arthonia*
22.	Spores with symmetrical locules	*Melaspilea*
23.	Exciple lateral along the margin of the hymenium only	*Aulaxina*
23.	Margin either surrounding the apothecium or absent	24
24.	Hypothecium black, carbonaceous	*Lecanactis*
24.	Hypothecium pale	*Melampydium*
25.	Exciple lateral along the margin of the hymenium only	*Opegrapha*
25.	Exciple surrounding the roundish hymenium, or absent	26
26.	Exciple carbonaceous, without thalloid covering	*Lecanactis*
26.	Exciple usually absent, but if present with a thalloid covering	27
27.	Thallus with a uniform, continuous algal layer	*Schismatomma*
27.	Thallus with algae restricted to small tubercles (goniocysts)	*Micarea*
28.	Paraphyses reticulately branched and anastomosing	29
28.	Paraphyses simple or forked, but not anastomosing	32
29.	Upper surface of thallus covered by black hairs	*Tricharia*
29.	Upper surface of thallus naked	30
30.	Exciple absent, or if present poorly developed with a thalloid cover	48
30.	Exciple well developed, without thalloid cover	31
31.	Spores acicular, transversely septate only, Phycobiont *Trentepohlia* on wood and rock	*Lecanactis*
31.	Spores ellipsoid or oblong-ellipsoid, transversely septate or muriform, Phycobiont *Trebouxia*, foliicolous	*Tapellaria*
32.	Apothecia with a thalloid margin at maturity	33
32.	Apothecia without a thalloid margin at maturity	39
33.	Spore walls unequally thickened, locules lenticular	34
33.	Spore walls of even thickness, locules cylindrical	35
34.	Disk initially enclosed by a proper exciple which later cracks away	*Ocellularia*
34.	Disk not enclosed by a proper exciple, although a poorly developed proper exciple may occur	*Phlyctella*
35.	Hypothecium carbonaceous	*Sagiolechia*
35.	Hypothecium pale	36
36.	Spores oblong-ellipsoid, 1-3 or rarely more septate	37
36.	Spores acicular 5+ septate	*Haematomma*
37.	Phycobiont *Trentepohlia*, forming chains in the medulla	*Gyalecta*
37.	Phycobiont Trebouxoid, not forming chains	38
38.	Apothecium pink	*Baeomyces*
38.	Apothecium pale or dark but not pink	*Lecania*
39.	Apothecial margin with an arachnoid veil	*Byssoloma*
39.	Apothecial margin without a veil	41

40. Phycobiont green	46
40. Phycobiont blue-green	42
41. Phycobiont Trebouxoid, not in chains	43
41. Phycobiont *Trentepohlia*, forming chains in the medulla	44
42. Spore walls unequally thickened, locules lenticular	*Bombyliospora*
42. Spore walls evenly thickened, locules cylindrical	43
43. Spores many (up to 100) septate	*Conotremopsis*
43. Spores few septate	*Bacidia*
44. Hypothecium pale	*Gyalecta*
44. Hypothecium carbonaceous	45
45. Spore walls unequally thickened, locules lenticular	*Lecanactis*
45. Spore walls of even thickness, locules cylindrical	*Sagiolechia*
46. Phycobiont *Nostoc*, over mosses	*Arctomia*
46. Phycobiont *Dichothrix*, on soil	*Placynthium*
47. Phycobiont coccoid (*Trebouxia* like)	*Echinoplaca*
47. Phycobiont plate forming (*Phycopeltis*)	*Mazosia*
48. Exciple poorly developed, hyothecium dark	*Schismatomma*
48. Exciple well developed, hypothecium pale	*Haematomma*

Key to genera of Group F: fruiting structures open, spores muriform

1. Spores brown	2
1. Spores hyaline	12
2. Paraphyses reticulately branched and anastomosing	3
2. Paraphyses simple or forked, but not anastomosing	5
3. Apothecia immersed deep in stromatic tissue	*Tremotylium*
3. Apothecia sessile or slightly immersed, but not in stromatic tissue	4
4. Thallus rudimentary, asci pyriform or globose	*Arthothelium*
4. Thallus well developed, areolate, asci clavate	*Rhizocarpon*
5. Fruiting bodies deeply immersed in the thallus or in stromatic tissue, often appearing punctiform	6
5. Fruiting bodies sessile to adnate or slightly immersed	9
6. Apothecia grouped in stromatic patches	*Sarcographina*
6. Apothecia not grouped in stromatic patches	7
7. Hymenium markedly elongate to stellate	*Phaeographina*
7. Hymenium round to ovoid	8
8. The proper exciple disintegrating to leave the hymenium free within the thalloid exciple	*Leptotrema*
8. The proper exciple retained, surrounded by a thalloid exciple also	*Diploschistes*
9. Apothecium markedly elongate to stellate	*Phaeographina*
9. Apothecia round to ovate	10

10. Apothecia immersed or with a distinct thalloid exciple	*Diploschistes*
10. Apothecia with a proper exciple only	11
11. Paraphyses unbranched, tightly packed, spores not mucilagenous	*Buellia*
11. Paraphyses reticulately branched and anastomosing, loose, spores mucilagenous	*Rhizocarpon*
12. Paraphyses branched and anastomosing	13
12. Paraphyses simple or branched, but not anastomosing	19
13. Thallus foliicolous	14
13. Thallus not foliicolous	17
14. Exciple well developed	*Tricharia*
14. Exciple poorly developed	15
15. Epithecium without algae	*Gyalectidium*
15. Epithecium with algae	16
16. Thallus corticate	*Echinoplaca*
16. Thallus ecorticate	*Sporopodium*
17. Thalloid exciple well developed	*Tremotylium*
17. Thalloid exciple absent	18
18. With a well developed proper exciple, asci clavate	*Rhizocarpon*
18. Without an exciple, asci pyriform or globular	*Arthothelium*
19. Fruiting bodies markedly elongate, or grouped in raised stromatic patches	20
19. Fruiting bodies more or less circular, not grouped in stromatic patches	23
20. Fruiting bodies markedly elongate, with lateral exciple only	*Graphina*
20. Fruiting bodies irregularly ovoid to round, immersed in stromatic patches	21
21. Spore walls of even thickness, locules cubical	*Enterodictyon*
21. Spore walls unequally thickened, locules spherical to lenticular	22
22. Apothecia grouped in stromatic patches	*Medusulina*
22. Apothecia single in warts	*Thelotrema*
23. Spore walls of even thickness, locules cubical	24
23. Spore walls unequally thickened, locules spherical to lenticular	*Thelotrema*
24. Spores with a distinct mucilagenous covering	*Rhizocarpon*
24. Spores without a mucilagenous covering	25
25. Exciple never well developed, thallus obligately foliicolous	*Gyalectidium*
25. Exciple usually well developed, not obligately foliicolous	25
26. Phycobiont *Trentepohlia*, algae beneath the hymenium	*Gyalecta*
26. Phycobiont coccoid, without algae beneath the hymenium	*Lopadium*

Leprose thalli

1. Thallus crustose	2
1. Thallus fruticose	*Leprocaulon*
2. Thallus white or grey to green	*Lepraria*
2. Thallus bright yellow	*Chrysothrix*

Basidiolichens

1. Thallus shelf-like, partly free from the substrate, blue-black to deep green	*Dictyonema*
1. Thallus prostrate, adnate to substrate, blood red at least on the margins	*Herpothallon*

Descriptions of Lichen Genera

Under the heading Morphology for each genus the description first deals with the form of the thallus, its anatomy and mode of attachment to the substrate. In the second sentence the reproductive structures are dealt with in order fruiting body form, ascus form and spore form. The third sentence deals with pycnidial structure.

The second heading, Chemistry, is followed by a figure in brackets, which indicates the number of species on which the follow data compilation is based. This is followed by a list of the secondary lichen chemical products reported for the genus in diminishing order of frequency, with the number of species having each constituent indicated in brackets.

The phycobiont is then indicated at least tentatively for all genera.

Notes on the distribution are necessarily sketchy. The number of species reported refers to all records for Australia (including Tasmania) and is followed by a number in brackets which is an estimate of the number of species in the genus for the world.

ACAROSPORA MASS.: *Ric. Lich. Crost.* 27 (1852)

MORPHOLOGY: Thallus crustose to squamulose, areoles or squamules more or less uniform or forming marginal lobes; attached to the substrate only by medullary hyphae; differentiated with a plectenchymatous upper and sometimes lower cortex; medulla compact. *Ascocarp* an apothecium, immersed or rarely sessile, single or many per areole, disk round or irregular, thalloid exciple; hypothecium pale, over an algal layer; paraphyses unbranched, septate; asci unitunicate, thick walled, inflated, I+ pale blue, tholus I+ pale blue, many spored; ascospores minute, simple, hyaline. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong-ellipsoid to globose.

CHEMISTRY: (39 species) rhizocarpic acid (13), gyrophoric acid (8), acaronoic acid (4), lecanoric acid (4), norstictic acid (2), usnic acid (1).

PHYCOBIONT: ?Trebouxia.

DISTRIBUTION: Widespread on rock and soil, especially on drier sites in all mainland states. 15 species reported (300).

ALECTORIA ACH.: *Lich. Univ.* 592 (1810)

MORPHOLOGY: Thallus fruticose, markedly elongate, prostrate or erect; attached by a basal holdfast; lobes terete or flattened, rarely angled; cortex horny, of agglutinated longitudinal hyphae; medulla of loose arachnoid longitudinal hyphae, distinctly segmented; pseudocyphellae and soredia not uncommon. *Ascocarp* an apothecium, lateral, stalked, thalloid margin with or without cilia; disk concave, brown to black; hypothecium pale, over an algal layer; paraphyses branched and anastomosing, asci unitunicate, thick walled, I+, tholus I+ blue, 4-8 spored; ascospores simple, ellipsoid, hyaline to brown, thin walled. *Pycnidia* immersed in thalloid warts; fulcrum endobasidial; pycnospores bacilliform.

CHEMISTRY: (8 species) usnic acid (8), alectoronic acid (6), thamnolic acid (5), barbatic acid (4), olivetoric acid (3), squamatic acid (3), α-collatolic acid (2), alectorialic acid (1), barbatolic acid (1), diffractaic acid (1).

PHYCOBIONT: Trebouxia.

DISTRIBUTION: On bark and soil, restricted to sub-alpine and alpine areas in Tasmania and New South Wales. 3 species reported (40).

ANAPTYCHIA KORB.: *Grund. Krypt.* 197 (1848)

MORPHOLOGY: Thallus foliose to more or less fruticose, usually somewhat ascending, attached to the substrate by rhizines; the lobes usually only a few millimetres broad, often

ciliate; differentiated into upper cortex, medulla and lower cortex; upper cortex of agglutinated longitudinal hyphae, not pseudoparenchymatous; medulla woolly of thin walled hyphae, lower cortex may be almost identical to upper, or less developed. *Ascocarp* an apothecium, laminal or terminal; exciple thalloid; disk dark, often pruinose; paraphyses unbranched; asci clavate unitunicate, thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores 1 septate, without blastidia, walls thickened, dark at maturity. *Pycnidia* immersed or protruding; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (6 species) atranorin (6), zeorin (6).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On trees and rocks, in wetter parts of Queensland, New South Wales, Victoria and Tasmania. 2 species reported (9).

ANTHRACOTHECIUM HAMPE ex MASS.: *Atti Ist. veneto Sci. ser 3,* 5: 330 (1860)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, not differentiated into layers; uniform. *Ascocarp* a perithecium, scattered, or grouped but not aggregate in a stroma; ostiole erect; paraphyses unbranched, free; asci clavate, bitunicate, endoascus well developed, I−, 8 spored; ascospores brown, ellipsoid to oblong, muriform, the walls unequally thickened to produce lenticular or rhomboid lumina. *Pycnidia* immersed; fulcrum exobasidial; pycnospores elongate-cylindrical to filiform.
CHEMISTRY: (1 species) fallacinal (1), parietin (1).
PHYCOBIONT: *?Trentepohlia.*
DISTRIBUTION: On bark, in wetter areas of Queensland and Victoria. 17 species reported (93).

ANZIA STIZ.: *Flora* 44, 390 (1861)

MORPHOLOGY: *Thallus* foliose, finely divided with more or less articulated lobes; upper surface grey, corticate, of anticlinal hyphae; lower surface a spongy tomentum of usually dark anastomosing medullary hyphae; some rhizines coming direct from the medulla. *Ascocarp* an apothecium, laminal, circular, stipitate; margin thalline; hypothecium pale; paraphyses unbranched or little branched; asci cylindrical, unitunicate, I+, tholus large and I+, many spored; ascospores small, bicornute, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores short-cylindrical or curved.
CHEMISTRY: (8 species) atranorin (7), divaricatic acid (7), lobaric acid (2), sekikaic acid (2), anziaic acid (1), caperatic acid (1), chloroatranorin (1), fumarprotocetraric acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: New South Wales and Victoria, on bark. 1 species reported (28).

ARCTOMIA TH. FR.: *Nova Acta Reg. Soc. Sci. Upsal.* 3, 3, 387 (1861)

MORPHOLOGY: *Thallus* crustose, granular to somewhat lobed; with rhizines; upper surface with one or two cortical cell layers. *Ascocarp* an apothecium, sessile, with a proper exciple only; paraphyses unbranched or reticulate with thickened ends; hypothecium pale; asci cylindrical-clavate, unitunicate, I+, thick walled, usually 8 spored; ascospores transversely 5-7 septate, hyaline. *Pycnidia* immersed; fulcrum endobasidial, pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: On mosses, in Tasmania. 1 species reported (2).

ARTHONIA ACH.: *Neues J. Bot.* 1(3): 3 (1806)

MORPHOLOGY: *Thallus* crustose ecorticate uniform, partly or wholly immersed in the substrate. *Ascocarp* a round to lirreliform pseudothecium, sessile to immersed in the thallus, without an exciple, disk flat to convex, usually dark; hypothecium usually dark; paraphyses branched and anastomosing, indistinct; asci globose to pyriform or obovoid, bitunicate, I−, 8 spored; ascospores oblong, ovoid or asymmetric, transversely septate, often with very unequal locules, usually hyaline but rarely brown. *Pycnidia* laminal; fulcrum exobasidial; pycnospores elongate cylindrical; stylospores also formed.
CHEMISTRY: (4 species) arthoniaic acid (1), emodin (1), fallacinal (1), lepranthin (1), rocellaric acid (1), teloschistin (1).
PHYCOBIONT: *Phycopeltis, Trentepohlia, ?Pleurococcus.*
DISTRIBUTION: On trees, rocks and soil, probably throughout Australia and Tasmania but especially in warmer and wetter areas. 28 species reported (500).

ARTHOPYRENIA MASS: *Ric. Lich. Crost.* 165 (1852)

MORPHOLOGY: *Thallus* crustose, ecorticate, uniform, undifferentiated, usually immersed in the substrate. *Ascocarp* a perithecium-like pseudothecium, opening by a punctiform erect ostiole; paraphyses branched and anastomosing often gelatinizing; asci bitunicate, I−, 8 spored; ascospores asymmetric or oval to oblong with or without terminal protruberances, transversely 1-5 septate, the cells cylindrical, walls hyaline. *Pycnidia* fulcrum endobasidial; pycnospores bacilliform; 1 septate stylospores also formed.
CHEMISTRY: No data.
PHYCOBIONT: *Hyella.*
DISTRIBUTION: Queensland, New South Wales and Victoria. 17 species reported (200).

ARTHOTHELIUM MASS.: *Ric. Lich. Crost.* 54 (1852)

MORPHOLOGY: *Thallus* crustose, ecorticate, uniform, partly or wholly immersed in the substrate. *Ascocarp* a round to lirreliform pseudothecium, sessile to immersed in the thallus, without an exciple, disk flat to convex, usually dark; hypothecium usually dark, paraphyses branched and anastomosing, indistinct; asci globose to pyriform or obovoid, bitunicate, I−, 8 spored; ascospores oblong to ovoid, muriform with angular locules, usually hyaline, sometimes brown. *Pycnidia* laminal; fulcrum exobasidial; pycnospores elongate cylindrical; stylospores also formed.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 11 species reported (80).

ASPICILIA MASS.: *Ric. Lich. Crost.* 169 (1852)

MORPHOLOGY: *Thallus* crustose to areolate, foliose or fruticose, attached by hyphae, upper cortex often distinctly paraplectenchymatous. *Ascocarp* an apothecium, immersed in the thallus, with a thalloid exciple; paraphyses unbranched, often moniliform; hypothecium hyaline; asci unitunicate, thin walled I+ blue, tholus I+ blue, flaccid, up to 8 (but often fewer) spores; ascospores rather large, thin walled, simple, hyaline. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical or filiform, straight or curved.

CHEMISTRY: (35 species) norstictic acid (11), aspicilin (5), unknown phenolics (5), atranorin (2), physodalic acid (2), gyrophoric acid (1), placodin (1), taurine (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Common on rocks and soil, in alpine and dry areas of Australia. 5 species reported (100).

ASPIDOTHELIUM VAIN. em R. SANT.: *Symb. bot. Upsal.* 12: 279 (1952)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate. *Ascocarp* a perithecium, solitary, opening by an erect ostiole which extends into a canal with a broad light coloured flange around its opening; hymenium without algae; paraphyses thin, unbranched; asci oblong to oblong-cylindrical, bitunicate, thick walled, I−, 2-8 spored; ascospores oblong to spindle-shaped with terminal protruberances, muriform, hyaline. *Pycnidia* sessile or immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Chlorococcus*-like.
DISTRIBUTION: Queensland, on leaves. 1 species reported (4).

ASTEROPORUM MULL. ARG.: *Rev. Mycol.* 6: 14 (1884)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform, undifferentiated. *Ascocarp* a perithecium-like pseudothecium, single, not aggregated in stroma, sessile or partly immersed, the ostiole erect with a star-shaped appendage; paraphyses branched and reticulate; asci bitunicate, I−, oblong to cylindrical, 8 spored; ascospores 1 septate with unequal locules, brown. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia*-like.
DISTRIBUTION: On bark, in Queensland and New South Wales. 2 species reported (3).

AULAXINA FEE.: *Essai Crypt.* 60 (1824)

MORPHOLOGY: *Thallus* crustose, attached by rhizoidal hyphae, undifferentiated, uniform, ecorticate. *Ascocarp* a lirelliform apothecium; with a carbonaceaous, proper exciple lateral to the hymenium; hymenium linear, unbranched; hypothecium light brown; paraphyses thin, reticulate; asci oblong to spherical, unitunicate, I−, thin walled, 2-8 spored; ascospores transversely 3-8 septate, elongate, hyaline, I+ violet, walls thin. *Pycnidia* adnate; fulcrum endobasidial, pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Palmella*-like.
DISTRIBUTION: On leaves, in Queensland. 1 species reported (8).

BACIDIA DE NOT.: *Giorn. Bot. Ital.* 2: 189 (1846)

MORPHOLOGY: *Thallus* crustose, attached by rhizoidal hyphae, uniform, ecorticate. *Ascocarp* an apothecium, sessile to somewhat immersed in the thallus; disk round, flat to convex; hypothecium pale to dark; paraphyses unbranched, often capitate; asci long-clavate to cylindrical, unitunicate, I + blue, 8-16 spored; ascospores with 3-many transverse septa, fusiform to acicular, both ends alike or one end pointed one convex, curved, straight or

helically interwoven, walls thin, transverse septa often difficult to see. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform to acicular.
CHEMISTRY: (14 species) atranorin (2), rhizocarpic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 38 species reported (400).

BAEOMYCES PERS.: *Ann. Bot. (Usteri)* 7, 19 (1794)

MORPHOLOGY: *Thallus* crustose, granular or sub-squamulose; attached by medullary hyphae, ecorticate. *Ascocarp* an apothecium terminal on an erect unbranched hollow stipe; the stipe naked or with a thalloid covering; disk flat to almost spherical, pale or often pink; hypothecium usually pale; paraphyses unbranched; asci narrow, unitunicate, tholus I+ blue, 8 spored; ascospores ellipsoid to fusiform, simple to 3 septate, walls thin, hyaline. *Pycnidia* immersed in thalloid warts; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (9 species) norstictic acid (5), baeomycesic acid (3), squamatic acid (2), stictic acid (2), atranorin (1).
PHYCOBIONT: *Coccomyxa.*
DISTRIBUTION: On acid soils or rocks, in Queensland, Victoria and Tasmania. 7 species reported (44).

BIATORELLA TH.FR.: *Nova Acta R. Soc. Scient. Upsal.* (Ser 3), 3: 299 (1861)

MORPHOLOGY: *Thallus* crustose, uniform or with marginal lobes, ecorticate or with a poorly developed upper cortex; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, sessile; disk circular, pale to flesh coloured, margin proper; hypothecium pale; paraphyses rarely branched, free; asci thick walled, unitunicate, I+ pale blue, tholus I+ pale blue, many spored; ascospores ellipsoid to globose, simple, hyaline, minute, thin walled. *Pycnidia* immersed in the thallus or in small warts; fulcrum exobasidial; pycnospores short-cylindrical.
CHEMISTRY: (4 species) parietin (2).
PHYCOBIONT: *?Myrmecia, ?Trebouxia.*
DISTRIBUTION: Queensland and Victoria. 4 species reported (50).

BOMBYLIOSPORA MASS.: *Ric. Lich. Crost.* 114 (1852)

MORPHOLOGY: *Thallus* crustose, undifferentiated, uniform, attached by medullary or prothallial hyphae, ecorticate. *Ascocarp* an apothecium, sessile to adnate; disk round, flat to slightly convex; hypothecium pale or dark, devoid of algae; margin proper; paraphyses unbranched, thread-like; asci broadly clavate unitunicate I+ blue, 1-8 spored; ascospores transversely 3-11 septate, hyaline (or pale brown), the septa unequally thickened to give lenticular loculi. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: no data.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: Queensland, New South Wales, Victoria, Tasmania and South Australia. 10 species reported (30).

BOTTARIA MASS.: *Misc. Lich.* 42 (1856b)

MORPHOLOGY: Thallus crustose, epi- or endophloic, uniform, ecorticate, or with an amorphous upper cortex. *Ascocarp* a perithecium; perithecia solitary or grouped in a stroma, globose with vertical ostioles; paraphyses unbranched or reticulately branched; asci cylindrical-clavate, bitunicate, I−, 1-8 spored; ascospores muriform, brown, with thin walled septa. *Pycnidia* small; fulcrum exobasidial; pycnospores filiform.
CHEMISTRY: No data.
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: Queensland. 2 species reported (6).

BUELLIA DE NOT.: *Giorn. Bot. Ital.* 2(1): 195 (1846)

MORPHOLOGY: Thallus crustose, sometimes distinctly lobed at the margins; or squamulose, sometimes endolithic; usually ecorticate but sometimes with a well developed cortex; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium; immersed, adnate or sessile; disk round, margin proper; hypothecium dark, without algae; paraphyses unbranched, thickened at the tips; asci clavate or cylindrical, unitunicate, I+ blue, tholus I+ blue, usually 8 (rarely 32) spored; ascospores usually 1 septate, sometimes falsely 4 celled by ingrowth of outer wall, wall and septa sometimes very unequally thickened, wall brown. *Pycnidia* immersed or in warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (59 species) atranorin (19), norstictic acid (17), unknown phenolics (8), arthothelin (6), 2-7 dichloronorlichexanthone (6), 2-chloronorlichexanthone (5), thiophanic acid (4), granulosin (2), unidentified xanthones (2), chloroatranorin (1), constictic acid (1), fumarprotocetraric acid (1), physodalic acid (1), stictic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: On rock, bark and wood, throughout the region. 55 species reported (600).

BULBOTHRIX HALE: *Phytologia* 28: 479 (1974b)

MORPHOLOGY: Thallus foliose; attached to the substrate by rhizines; with well developed upper and lower cortices, upper cortex of pallisade plectenchyma; lower surface pale to black, rhizines simple to richly dichotomously branched; margins of lobes with bulbate cilia. *Ascocarp* an apothecium; sessile; margin thalloid, with cilia or corona of sessile pycnidia; disk round, flat or concave; hypothecium pale, with algae; paraphyses unbranched, capitate; asci cylindrical-clavate, unitunicate, I+ blue, 8 spored; ascospores simple, ovoid or bicornute, thick walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (31 species) atranorin (31), salazinic acid (9), gyrophoric acid (7), lecanoric acid (3), norstictic acid (2), protocetraric acid (2), lobaric acid (1), norlobaridone (1), skyrin (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: On trees, in coastal Queensland and New South Wales. 5 species reported (31).

BYSSOLOMA TREVIS.: *Spighe e Paglie.* 6 (1853)

MORPHOLOGY: Thallus crustose, ecorticate, foliicolous. *Ascocarp* an apothecium, sessile or adnate; disk round, flat or slightly convex, margin proper; hypothecium dark; paraphyses unbranched or little branched; asci cylindrical-clavate, unitunicate, tholus I+ blue, 8 spored;

ascospores transversely 1-3 septate, hyaline. *Pycnidia* sessile, globose; fulcrum endobasidial; pycnospores spherical to bacilliform.
CHEMISTRY: (1 species) 2-chloroemodin, emodin, fragilin.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: Queensland and New South Wales. 1 species reported (6).

CALICIUM PERS.: *Ann. Bot. (Usteri)* 7: 20 (1794)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform, ecorticate. *Ascocarp* a minutely (less than 2 mm tall) stipitate apothecium; usually cupular; disk flat to strongly convex, circular; margin and stipe without algae; hypothecium brown; paraphyses thread-like; asci thin walled, unitunicate (disintegrating into a mazaedium of ascal and hyphal fragments with spores) 8 spored; ascospores 1 septate, brown to black. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (3 species) vulpinic acid (3), atranorin (1), norstictic acid (1).
PHYCOBIONT: *Chlorella, Stichoccoccus.*
DISTRIBUTION: Queensland, Victoria, Tasmania and South Australia. 36 species reported (100).

CALOPLACA TH. FR.: *Lich. Scand.* 1: 167 (1871)

MORPHOLOGY: *Thallus* crustose; uniform to lobed at the margins; attached by medullary or prothallial hyphae; ecorticate or with a well developed upper cortex; cortex often paraplectenchymatous, of vertical agglutinate hyphae. *Ascocarp* an apothecium, immersed to sessile; disk round, with parietin; margin proper or thalloid; hypothecium pale, with or without algae; paraphyses unbranched, thickened at the tips; asci clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores polarilocular, with unequally thickened walls but the two loculi linked by a canal. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (of many known 110 considered) emodin (87), parietin (87), fallacinal (71), erythroglaucin (66), teloschistin (66), xanthorin (65), 2-chloroemodin (17), fragilin (15), parietinic acid (15), 1-0-methyl-fragilin (2), usnic acid (2), atranorin (1), citeorosein (1), emodic acid (1), emodinal (1), gyrophoric acid (1), lichexanthone (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On rock, bark and soil, in all states. 26 species reported (450).

CAMPYLOTHECIUM MULL. ARG.: *Flora, Jena* 66, 245 (1883)

MORPHOLOGY: *Thallus* crustose, without lobes, epi-or endophloic, uniform, ecorticate or with a cortex of horizontal hyphae. *Ascocarp* a perithecium opening by more or less oblique ostiolar canal, usually clad in thalline material; paraphyses reticulate; asci cylindrical-clavate, bitunicate, usually thick walled. I−, 1-8 spored; ascospores muriform, hyaline, thin walled, locules angular. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia*-like.
DISTRIBUTION: Queensland. 2 species reported (9).

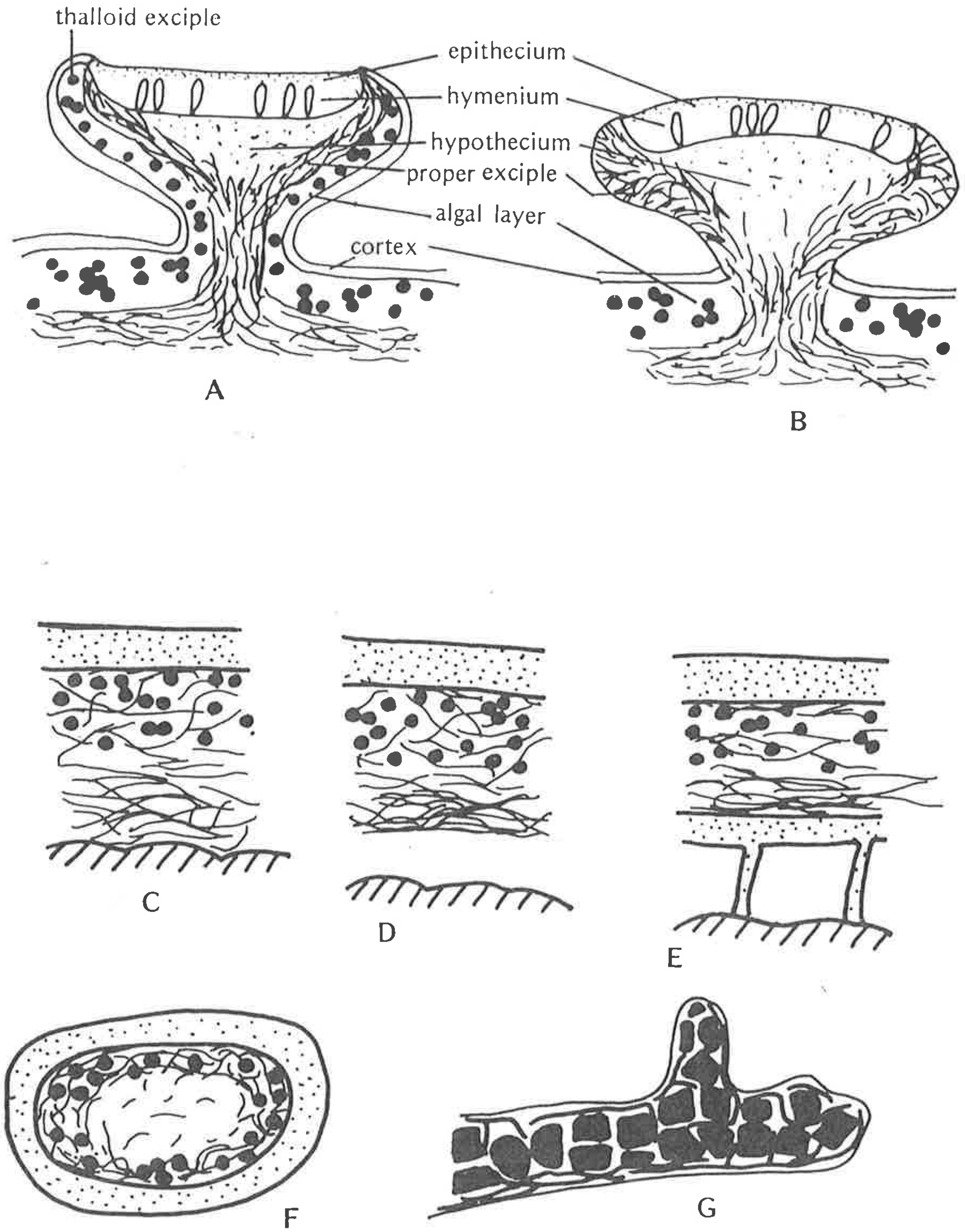

FIGURE 1 A and B are sections through the type of apothecia with margins referred to as thalloid (A) and proper (B) throughout the text. The apothecia with a thalloid margin can be seen to normally possess a thin, concealed proper margin also. C to G are stylized sections through the thallus of various growth forms: (C) crustose, (D) squamulose, (E) foliose, (F) fruticose, and (G) filamentous. Stippled areas represent cortex, hatched substrate; algae are represented by black dots or patches, and loosely woven hyphae by lines. In the filamentous form the hyphae are within a layer of algal gel.

CANDELARIA MASS.: *Ric. Lich. Crost.* 567 (1852)

MORPHOLOGY: *Thallus* foliose, much lacerate, coloured yellow with pulvinic acid derivatives, attached by rhizoids, upper and lower cortices well developed, paraplectenchymatous, lower cortex rhizinate. *Ascocarp* an apothecium, sessile, round, margin thalline; disk depressed, yellow; asci clavate, unitunicate, thick walled I+ blue, tholus I+ blue; 16-32 spored; paraphyses little branched; ascospores simple, often with two large oil drops, or rarely 1 septate, hyaline. *Pycnidia* immersed in small warts; fulcrum exobasidial; pycnospores ellipsoid.
CHEMISTRY: (2 species) calycin (2), pulvinic dilactone (2).
PHYCOBIONT: *?Trebouxia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and South Australia. 3 species reported (7).

CANDELARIELLA MULL. ARG.: *Bull. Herb. Boissier* 2 append 1, 11 (1894)

MORPHOLOGY: *Thallus* crustose, uniform or granular or lobed at the margins, pale or deep yellow from pulvinic acid derivatives; attached to the substrate by hyphae; upper surface paraplectenchymatous. *Ascocarp* an apothecium, sessile, circular, thalloid margin; hypothecium pale, with algae below; paraphyses usually unbranched; asci unitunicate, thick walled, clavate, I+ blue, tholus I+ blue, 8-many spored; ascospores simple or 1 septate, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform, somewhat constricted at the centre.
CHEMISTRY: (4 species) calycin (4), pulvinic dilactone (4), stictaurin (3).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: South Australia and Victoria. 2 species reported (40).

CATILLARIA MASS. em. TH. FR.: *Lich. Scand.* 563 (1874)

MORPHOLOGY: *Thallus* crustose, often granular; ecorticate; attached by hyphal rhizoids. *Ascocarp* an apothecium, immersed to sessile; disk round, pale to dark, hypothecium pale or dark; margin and hypothecium without algae; paraphyses unbranched, free, sometimes capitate; ascus clavate-cylindrical, unitunicate, tholus I+ blue, 8-spored; ascospores 1 septate, thin walled, hyaline. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong to pyriform or curved.
CHEMISTRY: (3 species) usnic acid (2), atranorin (1).
PHYCOBIONT: *?Trebouxia, ?Myrmecia.*
DISTRIBUTION: Widespread, especially on smooth barked trees. 31 species reported (300).

CATINARIA VAIN.: *Acta Soc. Fauna Flora fenn.* 53(1), 143 (1922)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, attached by medullary or prothallial hyphae. *Ascocarp* an apothecium-like pseudothecium, more or less immersed; circular or somewhat irregular; initially with a proper exciple which later disappears; hypothecium black; paraphyses often reticulate, asci clavate, bitunicate, I−, 8 spored; ascospores oblong or ellipsoid, 1 septate, hyaline, slightly constricted at the septum, walls somewhat thickened. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Chlorophyceae.*
DISTRIBUTION: Victoria. 1 species reported (?).

CETRARIA ACH.: *Meth. Lich.* 292 (1803)

MORPHOLOGY: *Thallus* foliose to fruticose, more or less ascending from the substrate, often markedly flattened and strap-like, sometimes cylindrical; all surfaces corticate; lower surface often pseudocyphellate, without rhizines; margins sometimes spiny; free, partly buried or attached by a holdfast. *Ascocarp* an apothecium, marginal on lobes, round; margin thalline; hypothecium pale; paraphyses unbranched or rarely branched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoidal to spherical, simple, hyaline, thin or thick walled. *Pycnidia* sessile; fulcrum endobasidial, short; pycnospores ellipsoidal to cylindrical, or bacilliform.
CHEMISTRY: (58 species) protolichesterinic acid (15), usnic acid (15), atranorin (7), vulpinic acid (6), alectoronic acid (5), caperatic acid (5), fumarprotocetraric acid (5), physodic acid (4), pinastric acid (4), norrangiformic acid (3), rangiformic acid (3), stictic acid (3), α-collatolic acid (2), endocrocin (2), friedelin (2), lichesterinic acid (2), olivetoric acid (2), *allo*-protolochesterinic acid (2), gyrophoric acid (1), hiascic acid (1), microphyllinic acid (1), nephrosteranic acid (1), norstictic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: New South Wales, Victoria and Tasmania, in alpine areas. 2 species reported (45).

CETRELIA W. CULB. et C. CULB.: *Contr. U.S. Natn. Herb.* 34 (1968)

MORPHOLOGY: *Thallus* foliose, lobes to 2.5 cm broad, pale above; upper surface prosoplectenchymatously corticate, with punctiform pseudocyphellae, isidate or sorediate; lower surface black, shiny, corticate, rhizinate; without marginal cilia. *Ascocarp* an apothecium, round, stipitate, sub-marginal, usually perforate; hypothecium hyaline; paraphyses unbranched or little branched; asci cylindrical, unitunicate, thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline. *Pycnidia* marginal; fulcrum ?endobasidial; pycnospores bacilliform.
CHEMISTRY: (14 species) atranorin (14), imbricaric acid (4) alectoronic acid (3), α-collatolic acid (3), olivetoric acid (3), anziaic acid (2), perlatolic acid (2), microphyllinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, on bark. 1 species reported (14).

CHAENOTHECA TH. FR.: *Lich. Scand.* 563 (1874)

MORPHOLOGY: *Thallus* crustose to rarely squamulose or endophloic, ecorticate, attached by hyphae. *Ascocarp* an apothecium on a stipe; disk round, often deeply concave; margin without algae, dark; paraphyses unbranched; asci cylindrical, unitunicate, thin walled, 8 spored; ascospores simple, globose, dark coloured; asci and paraphyses disintegrate leaving the spores lying free in a mazaedium. *Pycnidia* punctiform; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (1 species) vulpinic acid (1).
PHYCOBIONT: *Stichococcus, Trentepohlia.*
DISTRIBUTION: Victoria and Tasmania. 3 species reported (23).

CHIODECTON ACH.: *Syn. Meth. Lich.* 108 (1814)

MORPHOLOGY: *Thallus* crustose, ecorticate, uniform, undifferentiated; attached by prothallial hyphae. *Ascocarp* a pseudothecium, immersed or sessile in groups in stroma;

Filamentous thalli

1. Thallus of algal filaments ensheathed in fungal hyphae	2
1. Thallus a loose weft of hyphae loosely entangling algal cells or filaments	4
2. Algal filaments blue-green *(Stigonema)*	3
2. Algal filaments green *(Trentepohlia)*	*Cystocoleus*
3. Apothecia immersed in swellings on filaments	*Ephebe*
3. Apothecia terminal on filaments	*Spilonema*
4. Spores septate (up to 100)	*Conotremopsis*
4. Spores simple or 1 septate	5
5. Thallus with thick black hypothallus	*Crocynia*
5. Thallus without a distinctive hypothallus	6
6. Thallus bright yellow	*Chrysothrix*
6. Thallus white to grey	*Coenogonium*

hymenium open, ovoid to stellate; margin well developed, black, without algae, or rudimentary; hypothecium black; paraphyses reticulate; asci bitunicate, clavate, I−, 8 spored; ascospores fusiform to acicular, transversely many septate, hyaline, walls thin, locules cylindrical. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical, oblong to ellipsoid, straight or curved.
CHEMISTRY: (4 species) atranorin (1), erythrin (1), gyrophoric acid (1), norstictic acid (1), psoromic acid (1), salazinic acid (1).
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 19 species reported (175).

CHONDROPSIS NYL. in CROMBIE: *J. Linn. Soc. Bot.* 17: 397 (1879)

MORPHOLOGY: Thallus foliose, repeatedly dichotomously branched; devoid of attachment to the substrate; upper cortex prosoplectenchymatous, opaque when dry, transparent when wet; lower cortex of interwoven hyphae; the whole rolling into a ball when dry with the lower cortex outermost. *Ascocarp* an apothecium; rare, sessile, margin thalline; disk round, concave to flat, light brown; hypothecium pale; paraphyses unbranched; asci cylindrical, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline. *Pycnidia* not known.
CHEMISTRY: (monospecific genus) fumarprotocetraric acid, succinprotocetraric acid, usnic acid.
PHYCOBIONT: Trebouxia.
DISTRIBUTION: On soil, in semi-arid southern Australia, and the Snowy mountains. 1 species (1).

CHRYSOTHRIX MONT.: *Annls Sci. nat. (Bot.)* Ser. 3, 18, 312 (1852)

MORPHOLOGY: Thallus a tangled weft of hyphae enclosing soredium-like clusters of algae, forming a crust or small polsters; attached to the substrate by hyphae. *Ascocarp* very rarely seen, immersed in the thallus or sessile, disk round; margin proper; hypothecium hyaline; paraphyses disappearing; asci 8-spored; ascospores transversely septate, hyaline. *Pycnidia* not known.
CHEMISTRY: (3 species) calycin (3), vulpinic acid (2), leprapinic acid (1), leprapinic acid methyl ether (1), pinastric acid (1).
PHYCOBIONT: Coccoid green algae.
DISTRIBUTION: On wood and bark throughout the region. 1 species reported (3).

CLADIA NYL.: *Bull. Soc. Linn. Normandie ser 2,* 6: 167 (1870)

MORPHOLOGY: Primary thallus absent; pseudopodetia much or little branched; esquamulose, esorediose, non-isidiose, often reticulately fenestrate; cortex of longitudinal hyphae, medulla variable. *Ascocarp* an apothecium; apothecia often in cymose stacks, terminal on pseudopodetia; disk round; margin prominent, dark, without algae; hypothecium pale or dark; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline. *Pycnidia* sessile or substipitate; fulcrum exobasidial; pycnospores curved.
CHEMISTRY: (7 species) ursolic acid (7), usnic acid (4), protocetraric acid (4), protolichesterinic acid (4), atranorin (3), divaricatic acid (2), fumarprotocetraric acid (2), norstictic acid (1), barbatic acid (1), 4-0-demethylbarbatic acid (1), gyrophoric acid (1), homosekikaic acid (1).

PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Widespread on soils and rotting wood, across southern Australia (including southern Queensland). 7 species reported (7).

CLADINA NYL. in OLIV.: *Expos Lich. Ouest France* 1: 41 (1897)

MORPHOLOGY: *Primary thallus* crustose, ecorticate, short lived; *Podetia* much branched, hollow, cylindrical ecorticate, without squamules. *Ascocarp* an apothecium, terminal on podetia, cymose, minute, pale or brown, margin proper; hypothecium pale; paraphyses unbranched or little branched; asci clavate-cylindrical, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline. *Pycnidia* terminal on podetia; fulcrum exobasidial; pycnospores filiform, curved or straight.
CHEMISTRY: (6 species) usnic acid (4), fumarprotocetraric acid (3), perlatolic acid (2), ursolic acid (2), atranorin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On soil in cooler, commonly alpine or sub-alpine, areas in New South Wales, Victoria and Tasmania. 2 species reported (10).

CLADONIA HILL.: *Hist. pl.* 91 (1773)

MORPHOLOGY: *Primary thallus* squamulose to foliose, corticate, upper cortex of thick walled hyphae perpendicular to the surface, attached to the substrate by hyphal rhizines. *Podetia* common, laminal or rarely marginal, simple or branched, often cup-shaped, appearing fruticose, naked or covered in squamules or soredia, corticate or ecorticate, hollow, axils open or perforate. *Ascocarp* an apothecium, raised on podetia, terminal or on margins of cups, rarely sessile or squamules, disk markedly convex, pale brown, dark brown or red; margin proper, not prominent; hypothecium colourless; paraphyses unbranched or little branched; Asci clavate-cylindrical, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline, thin walled. *Pycnidia* terminal on podetia or sessile or stipitate on squamules or on cups; fulcrum exobasidial; pycnospores filiform, straight or curved.
CHEMISTRY: (94 species) usnic acid (35), fumarprotocetraric acid (27), atranorin (14), squamatic acid (13), barbatic acid (12), thamnolic acid (9), bellidiflorin (6), baeomycesic acid (4), didymic acid (4), homosekikaic acid (4), ursolic acid (4), psoromic acid (4), destrictinic acid (3), constictic acid (2), merochlorophaeic acid (2), norstictic acid (2), perlatolic acid (2), porphyrilic acid (2), protolichesterinic acid (2), stictic acid (2), succinprotocetraric acid (2), zeorin (2) bourgeanic acid (1), caperatic acid (1), cryptochlorophaeic acid (1), diacetylgraciliformin (1), decarboxythamnolic acid (1), graciliformin (1), grayanic acid (1), imbricaric acid (1), lichesterinic acid (1), 4-0-methyl-cryptochlorophaeic acid (1), monoactylgraciliformin (1), rhodocladonic acid (1), skyrin (1), strepsilin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: In all states, especially common in southern regions, on soil and rotting logs. 50 species reported (300)

CLATHROPORINA MULL. ARG.: *Flora, Jena* 65, 517 (1882)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform, ecorticate. *Ascocarp* a perithecium, sessile to somewhat immersed, not aggregated, ostiole erect; paraphyses unbranched; asci thin walled, unitunicate, clavate, I−, 8 spored; ascospores ellipsoid to fusiform, muriform, hyaline, walls thin, of even thickness. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong to oblong-cylindrical.

CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On trees, in Queensland and Tasmania. 9 species reported (60).

COCCOCARPIA PERS. in GAUD.: *Voyage Uranie et Physicienne* 206 (1826)

MORPHOLOGY: *Thallus* squamulose to foliose, often much lobed, attached by a rhizoidal tomentum, upper surface with a cortex composed of longitudinally interwoven hyphae, algal layer immediately below the upper cortex, medulla grading into lower cortex. *Ascocarp* an apothecium, sessile; proper margin barely visible; devoid of algae; hypothecium pale or dark; paraphyses unbranched; asci unitunicate, clavate, tholus I+ blue, 8 spored; ascospores simple, globose to fusiform, thin walled, hyaline. *Pycnidia* immersed in thalline warts; fulcrum endobasidial, much septate; pycnospores bacilliform.
CHEMISTRY: (4 species) no lichen substances.
PHYCOBIONT: *Scytonema.*
DISTRIBUTION: On trees and rocks, in Queensland, New South Wales and Victoria. 5 species reported (25).

COCCOTREMA MULL. ARG.: *Miss. Sci. Cap Horn* vol. 5: 171 (1889)

MORPHOLOGY: *Thallus* crustose, uniform, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed in fruiting warts, without a proper margin; hymenium and receptacle clearly but narrowly perforate; paraphyses indistinct, unbranched, branched or reticulate; hypothecium hyaline; asci clavate, unitunicate (but of several distinct layers), thick walled, I+ blue, tholus I+; ascospores simple, hyaline, not greatly thickened. *Pycnidia* not known.
CHEMISTRY: (3 species) constictic acid (2), stictic acid (2), norstictic acid (1).
PHYCOBIONT: *Trebouxia*-like or *Trentepohlia*-like.
DISTRIBUTION: On bark, in Tasmania. 1 species reported (6).

COELOCAULON LINK: *Grund. der Krauterkunde* vol. III, 165 (1833)

MORPHOLOGY: *Thallus* ascending, fruticose, fragile, cylindrical in cross-section, hollow attached by sparse rhizines, corticate or dissolving into soredia. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (2 species) olivetoric acid (1), protolichesterinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On rocks, in South Australia and Western Australia. 1 species reported (7).

COENOGONIUM EHRENB. ex NEES.: *Horae Physic. Berol.* 120 (1820)

MORPHOLOGY: *Thallus* a spongy filamentous mass forming a mound or disk, either shelf-like or pendant from the substrate; hyphae entangling the phycobiont. *Ascocarp* an apothecium, laminal or marginal, short stalked; margin proper, pseudoparenchymatous; paraphyses loose, unbranched; asci unitunicate, thin walled, I+ blue, 8 spored, ascospores simple or 1 septate, hyaline, uniformly thin walled. *Pycnidia* globose; fulcrum exobasidial, bushy; pycnospores fusiform, straight.
CHEMISTRY: No data.

PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, Victoria and Tasmania. 9 species reported (15).

COLLEMA WEB. in WIGG.: *Prim. Flor. Holsat.* 89 (1780)

MORPHOLOGY: *Thallus* foliose, sometimes almost crustose, gelatinous, ecorticate, comprising a mycelial weft through an algal gelatinous matrix, directly attached to the substrate. *Ascocarp* an apothecium, immersed to sessile; disk round; margin thalline; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, I+ blue, 8 spored; ascospores transversely 1-many septate or muriform, hyaline, thin walled. *Pycnidia* immersed in the thallus or in warts; fulcrum endobasidial, short celled; pycnospores bacilliform.
CHEMISTRY: Without characteristic lichen substances.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: On soil, rocks and trees, throughout Australia. 12 species reported (80).

CONIOCYBE ACH.: *Kgl. Vetensk-Akad. Nya Handl.* 37, 286 (1815)

MORPHOLOGY: *Thallus* crustose, powdery or disappearing, ecorticate. *Ascocarp* an apothecium, stipitate on long fine stalks; disk initially flat, becoming globose as the proper exciple is displaced; paraphyses thread-like; asci cylindrical, thin walled, unitunicate, 8 spored; ascospores globose, simple, yellowish or hyaline; asci and paraphyses disintegrating leaving the spores free in a powdery mass or mazaedium. *Pycnidia* protruding from the thallus; fulcrum exobasidial; pycnospores oblong-ellipsoid.
CHEMISTRY: No data.
PHYCOBIONT: *Stichococcus.*
DISTRIBUTION: Victoria. 4 species reported (20).

CONOTREMOPSIS VEZDA: *Folia Geobot. Phytotax. Praha* 12, 313 (1977)

MORPHOLOGY: *Thallus* filamentous, woolly. *Ascocarp* an apothecium, narrowly cylindrical, closed at first then opening, disk round; thalline margin disappearing leaving a thick proper margin; hypothecium dark; paraphyses unbranched; asci cylindrical, unitunicate, I−; ascospores long and filamentous, transversely many (up to 100) septate, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Known only from type collected in Tasmania. 1 species reported (1).

CROCYNIA (ACH.) MASS.: *Atti I.R. Ist. Veneto Ser 3,* 5, 251 (1860)

MORPHOLOGY: *Thallus* lobed, of interwoven hyphal filaments, almost membranous, with a distinct prothallus, without rhizines, ecorticate; the phycobiont loosely entangled in a hyphal weft. *Ascocarp* an apothecium, laminal, shortly stipitate; disk circular; margin proper, well developed; hypothecium hyaline; paraphyses obscure; asci cylindrical, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: (1 species) usnic acid, zeorin.
PHYCOBIONT: *?Trebouxia, ?Chlorella, Stichoccus.*
DISTRIBUTION: On bark, in Victoria and Tasmania. 3 species reported (?)

CYPHELIUM ACH.: *K. svensk Vetensk Akad. Handl.* 261 (1815)

MORPHOLOGY: *Thallus* crustose, powdery, uniform, ecorticate. *Ascocarp* an apothecium, almost immersed in thalline tissue or sessile; disk at first almost closed, later open; margin black, proper, with or without thalline rim; paraphyses thread-like; asci cylindrical, thin walled, unitunicate 8-spored; ascospores 1-septate (rarely simple), dark; asci and paraphyses disintegrating leaving the spores free in a powdery mass or mazaedium. *Pycnidia* small, fulcrum endobasidial (?); pycnospores bacilliform.
CHEMISTRY: (10 species) rhizocarpic acid (5), atranorin (2), chloroatranorin (2), usnic acid (2), epanorin (1), norstictic acid (1), vulpinic acid (1).
PHYCOBIONT: *?Stichococcus.*
DISTRIBUTION: Queensland, Victoria and Tasmania, on wood and bark. 5 species reported (30).

CYSTOCOLEUS THW.: *Ann. Nat. Hist. Ser 2,* 3, 241 (1849)

MORPHOLOGY: *Thallus* erect, of radiating filaments comprised of algal cells entwined in fungal hyphal cylinders. *Ascocarp* unknown. *Pycnidia* unknown.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Tasmania. 1 species reported (1 or 2).

DENDRISCOCAULON NYL.: *Flora, Jena* 68, 299 (1885)

MORPHOLOGY: *Thallus* fruticose, erect, cylindrical or somewhat flattened, often much branched or arborescent; cortex unevenly developed, sometimes with cyphella-like pores; sometimes bearing flattened lobes which can be referred to species of *Sicta* or *Lobaria*, and which may be interpreted as cephalodia containing green algae; attached by a basal holdfast. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (1 species) no secondary lichen substances.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: Victoria and Tasmania, in wet areas. 1 species reported (?6).

DERMATOCARPON ESCHW.: *Syst. Lich.* 21 (1824)
(including *Catapyrenium* Fee.)

MORPHOLOGY: *Thallus* squamulose or foliose, apressed or somewhat ascending; upper or upper and lower surfaces paraplectenchymatously corticate; attached by rhizoids or prothallial hyphae. *Ascocarp* a perithecium, immersed in the thallus; hymenium without algae; paraphyses reticulately branched, soon gelatinizing; asci unitunicate, thick walled, I−, 8 spored; ascospores simple, hyaline. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (5 species) no secondary lichen substances.
PHYCOBIONT: *Myrmecia, Hyalococcus.*
DISTRIBUTION: On soil and rock, in Queensland, New South Wales, Victoria, South Australia and Western Australia. 4 species reported (80).

DERMATINA ALMQ.: *Kgl. Svensk Vetensk-Akad. Handl.* 17(6), 8 (1880)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate. *Ascocarp* a perithecium-like pseudothecium, opening by a pore or irregular slit, often several fused together immersed in a stroma, black; paraphyses reticulate, often disintegrating; asci oval or clavate, bitunicate, thick walled, I−, 8 spored; ascospores ellipsoid, hyaline or brown, muriform, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong, cylindrical.
CHEMISTRY: No data.
PHYCOBIONT: *Palmella*-like.
DISTRIBUTION: Victoria. 1 species reported (30).

DICTYONEMA C.AG. ex KUNTH.: *Syn. Pl. Aequinoct.* vol. 1, 1 (1822)

MORPHOLOGY: *Thallus* initially of tangled hyphae which form a crust and eventually semi-circular brackets standing out from the substrate; the upper surface becomes shaggy with concentric markings; lower surface eventually covered by a hymenium; composed of thin hyaline articulate hyphae which are irregularly branched or at times dichotomous. *Hymenium* confined to the lower surface bearing an irregular layer of basidia; basidia bear four simple hyaline or yellowish-brown spores.
CHEMISTRY: (4 species) no secondary lichen substances found.
PHYCOBIONT: *Scytonema* or *Chroococcus.*
DISTRIBUTION: In rainforests in Queensland. 2 species reported (5).

DIMERELLA TREVIS.: *Rc. Ist. Lomb. Sci. Lett. ser. 2,* 13, 65 (1880)

MORPHOLOGY: *Thallus* crustose, effuse, uniform, ecorticate. *Ascocarp* an apothecium, sessile; disk round; margin proper, yellow or orange; hypothecium, hyaline; paraphyses unbranched; asci cylindrical to clavate, unitunicate, thin walled, I+ blue, 8 spored; ascospores oblong to fusiform, 1 septate, hyaline. *Pycnidia* immersed or sessile; fulcrum endobasidial; pycnospores bacilliform, 1 septate.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On trees, in Queensland, New South Wales, Victoria and Tasmania. 4 species reported (25).

DIPLOGRAMMA MULL. ARG.: *Nuov. Giorn. Bot. Ital.* 23, 399 (1891)

MORPHOLOGY: *Thallus* endophloic, ecorticate, uniform. *Ascocarp* an apothecium, sessile, elongate, with twin longitudinal hymenia; margin carbonaceous; hymenia black, narrow; paraphyses reticulately branched; asci 8 spored; ascospores transversely septate, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Palmella*-like.
DISTRIBUTION: On bark, in Queensland. 1 species reported (1).

DIPLOICIA MASS.: *Ric. Lich. Crost.* 86 (1852)

MORPHOLOGY: *Thallus* squamulose; corticate; attached by medullary hyphae. *Ascocarp* an

apothecium, sessile; disk round, margin proper, black; hypothecium dark; paraphyses unbranched; asci unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores transversely 1-3 septate, brown. *Pycnidia* immersed or in thalline warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (1 species) atranorin, chloroatranorin, diploicin.
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On soil and rocks, in New South Wales, South Australia, Victoria and Western Australia. 2 species reported (4).

DIPLOSCHISTES NORM.: *Nytt. Mag. Naturv.* 7, 213 (1853)

MORPHOLOGY: *Thallus* crustose, often areolate, without lobes, ecorticate or with a cortex of tangled hyphae; attached by medullary hyphae. *Ascocarp* an apothecium, immersed to sessile; disk closed or open; proper exciple well developed; thalline exciple often well developed; paraphyses unbranched or branched near the apices; asci clavate, unitunicate, thick walled, I+, 2-8 spored; spores muriform, brown, thin walled. *Pycnidia* immersed; fulcrum endobasidial (?); pycnospores bacilliform.
CHEMISTRY: (22 species) lecanoric acid (14), diploschistesic acid (9), atranorin (6), connorstictic acid (2), gyrophoric acid (2), norstictic acid (2), ursolic acid (2), ethyl orsellinate (1), fumarprotocetraric acid (1), orsellinic acid (1), zeorin (1).
PHYCOBIONT: Coccoid Chlorophyceae.
DISTRIBUTION: Across the southern half of the continent and Tasmania, on soil and rock. 6 species reported (35).

DIRINARIA TUCK.: *Proc. Amer. Acad. Arts & Sci.* 12, 166 (1877)

MORPHOLOGY: *Thallus* foliose, closely apressed to the substrate, attached by rhizines, upper cortex paraplectenchymatous. *Ascocarp* an apothecium, sessile; disk concave to convex, round, thalline margin; hypothecium dark; paraphyses unbranched; asci clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores 1 septate, brown, thick walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores short, cylindrical.
CHEMISTRY: (26 species) atranorin (26), divaricatic acid (19), sekikaic acid (6), triterpenoids (5), zeorin (2), chloroatranorin (1), lecanoric acid (1), ramalinolic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On rocks and trees, especially in the northern half of the continent. 8 species reported (26).

DIRINASTRUM MULL. ARG.: *Bull. Herb. Boissier* 1, 55 (1893)

MORPHOLOGY: *Thallus* crustose, uniform; cortex of anticlinal hyphae; attached by medullary hyphae. *Ascocarp* an apothecium-like pseudothecium, sessile to immersed, round or elongate; proper and thalline margins well developed; hypothecium black; paraphyses unbranched; asci bitunicate, I−, 8 spored; ascospores transversely 3-7 septate, brown. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform; curved.
CHEMISTRY: (1 species), erythrin.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Coastal rocks, in Victoria. 1 species reported (1).

ECHINOPLACA FEE: *Essai Crypt.* 50 (1824)

MORPHOLOGY: Thallus crustose, uniform, often with white hairs, with a developed cortex. *Ascocarp* an apothecium, immersed to sessile, round to oval, exciple poorly developed or absent; paraphyses reticulate; asci thick walled, unitunicate, 1-8 spored; ascospores transversely several septate or muriform, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: Trebouxia-like.
DISTRIBUTION: On leaves, in Queensland. 3 species reported (9).

ENDOCARPON HEDW.: *Descr. et adum. Musc.* 56 (1789)

MORPHOLOGY: Thallus squamulose to rarely foliose; upper surface paraplectenchymatous; attached by rhizoids. *Ascocarp* a perithecium, immersed, ostiole erect; with hymenial algae; paraphyses gelatinizing; asci globose, unitunicate, thick walled, 1-8 spored; ascospores muriform, hyaline to brown, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical, straight.
CHEMISTRY: No data.
PHYCOBIONT: Pleurococcus, Stichococcus.
DISTRIBUTION: On soil, in New South Wales, Victoria, South Australia and Western Australia. 4 species reported (30).

ENTERODICTYON MULL. ARG.: *J. Linn. Soc. Bot.* 29, 230 (1892)

MORPHOLOGY: Thallus crustose, uniform, ecorticate, attached by medullary hyphae. *Ascocarp* an apothecium, sessile in stroma; disk open, irregular; proper exciple brown, well or poorly developed; paraphyses unbranched; asci bitunicate, I−, 8 spored; spores muriform, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: On bark, in New South Wales. 1 species reported (3).

ENTEROGRAPHA FEE:: *Essai Crypt.* 32 (1824)

MORPHOLOGY: Thallus crustose, uniform, of densely interwoven hyphae, ecorticate; attached by medullary or prothallial hyphae. *Ascocarp* a pseudothecium, immersed in stroma, single or grouped; exciple absent or poorly developed; hypothecium pale; paraphyses reticulate; asci bitunicate, clavate, I−, 8 spored; ascospores transversely many septate, hyaline, walls thin, locules cylindrical. *Pycnidia* not known.
CHEMISTRY: (1 species) confluentic acid.
PHYCOBIONT: Phycopeltis or *Trentepohlia.*
DISTRIBUTION: On bark, in Victoria. 1 species reported (30).

EPHEBE FR.: *Syst. orb.* 256 (1825)

MORPHOLOGY: Thallus filamentous, ramifying in the gelatinous sheath of the phycobiont, appearing minutely fruticose. *Ascocarp* an apothecium, immersed in thickenings in the filaments, almost globose, punctiform; disk almost closed; proper exciple thin; hypothecium

hyaline, paraphyses absent; asci clavate, unitunicate, I+ blue, 8 spored; ascospores simple or 1 septate, hyaline, walls thin. *Pycnidia* immersed in globose swellings; fulcrum exobasidial, filiform; pycnospores bacilliform.
CHEMISTRY: (1 species) no secondary lichen substances.
PHYCOBIONT: *Stigonema.*
DISTRIBUTION: On rocks, in New South Wales, Victoria, Tasmania, South Australia and Western Australia. 3 species reported (12).

ERIODERMA FEE: *Essai Crypt.* 145 (1824)

MORPHOLOGY: *Thallus* foliose, lobed, corticate; upper cortex pseudoparenchymatous, shaggy; lower surface ecorticate, tomentose, sometimes veined; attached by laminal or marginal rhizines. *Ascocarp* an apothecium, marginal or laminal, sessile to stipitate; proper exciple well developed; disk round; hypothecium pale; asci unitunicate, clavate, I+ blue, 8 spored; ascospores simple, hyaline. *Pycnidia* marginal, sessile; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (4 species) unidentified depsidone like pannarin.
PHYCOBIONT: *Scytonema.*
DISTRIBUTION: On bark, in Queensland. 1 species reported (16).

EVERNIA ACH.: *Lich. Univ.* 84 (1810)

MORPHOLOGY: *Thallus* fruticose to apparently foliose, upright or pendulous, dorsiventral; both surfaces corticate, cortex of anticlinal hyphae; without rhizines, attached by a basal disk. *Ascocarp* an apothecium, lateral or terminal, stipitate, concave, thalline margin; hypothecium hyaline, paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores simple, hyaline, thin walled. *Pycnidia* marginal, immersed; fulcrum endobasidial; pycnospores acicular.
CHEMISTRY: (4 species) divaricatic acid (4), usnic acid (2), atranorin (1), chloroatranorin (1), evernic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: In alpine/sub-alpine areas of New South Wales. 1 species reported (6).

FISTULARIELLA BOWLER & RUNDEL: *Mycotaxon* 6, 195 (1977)

MORPHOLOGY: *Thallus* fruticose, erect, hollow and inflated, little branched, corticate, fenestrate; attached by a basal disk. *Ascocarp* an apothecium, usually appearing terminal, concave; well developed thalloid exciple; disk round; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores 1 septate, thin walled, hyaline. *Pycnidia* immersed in the thallus; fulcrum exobasidial, little branched; pycnospores bacilliform, straight.
CHEMISTRY: (5 species) usnic acid (4), sekikaic acid (3), divaricatic acid (2), norstictic acid (2), evernic acid (1), obtusatic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On twigs, wood or soil and rock, throughout Australia except in very dry inland areas. 8 species reported (27).

FULGENSIA MASS. ex DE NOT. in MASS.: *Gen. Lich.* 10 (1854b)

MORPHOLOGY: *Thallus* crustose, granular, lobed at the margins. *Ascocarp* an apothecium, sessile; thalloid exciple developed; disk round, orange, hypothecium pale; paraphyses unbranched, thickened at the tips; asci unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores simple, hyaline. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (9 species) parietin (9), emodin (8), fragilin (4), teloschistin (3), 2-chloroemodin (2), fallacinal (2), parietinic acid (2).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On dry calcareous substrates, in the southern half of the continent and Tasmania. 1 species reported (10).

GLYPHIS ACH.: *Syn. Lich.* 106 (1814)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate or with a poorly developed cortex of periclinal hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, elongate or irregular; immersed in stroma; well developed proper exciple; hypothecium pale; hymenium gelatinous; paraphyses unbranched; asci oblong, unitunicate, I−, 8 spored; ascospores transversely 3-11 septate, walls unequally thickened to produce lenticular locules, hyaline, I+ violet. *Pycnidia* not know.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On bark, in Queensland. 3 species reported (30).

GRAPHINA MULL. ARG.: *Flora, Jena* 63, 22 (1880)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic; ecorticate or with a cortex of interwoven hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, elongate, often branched; adnate or immersed; disk narrow; proper exciple usually well developed; hypothecium pale to black; paraphyses unbranched; asci clavate, unitunicate, I−, usually only 1-3 spored; ascospores oblong-ellipsoid to elongate-ellipsoid, large, muriform, hyaline, thin walled, I+ violet. *Pycnidia* rare, immersed; fulcrum exobasidial; pycnospores oblong-cylindrical to bacilliform.
CHEMISTRY: (19 species) norstictic acid (6), stictic acid (6), atranorin (3), protocetraric acid (3), lichexanthone (2), salazinic acid (2), zeorin (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On wood and bark, throughout the region. 18 species reported (270).

GRAPHIS ADANS.: *Fam. Pl.* 11 (1763)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic; ecorticate or with a cortex of interwoven hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, immersed to sessile, elongate, often branched, disk narrow; proper exciple often black; thalloid exciple sometimes present; hypothecium pale to black; paraphyses unbranched; asci clavate, unitunicate, I−, thick walled, 8 spored; ascospores transversely 3-many septate, hyaline, walls unequally thickened resulting in lenticular locules, I+ violet. *Pycnidia* rare, immersed; fulcrum exobasidial; pycnospores oblong cylindrical to bacilliform.
CHEMISTRY: (16 species) norstic acid (8), stictic acid (4), protocetraric acid (2), atranorin (1), lecanoric acid (1), salazinic acid (1).

PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On wood and bark, throughout the region. 41 species reported (300).

GYALECTA ACH.: *Kgl. Vetensk Akad. Nya Handl.* 29, 228 (1808)

MORPHOLOGY: *Thallus* crustose, uniform; attached to the substrate by prothallial hyphae; ecorticate. *Ascocarp* an apothecium, circular; immersed to sessile; proper exciple pale, waxy; thalloid exciple often present; hypothecium pale, soft; paraphyses unbranched; asci clavate, unitunicate, thin walled, I+ blue, without a tholus, 8 spored; ascospores transversely 3-11 septate or muriform, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores linear or bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia, Gloeocystis.*
DISTRIBUTION: In Victoria and Tasmania. 1 species reported (34).

GYALECTIDIUM MULL. ARG.: *Flora, Jena* 64, 100 (1881)

MORPHOLOGY: *Thallus* crustose, effuse or with sharply delimited algal patches, corticate; the cortex of rectangular to rounded cells, often with white hairs. *Ascocarp* an apothecium, immersed in the thallus, erumpent; proper exciple poorly developed; paraphyses almost unbranched, branched or anastomosing; epithecium containing algae; asci unitunicate, thick walled, 1 spored; ascospores muriform, hyaline, walls thin. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: On leaves, in Queensland. 1 species reported (3).

GYMNODERMA NYL.: *Syn. Lich.* 26 (1860)

(including *Neophyllis* F. Wils.)

MORPHOLOGY: *Thallus* foliose to squamulose, upper surface corticate; lower surface of medullary hyphae, without rhizines. *Ascocarp* an apothecium on short podetia; podetia marginal on the lobes, hollow; apothecia capitate to barrel shaped; paraphyses reticulate, agglutinated; asci unitunicate, clavate, tholus I+, 8 spored; ascospores simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial.
CHEMISTRY: (3 species) atranorin (2), didymic acid (1), grayanic acid (1), protolichesterinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On bark, in humid forests of New South Wales and Victoria. 1 species reported (3).

GYMNOGRAPHA MULL. ARG: *Flora, Jena* 70, 62 (1887)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached by prothallial or medullary hyphae. *Ascocarp* an apothecium, immersed, irregular, poorly developed or emarginate; hypothecium pale; paraphyses not known; asci 8 spored; ascospores transversely 3-septate, brown, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On bark, in Queensland. 1 species reported (1).

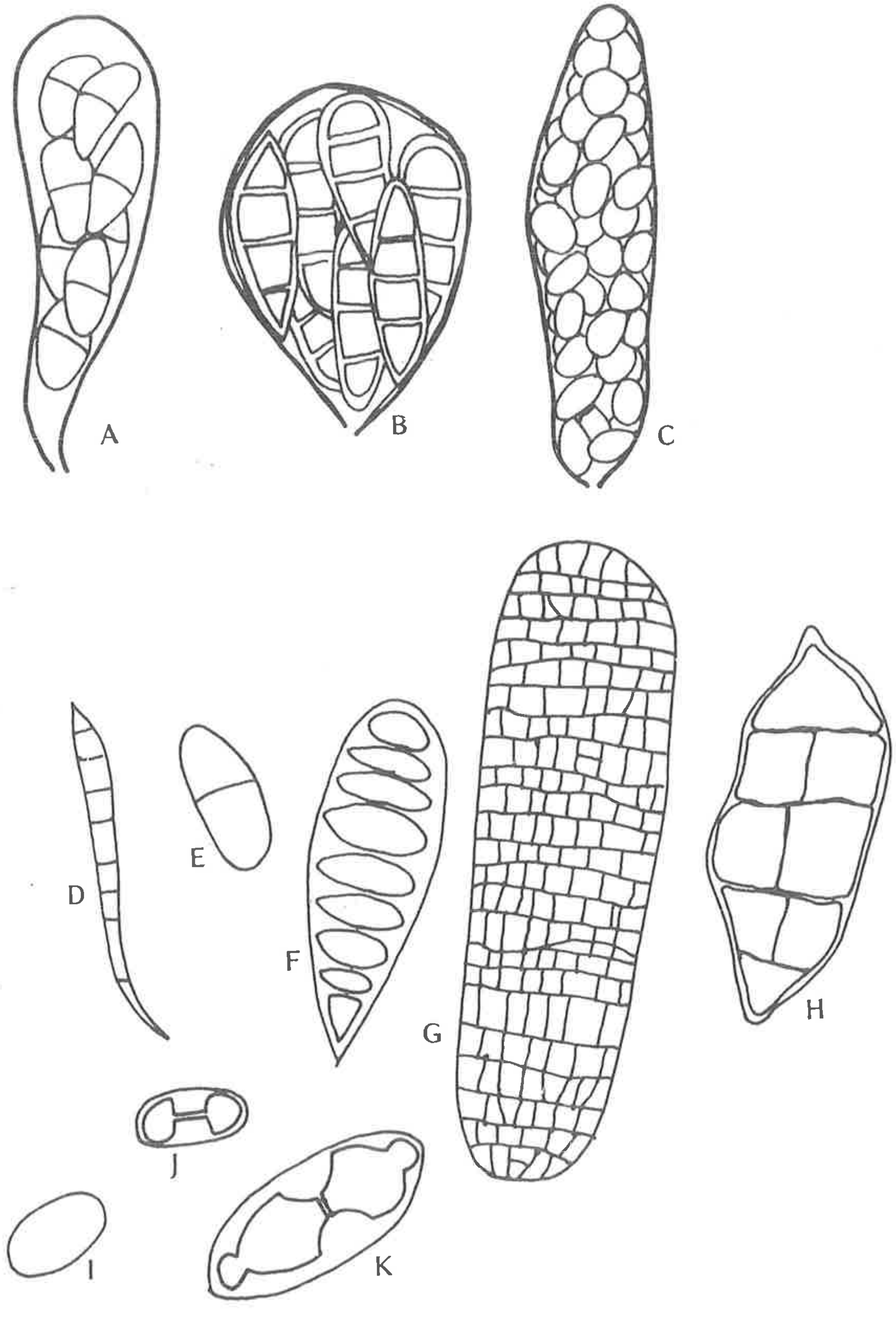

FIGURE 2 **Top:** A to C are asci containing spores: (A) *Buellia,* showing a clavate ascus with 1 septate spores, (C) *Acarospora* showing numerous minute simple spores. (B) shows a globuse ascus containing transversely septate spores of *Arthonia.*
Bottom: D to E are various spore types: (D) transversely septate thin walled spore of *Haematomma* showing cylindrical locules, (E) 1 septate thin walled spore of *Lopadium*, (F) transversely septate, unequally thickened spore of *Graphis*, showing lenticular locules, (G) muriform spore of *Graphina*, (H) muriform spore of *Diploschistes*, (I) simple spore of *Lecanora*, (J) polarilocular spore of *Caloplaca* showing the unequally thickened wall with two chambers joined by a canal, (K) 1 septate spore of *Buellia* showing unequal thickening and development of false septa near the ends.

HAEMATOMMA MASS.: *Ric. Lich. Crost.* 32 (1852)

MORPHOLOGY: *Thallus* crustose, uniform, corticate; cortex of agglutinate thin walled hyphae; attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed to sessile, round or somewhat irregular, thalloid margin usually well developed; hypothecium pale; paraphyses unbranched, branched, or reticulate; asci cylindrical, unitunicate, thin walled, tholus I+ blue, 8 spored; ascospores acicular, transversely 3-many septate, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, little branched or unbranched; pycnospores bacilliform.
CHEMISTRY: (21 species) atranorin (10), thamnolic acid (6), divaricatic acid (3), psoromic acid (3), usnic acid (3), zeorin (3), porphyrilic acid (2), decarboxythamnolic acid (1), erythrommone (1), haemoventosin (1), imbricaric acid (1), pachycarpin (1), perlatolic acid (1), placodiolic acid (1), ventosic acid (1), xanthone pigments.
PHYCOBIONT: Coccoid Chlorophyceae.
DISTRIBUTION: On wood or bark, throughout the region. 6 species reported (30).

HELMINTHOCARPON FEE: *Essai Crypt. Suppl.* 156 (1837)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate or poorly corticate, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, apothecia immersed to adnate, irregular, roundish to stellate or branched; proper margin thin, usually covered in a thalloid layer; hypothecium pale; paraphyses thin, reticulate; asci cylindrical to clavate, unitunicate, I−, thin walled, 4-8 spored; ascospores fusiform to oblong, muriform, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland. 2 species reported (15).

HEPPIA NAEG. in HEPP: *Flecht. Eur.* 49 (1853)

MORPHOLOGY: *Thallus* squamulose, paraplectenchymatous throughout, usually without a distinct medulla, attached to the substrate by hyphal rhizoids. *Ascocarp* an apothecium, immersed, disk open, round; proper exciple absent or dissappearing; paraphyses unbranched; hypothecium pale; asci clavate, unitunicate, thin walled, I+ blue, tholus I+ blue, 8 spored; ascospores simple, hyaline, thin walled. *Pycnidia* immersed, fulcrum exobasidial; pycnospores ellipsoid to oblong.
CHEMISTRY: No data.
PHYCOBIONT: *Scytonema.*
DISTRIBUTION: On soil, in arid areas. 1 species reported (1).

HERPOTHALLON TOBLER: *Flora, Jena* 131, 446 (1937)

MORPHOLOGY: *Thallus* of a loose construction, more or less crustose, forming patches up to 8 cm diameter, coloured red, white and green in concentric patterns; constructed from loosely woven hyphae which often terminate in pyramidal swellings. *Hymenium* not known.
CHEMISTRY: Not known.
PHYCOBIONT: *Trentepohlia* and some coccoid green algae.
DISTRIBUTION: In rainforests of Queensland, probably over mosses. 1 species reported (1).

HETERODEA NYL.: *Bull. Soc. Linn. Normandie ser 2,* 2, 47 (1867)

MORPHOLOGY: *Thallus* foliose, prostrate or ascending, much branched, upper surface corticate, cortex of agglutinated longitudinal hyphae; lower surface ecorticate, with a more or less complete layer of tomentum or rhizines which may appear cyphellate or veined. *Ascocarp* an apothecium, marginal, peltate, cymosely aggregate, proper exciple developed; hypothecium pale, over an algal layer; paraphyses unbranched; asci cylindrical, unitunicate, tholus I+, 8 spored; ascospores ovoid, simple, hyaline, thin walled. *Pycnidia* sessile, marginal; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (2 species) usnic acid (2), condivaricatic acid (1), diffractaic acid (1), divaricatic acid (1).
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: Widespread in temperate and semi-arid Australia and New Caledonia. 2 species reported (2).

HETERODERMIA TREVIS.: *Atti Soc. Ital. Sci. Nat. Milano* 9, 613 (1868)

MORPHOLOGY: *Thallus* foliose, usually prostrate, attached by rhizines, lobes usually 2-5 mm broad, ciliate, with a well developed upper cortex of longitudinal hyphae; lower cortex often absent; medulla woolly. *Ascocarp* an apothecium, laminal; exciple thalloid; disk dark, often pruinose; paraphyses unbranched; asci unitunicate, clavate, thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores 1 septate, brown, thick walled, with blastidia. *Pycnidia* immersed or prominent; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (61 species) atranorin (61), zeorin (54), leucotylin (44), α-0-acetylleucotylins (43), triterpenoids (38), salazinic acid (25), norstictic acid (19), 2-chloroemodin (9), flavo-obscurins (8), 2-4 dichloroemodin (7), anthroquinones (5), dissectic acid (5).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On trees and rocks in Queensland, New South Wales, Victoria, Tasmania and South Australia. 12 species reported (60).

HYPOGYMNIA NYL.: *Lich. Env. Paris* 39 (1896)

MORPHOLOGY: *Thallus* foliose, radiate, corticate on both surfaces; cortex of anticlinal hyphae; medulla very lax, lobes often hollow, imperforate; without rhizines. *Ascocarp* an apothecium, stipitate, round, thalline exciple; disk brown; asci small, cylindrical, unitunicate, I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (28 species) atranorin (28), physodic acid (24), chloroatranorin (20), physodalic acid (12), oxyphysodic acid (11), protocetraric acid (10), 2-0'-methylphysodic acid (6), salazinic acid (2), anthroquinones (1), barbatic acid (1), fumarprotocetraric acid (1), lobaric acid (1), usnic acid (1), vittatolic acid (1), zeorin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, New South Wales, Victoria, Tasmania, South Australia and Western Australia in moist and cool to cold areas, commonly sub-alpine. 11 species reported (44).

HYPOTRACHYNA HALE: *Phytologia* 28, 340 (1974c)

MORPHOLOGY: *Thallus* foliose, lobes sub-linear, apically truncate, both surfaces corticate, paraplectenchymatous, attached by dichotomously branched rhizines, lower surface black.

Ascocarp an apothecium, adnate to substipitate, imperforate, round, thalloid exciple well developed; disk brown; hypothecium pale; paraphyses unbranched; asci cylindrical, unitunicate, thin walled, I+ blue, 8 spored; ascospores ovoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (77 species) atranorin (57), protocetraric acid (15), usnic acid (14), obtusatic acid (13), barbatic acid (12), norstictic acid (11), lichexanthone (10), salazinic acid (10), rhodophyscin (9), alectoronic acid (8), colensoic acid (7), gyrophoric acid (7), lividic acid (6), anziaic acid (5), α-collatolic acid (5), entothein (4), evernic acid (4), lecanoric acid (4), constictic acid (3), echinocarpic acid (3), galbinic acid (3), sticic acid (3), olivetoric acid (2), physodalic acid (2), fumarprotocetraric acid (1), microphyllinic acid (1), perlatolic acid (1), succinprotocetraric acid (1).
PHYCOBIONT: *Trebouxia*.
DISTRIBUTION: On trees, especially in the southern half of the region. 8 species reported (83).

LAURERA REICHENBACH: *Deutsche Bot.* 15 (1841)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; epi- or endophloic. *Ascocarp* a perithecium, immersed singly or aggregated in stroma; ostioles erect; paraphyses reticulate; asci cylindrical-clavate, I−; bitunicate, 2-8 spored; ascospores muriform, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial.
CHEMISTRY: (5 species) parietin (2), xanthorin (2), lichexanthone (1), papulosin (1).
PHYCOBIONT: *Trentepohlia*.
DISTRIBUTION: Queensland and Tasmania. 4 species reported (28).

LECANACTIS ESCHW.: *Syst. Lich.* 14 (1824)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, attached by medullary or prothallial hyphae. *Ascocarp* a pseudothecium, immersed to sessile; circular or somewhat irregular; margin proper, black; hypothecium black; paraphyses branched, often reticulate; asci clavate, bitunicate, I−, 4-8 spored; ascospores oblong-acicular, transversely 3-15 septate, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores ellipsoid to oblong.
CHEMISTRY: (11 species) lecanoric acid (4), erythrin (3), phenolics (3), atranorin (1), conpsoromic acid (1), psoromic acid (1), schizopeltic acid (1), triterpenoids (1).
PHYCOBIONT: *Trentepohlia*.
DISTRIBUTION: Queensland and Tasmania. 5 species reported (90).

LECANIA MASS.: *Alcuni Gener. Lich.* 12 (1855)

MORPHOLOGY: *Thallus* crustose; uniform, lobed at the margins or squamulose; corticate or ecorticate; attached by medullary or prothallial hyphae; medulla woolly. *Ascocarp* an apothecium, sessile, round; margin thalloid; well developed, with or without a proper exciple; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 or rarely 16-32 spored; ascospores oblong-ellipsoid, 1 (rarely more) septate, hyaline, thin walled. *Pycnidia* immersed, fulcrum exobasidial.
CHEMISTRY: (1 species) lecanin.
PHYCOBIONT: *Trebouxia*.
DISTRIBUTION: On rock or bark, in Queensland, New South Wales, Victoria and Tasmania. 9 species reported (90).

LECANORA ACH.: *Lich. Univ.* 77 (1810)

Recent studies have resulted in a number of genera being segregated from this taxon (Hawksworth, James and Coppins 1980). Knowledge of Australian material is insufficient to allow certainty about which are present in Australia.

MORPHOLOGY: *Thallus* crustose, uniform or lobed at the margins; ecorticate or with a developed cortex; medulla woolly; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, round, sessile; thalloid margin well developed; paraphyses unbranched; hypothecium pale, asci clavate, unitunicate, tholus I+ blue, 8 (or rarely 16-32) spored; ascospores oblong-ellipsoid simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum usually exobasidial, rarely endobasidial; pycnospores bacilliform to filiform.
CHEMISTRY: (53 species) atranorin (20), usnic acid (19), zeorin (7), chloroatranorin (6), norstictic acid (5), lecanoric acid (4), protocetraric acid (3), psoromic acid (3), rocellic acid (3), epanorin (2), gangaleodin (2), rhizocarpic acid (2), α-collatolic acid (1), divaricatic acid (1), fumarprotocetraric acid (1), leucotylin (1), lobaric acid (1), melanophthalmic acid (1), olivetoric acid (1), pannarin (1), placodiolic acid (1), sordidone (1), sulphurellin (1), thiophanic acid (1), variolaric acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On trees, soil and rock, throughout Australia. 70 species reported (400).

LECIDEA ACH. em ZAHLBR.: *Nat. Pflanz.* 1, 130 (1905)

Recent studies have resulted in a number of genera being segregated from this taxon (Hawksworth, James and Coppins 1980). Knowledge of Australian material is insufficient to allow certainty about which are present in Australia.

MORPHOLOGY: *Thallus* crustose; uniform, warty-cracked areolate to marginally lobed; ecorticate or corticate; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, sessile, disk round; margin proper; hypothecium hyaline, coloured or black; paraphyses unbranched, often capitate at the tip; asci cylindrical-clavate, unitunicate, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform to filiform.
CHEMISTRY: (65 species) gyrophoric acid (12), atranorin (11), lecanoric acid (8), norstictic acid (8), confluentic acid (4), fumarprotocetraric acid (4), constictic acid (2), lichexanthone (2), 2-0-methylanziaic acid (2), planaic acid (2), psoromic acid (2), rhizocarpic acid (2), salazinic acid (2), stictic acid (2), anziaic acid (1), arthothelin (1), calycin (1), chloroatranorin (1), 7-chloroemodin (1), diploicin (1), divaricatic acid (1), ergosterol (1), glomelliferic acid (1), leprapinic acid (1), 2-0-methylconfluentic acid (1), 2-0-methylperlaolic acid (1), miriquidic acid (1), norsolorinic acid (1), perlatolic acid (1), porphyrilic acid (1), thiophanic acid (1),thuringione (1), schizopeltic acid (1).
PHYCOBIONT: *Trebouxia, Chlorella, Chlorosarcina, Coccobotrys, Myrmecia, Pleurococcus, Pseudochlorella.*
DISTRIBUTION: On trees, rocks and soil, throughout Australia. 87 species reported (800).

LEMPHOLEMMA KORB.: *Syst. Lich. Germ.* 400 (1855)

MORPHOLOGY: *Thallus* wholly mycelial, irregular, gelatinous, lobed or branched, smooth or rough, taking the form of the phycobiont; ecorticate; attached to the substrate by hyphae. *Ascocarp* an apothecium, immersed to adnate; sometimes lateral or terminal; disk round, flat

to concave; margin thalloid, thin; hypothecium hyaline; paraphyses unbranched; asci clavate, unitunicate, thin walled, I+ blue, 8 spored; ascospores spherical to ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: Queensland and Victoria, in humid forests. 2 species reported (30).

LEPRARIA ACH.: *Meth. Lich.* 3 (1803)

MORPHOLOGY: *Thallus* crustose, devoid of differentiation, uniform, of tangled hyphae and phycobiont cells, forming a soredioid mass. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (10 species) atranorin (4), calycin (2), fumarprotocetraric acid (2), leprapinic acid (2), roccellic acid (2), barbatolic acid (1), divaricatic acid (1), lepraric acid (1), pinastric acid (1), usnic acid (1), vulpinic acid (1), zeorin (1).
PHYCOBIONT: *Chlorella, Stichococcus, (+?Trebouxia).*
DISTRIBUTION: On rock, wood and bark, throughout the region. 2 species reported (20).

LEPROCAULON NYL. ex LAMY: *Bull. Soc. Bot. Fr.* 25, 352 (1868)

MORPHOLOGY: *Thallus* fruticose, dwarfed, ecorticate, smooth, branches slender, more or less erect, sometimes squamulose, becoming powdery, fragile. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (7 species, all variable) atranorin (5), rangiformic acid (4), fatty acids (4), baeomycesic acid (3), conpsoromic acid (3), protocetraric acid (3), psoromic acid (3), divaricatic acid (2), barbatic acid (1), dibenzofuran (1), didymic acid (1), evernic acid (1), grayanic acid (1), lecanoric acid (1), physodalic acid (1), sekikaic acid (1), succinprotocetraric acid (1), thamnolic acid (1), usnic acid (1), zeorin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On dry rock ledges, in New South Wales, Victoria, Tasmania and South Australia. 2 species reported (7).

LEPTOGIUM (ACH.) GRAY: *Nat. Arr. Br. Pl.* 400 (1821)

MORPHOLOGY: *Thallus* foliose to squamulose or fruticose; membranous, gelatinous; corticate, with two cell layers; medulla of hyphae in algal gel; adhering to the substrate or umbilicate. *Ascocarp* an apothecium, initially immersed, later adnate to stipitate; laminal or marginal; disk circular, margin thalline; hypothecium hyaline to brown, of interwoven hyphae or pseudoparenchymatous; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores oval to ellipsoid, hyaline, muriform, thin walled. *Pycnidia* immersed in the thallus or in warts; fulcrum endobasidial, small celled; pycnospores bacilliform.
CHEMISTRY: (21 species) no secondary lichen substances found.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: On rock, bark and soil, in humid areas of Queensland, New South Wales, Victoria, Tasmania, South Australia and Western Australia. 30 species reported (50).

LEPTOTREMA MONT. et BOSCH: *Plant. Junghuhn.* 4, 483 (1855)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform; ecorticate or with a woolly poorly developed cortex, attached by medullary or prothallial hyphae. *Ascocarp* an apothecium,

immersed to sessile in warts; disk round or elongate, punctiform or narrow; well developed proper exciple initially closed over the disk, later tearing and opening, then disintegrating leaving the disk free but surrounded by a thalline margin; paraphyses unbranched; asci cylindrical-clavate, unitunicate, thick walled, I−, 8 spored; ascospores ellipsoid or oblong-ellipsoid, brown, muriform, wall thickness unequal resulting in spherical or lenticular locules. *Pycnidia* fulcrum exobasidial (?).
CHEMISTRY: (17 species) stictic acid (7), constictic acid (5), norstictic acid (2), protocetraric acid (2), conpsoromic acid (1), hypoprotocetraric acid (1), psoromic acid (1), virensic acid (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland and Tasmania, in humid forests. 12 species reported (65).

LICHINA C. AG.: *Spec. Alg.* 104 (1821)

MORPHOLOGY: *Thallus* minutely fruticose, caespitose, gelatinous; branches cylindrical or flattened with a cortex of tangled hyphae; medulla of longitudinal hyphae. *Ascocarp* an apothecium, immersed in the swollen tips of branches; disk round or irregular; narrow proper exciple enclosed in a thalline exciple; paraphyses unbranched (rarely branched), thin; asci cylindrical, unitunicate, thin walled, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed in the thallus close to the apothecia; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (2 species) no secondary lichen substances.
PHYCOBIONT: *Calothrix.*
DISTRIBUTION: On maritime rocks, in the southern parts of Australia. 2 species reported (7).

LOBARIA SCHREB.: *Gener. Plant.* II, 768 (1791)

MORPHOLOGY: *Thallus* foliose, prostrate or ascending, attached to the substrate by a bushy tomentum; corticate on both surfaces, both cortex layers paraplectenchymatous, medulla woolly. *Ascocarp* an apothecium, marginal or laminal, sessile to stipitate; initially urn-like, later more open, disk concave, exciple paraplectenchymatously corticate, thalline; hypothecium pale or brown; paraphyses unbranched; asci cylindrical-clavate, unitunicate, tholus I+ blue, 8 spored; ascospores fusiform-acicular, transversely 1-several septate, hyaline, thin walled. *Pycnidia* in small warts; fulcrum endobasidial, small celled; pycnospores bacilliform or somewhat constricted at the centre.
CHEMISTRY: (55 species) gyrophoric acid (35), norstictic acid (15), stictic acid (14), 4-0-methylgyrophoric acid (13), constictic acid (10), thelephoric acid (9), atranorin (8), triterpenes (6), tenuiorin (4), scrobiculin (3), usnic acid (2), retigeric acid (1).
PHYCOBIONT: *Myrmecia, Trebouxia, Nostoc* (*Nostoc* often in cephalodia).
DISTRIBUTION: On bark and rock, in Queensland, New South Wales, Victoria and Tasmania, mostly in wetter areas. 22 species reported (80).

LOPADIUM KORB.: *Syst. Lich. Germ.* 210 (1855)

MORPHOLOGY: *Thallus* crustose, uniform ecorticate, attached to the substrate by prothallial or medullary hyphae. *Ascocarp* an apothecium, sessile or stipitate; disk round, margin soft or cartilaginous, proper; hypothecium pale to dark; hymenium mucilagenous; paraphyses unbranched or branched; asci cylindrical-clavate, unitunicate, thick walled, tholus I+ blue, 1-8 spored; ascospores ovoid, muriform, hyaline, thin walled. *Pycnidia* sessile; fulcrum endobasidial; pycnospores bacilliform.

CHEMISTRY: (8 species) 2-7 dichlorolichexanthone (4), parietin (3), atranorin (2), chloroatranorin (1), triterpene (1), usnic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, New South Wales and Tasmania, on bark in humid forests. 13 species reported (70).

MALLOTIUM GRAY: *Nat. Arr. Br. Pl.* 1, 399 (1821)

MORPHOLOGY: *Thallus* foliose, large; upper surface with a single layer of paraplectenchymatous cells; lower surface covered with a tomentum of filaments; gelatinous when wet. *Ascocarp* an apothecium, initially immersed, later adnate to stipitate; disk circular, margin thalline; hypothecium hyaline to brown; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores oval to ellipsoid, muriform, hyaline, thin walled. *Pycnidia* immersed in the thallus or warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: No secondary lichen substances known.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: Victoria and Western Australia. 3 species reported (12).

MARONEA MASS.: *Misc. Lich.* 291 (1856)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate or partly corticate; medulla woolly; attached by medullary hyphae. *Ascocarp* an apothecium, at first immersed, later sessile; disk round; margin thalloid only, corticate; hypothecium pale; paraphyses unbranched or little branched; asci clavate-globular, unitunicate, thin walled, I+ pale blue, tholus I+ pale blue, many spored; ascospores globular, simple (but sometimes apparently septate), thin walled, hyaline. *Pycnidia* immersed; fulcrum exobasidial; pycnospores thread-like, cylindrical.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Victoria and South Australia, on bark. 1 species reported (13).

MASTODIA HOOK. f. et HARV. apud HOOK. f.: *Bot. Antarctic Voyage* 1,499 (1847)

MORPHOLOGY: *Thallus* foliose to squamulose, of loosely woven hyphae and algae; without rhizines or prothallus. *Ascocarp* a perithecium, immersed in the thallus; paraphyses gelatinizing; ascus 8 spored; ascospores elongate, simple, hyaline. *Pycnidia* immersed; fulcrum exobasidial, pycnospores cylindrical, oblong to ellipsoid.
CHEMISTRY: No data.
PHYCOBIONT: *?Prasiola.*
DISTRIBUTION: Tasmania. 1 species reported (7).

MAZOSIA MASS.: *Neag. Lich.* 9 (1854a)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* a pseudothecium; round or irregular; immersed in the thallus; margin rudimentary to well developed; hypothecium hyaline to black; paraphyses reticulate; asci clavate, bitunicate, thin, I−, 8 spored; ascospores acicular to ovate, hyaline, transversely many septate, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical, oblong to ellipsoid.

CHEMISTRY: (3 species) No secondary lichen substances.
PHYCOBIONT: *Phycopeltis.*
DISTRIBUTION: Humid forests in Queensland, normally foliicolous. 3 species Reported (9).

MEDUSULINA MULL. ARG.: *Bull. Herb. Boissier* 2, 93 (1894a)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, attached to the substrate by hyphal rhizoids. *Ascocarp* an apothecium, lirreliform, grouped in raised stroma, immersed to superficial; exciple well developed; hypothecium hyaline; paraphyses unbranched; ascus cylindrical to clavate, unitunicate, I−, 1-8 spored, ascospores oblong-ellipsoid to fusiform, hyaline, muriform, walls unequally thickened resulting in spherical or lenticular locules. *Pycnidia* not known.
CHEMISTRY: (2 species) norstictic acid (1), stictic acid (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Humid forests in Queensland and Victoria, on bark. 2 species reported (6).

MEGALOSPORA MEYEN et FLOTOW: *Nov. acta Acad. Caesar Leop. Carol. 19 Suppl.* 228 (1843)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, often sorediate; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, sessile or adnate; disk circular, flat or convex; margin proper; hypothecium pale; paraphyses unbranched, branched or anastomosing; asci clavate, unitunicate, I+ blue, tholus I+ blue, 1-8 spored; ascospores ellipsoid, 1 septate, hyaline, thick walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (4 species) usnic acid (4), zeorin (4).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Humid forests, in Queensland, Victoria, New South Wales and Tasmania. 12 species reported (50).

MELAMPYDIUM STIRT.: *J. Linn. Soc. Bot.* 16, 471 (1875)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium-like pseudothecium; round to irregular; immersed or sessile, flat; proper margin little developed; hypothecium pale; paraphyses little branched; asci clavate, bitunicate, thin walled, I−, 8 spored; ascospores transversely septate or muriform, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: Queensland and Tasmania, on bark. 1 species reported (1).

MELANELIA ESSL.: *Mycotaxon* 7, 46 (1978)

MORPHOLOGY: *Thallus* foliose, lobed, radiate; loosely to moderately adnate to the substrate, attached by rhizines; lobes short and rotund or elongate, more or less flat; with a paraplectenchymatous cortex; commonly sorediate-isidiate or pseudocyphellate above, HNO_3−. *Ascocarp* an apothecium, laminal, sessile; disk concave, round; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue,

8 spored; ascospores ellipsoid simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (37 species) lecanoric acid (8), gyrophoric acid (7), protocetraric acid (6), fumarprotocetraric acid (5), perlatolic acid (4), stenosporic acid (4), rhodophyscin (2), caperatic acid (1), salazinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Throughout the southern part of the region, on a range of substrates. 4 species reported (37).

MELANOTHECA FEE: *Essai Crypt. Suppl.* 70 (1837)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, epi- or endophloic. *Ascocarp* a perithecium, immersed in groups in stroma, black; ostiole straight, erect; paraphyses unbranched or reticulate; asci cylindrical-clavate, bitunicate, thin walled, I−, 8 spored; ascospores ellipsoid to fusiform, transversely 3-several septate, brown, with unequally thickened walls resulting in lenticular or globose locules. *Pycnidia* immersed; fulcrum exobasidial; pycnospores filiform, curved.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland and New South Wales. 6 species reported (53).

MELASPILEA NYL.: *Act. Soc. Linn. Bordeaux* 21, 416 (1856)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; epi- or endophloic; attached to the substrate by prothallial or medullary hyphae. *Ascocarp* an apothecium, round or irregular to elongate; devoid of thalloid margin; proper exciple often black; hypothecium hyaline to brown; paraphyses unbranched or absent; asci cylindrical, unitunicate, thin walled, I−, 8 spored, ascospores ellipsoid or asymmetric, 1 septate, hyaline or brown, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (1 species) no secondary lichen substances found.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 9 species reported (60).

MENEGAZZIA MASS.: *Neag. Lich.* 3 (1854a)

MORPHOLOGY: *Thallus* foliose, radiately lobed to sub-fruticose; corticate on both surfaces; upper surface perforate; lower surface black, without rhizines; medulla very lax, normally hollow. *Ascocarp* an apothecium, sessile to stipitate; round, well developed thalloid margin; hypothecium hyaline; paraphyses unbranched; asci cylindrical-clavate, unitunicate, I+, tholus I+ blue, usually 2-4 spored; ascospores ellipsoid, simple, hyaline, thick walled, often large. *Pycnidia* immersed; fulcra endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (3 species) atranorin (3), stictic acid (3), constictic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Widely distributed in the southern half of the continent especially in cooler and wetter areas. 12 species reported (30).

MICAREA FR. em HEDL.: *Bih. Kgl. Svensk Vetensk Akad. Handl.* 18(3) 3, 27 (1892)

MORPHOLOGY: *Thallus* crustose, uniform; composed at least in part of goniocyste-like granules. *Ascocarp* an apothecium, sessile, emarginate, often globose; hypothecium pale or dark; paraphyses reticulate; asci unitunicate (?), thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple or transversely septate, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *?Myrmecia.*
DISTRIBUTION: Tasmania and probably other regions, on acid substrates. 1 species reported (30).

MICROTHELIA KORB.: *Syst. lich. Germ.* 372 (1855)

MORPHOLOGY: *Thallus* crustose, uniform, granular, ecorticate; epi- or endophloic, with an indistinct prothallus. *Ascocarp* a perithecium, sessile or partly immersed, black, ostiole erect; paraphyses reticulate, often gelatinizing; asci cylindrical-clavate, bitunicate, thick walled, I−, 4-8 spored; ascospores ellipsoid to fusiform, usually 1 septate but up to 5 septate, brown, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales and Victoria. 10 species reported (70).

MYCOPORELLUM MULL. ARG.: *Rev. Mycol.* 6, 14 (1884)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; epi- or endophloic. *Ascocarp* a perithecium-like pseudothecium, opening by a pore or irregular slit, black; often several immersed in a stroma; paraphyses absent or reticulate; asci oval or clavate, bitunicate, thick walled, I−, 8 spored; ascospores ellipsoid or asymetric to acicular, transversely 1-5 septate, hyaline or dark, thin walled, the locules often markedly unequal. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, Victoria and Tasmania. 3 species reported (30).

NEOFUSCELIA ESSL.: *Mycotaxon* 7, 49 (1978)

MORPHOLOGY: *Thallus* foliose to almost crustose or sub-fruticose; loosely or closely adnate, attached by rhizines; lobes short and rotund to linear-elongate; more or less flat to convex; with a paraplectenchymatous cortex; with neither soredia nor isidia; HNO_3+. *Ascocarp* an apothecium, laminal, sessile; disk concave, round; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (67 species) norstictic acid (12), gyrophoric acid (8), divaricatic acid (6), glomelliferic acid (6), perlatolic acid (6), fumarprotocetraric acid (5), glomellic acid (5), physodic acid (5), protocetraric acid (5), stenosporic acid (5), alectoronic acid (4), α-collatolic acid (4), salazinic acid (4), diffractaic acid (3), barbatic acid (2), constictic acid (2), loxodellic acid (2), norlobaridone (2), olivetoric acid (2), stictic acid (2), caperatic acid (1), 4-0-methylbarbatic acid (1), 4-0-methylolivetoric acid (1), 4-0-methylphysodic acid (1).
PHYCOBIONT: *Trebouxia.*

DISTRIBUTION: Throughout the southern part of the region, on rocks and soil. 10 species reported (67).

NEPHROMA ACH.: *Lich. Univ.* 101 (1810)

MORPHOLOGY: *Thallus* foliose, large, radiate, prostrate or a little ascending; both surfaces paraplectenchymatously corticate; attached to the substrate by rhizoids. *Ascocarp* an apothecium, immersed on the lower surface of lobes which recurve; without an exciple; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, I−, 8 spored; ascospores fusiform, transversely 1-5 septate, brown, thin walled. *Pycnidia* marginal, immersed in small warts; fulcrum endobasidial, branched; pycnospores short, straight, constricted in the middle.
CHEMISTRY: (11 species) nephrin (6), zeorin (6), usnic acid (2), nephroarctin (2), nephromin (2), anthraquinones (1), emodin (1), fragilin (1), phenarctin (1), stictic acid (1).
PHYCOBIONT: *Coccomyxa* or *Nostoc*.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 7 species reported (35).

NEUROPOGON NEES et FLOTOW: *Linnaea* 9, 496 (1835)

MORPHOLOGY: *Thallus* fruticose, erect or somewhat pendulous, corticate; cortex horny, brittle, of agglutinate periclinal hyphae; medulla woolly, central axis cartilagenous, solid, of longitudinal agglutinated hyphae; attached to the substrate by a basal disk; branches yellow, black at the tips, glossy. *Ascocarp* an apothecium, lateral or terminal on branches, well developed thalline margin; disk round, black or dark; hypothecium dark; paraphyses branched, agglutinate; asci clavate to cylindrical, unitunicate, thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores fusiform to acicular.
CHEMISTRY: (5 species) usnic acid (5), norstictic acid (2), fumarprotocetraric acid (1), salazinic acid (1).
PHYCOBIONT: *Trebouxia*.
DISTRIBUTION: Alpine or sub-alpine areas of Victoria and Tasmania. 5 species reported (10).

NORMANDINA VAIN.: *Acta Soc. Fauna Flora Fenn.* 7(2), 188 (1890)

MORPHOLOGY: *Thallus* squamulose to foliose; round to somewhat lobed; apressed or a little ascending; poorly developed upper cortex; attached by hyphal rhizoids. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: No identified secondary lichen substances.
PHYCOBIONT: Coccoid Chlorophyceae.
DISTRIBUTION: Queensland, New South Wales, Victoria and South Australia. 1 species reported (1).

OCELLULARIA MEYEN et FLOTOW: *Nov. Act. Acad. Caesar. Leop. Carol. 19 Supp.* (1843)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate or with a poorly developed cortex; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium,

immersed in the thallus or sessile in warts; disk round or rarely elongate; concave or flat; proper exciple completely closing the disk, but cracking with age and the remnants bordering the disk, or the disk left free within a thalloid margin; hypothecium hyaline; paraphyses unbranched; asci clavate, unitunicate, thick walled, I— (but hymenial gel may be I+), 1-8 spored; ascospores oblong to fusiform, transversely 1-many septate, hyaline, walls unequally thickened to form lenticular locules. *Pycnidia* unknown.
CHEMISTRY: (53 species) hypoprotocetraric acid (19), psoromic acid (12), conpsoromic acid (10), 4-0-demethylnotatic acid (10), protocetraric acid (5), constictic acid (4), stictic acid (4), endocrin (2), gyrophoric acid (1), lichexanthone (1), 4-0-methylhypoprotocetraric acid (1), norstictic acid (1), triterpenoids (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales and Victoria. 22 species reported (120).

OCHROLECHIA MASS.: *Ric. Lich. Crost.* 30 1852)

MORPHOLOGY: *Thallus* crustose, uniform, areolate, the areoles sometimes dwarf-fruticose; usually ecorticate, sometimes with a cortex of anticlinal hyphae; medulla woolly; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, at first immersed later sessile and constricted at the base; disk round; margin thalloid; hypothecium pale; paraphyses reticulate; asci clavate, unitunicate (but of several layers), thick walled, I+ blue, tholus I+, 2-8 spored; ascospores ellipsoid, simple, hyaline, walls thin or little thickened. *Pycnidia* immersed in warts; fulcrum exobasidial; pycnospores oblong to cylindrical.
CHEMISTRY: (29 species) lecanoric acid (18), gyrophoric acid (10), erythrin (5), variolaric acid (4), atranorin (3).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, New South Wales, Victoria, Tasmania and South Australia. 6 species reported (40).

OPEGRAPHA HUMB.: *Flor. Friberg.* 57 (1793)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, sometimes endophloic; attached by medullary or prothallial hyphae. *Ascocarp* a lirreliform pseudothecium, immersed, adnate or sessile, round or markedly elongate, with carbonaceous proper exciple; hypothecium dark or pale; paraphyses reticulate; asci clavate, bitunicate, thin walled, I—, 8 spored; ascospores ellipsoid to fusiform, transversely 1-many septate, hyaline or brown, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong to filiform, curved.
CHEMISTRY: (8 species) erythrin (3), lecanoric acid (3), confluentic acid (1), farinosin (1), norstictic acid (1), triterpenes (1).
PHYCOBIONT: *Trentepohlia, Phycopeltis.*
DISTRIBUTION: Queensland, Victoria and Tasmania. 24 species reported (300).

PANNARIA DEL. in BORY.: *Dict. Class. hist. nat.* 20 (1828)

MORPHOLOGY: *Thallus* squamulose to foliose; upper surface corticate, of anticlinal hyphae forming paraplectenchyma; attached to the substrate by a well developed blue to black hypothallus or by a tomentum of dark rhizoids; lower surface ecorticate, of loosely woven hyphae; medulla at least in part woolly. *Ascocarp* an apothecium, at first immersed, eventually sessile; laminal; disk circular; thalloid exciple; hypothecium hyaline or pale coloured; paraphyses unbranched or branched; ascus clavate, unitunicate, I+, tholus I+, 8 spored;

ascospores ellipsoid to fusiform, simple, hyaline, sometimes the wall thickened or warty. *Pycnidia* immersed in thalline warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (6 species) pannarin (3), atranorin (2), triterpenoids (2).
PHYCOBIONT: *Nostoc, Scytonema.*
DISTRIBUTION: Widespread in moist areas of all states, on rock, soil and bark. 18 species reported (80).

PANNOPARMELIA (MULL. ARG.) DARB.: *Wiss. Ergebn. Schwedisch Sudpolar-Expedit.* 1901-3 vol. 4(2), 11 (1912)

MORPHOLOGY: *Thallus* foliose, much divided, often moniliform; upper surface yellow-green, corticate, of anticlinal hyphae; lower cortex with a dense tomentum of black anastomosing hyphae in discrete patches. *Ascocarp* an apothecium, laminal, circular, stipitate; margin thalloid; hypothecium pale; paraphyses unbranched or little branched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoidal to almost globose, simple, hyaline, thin walled.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 3 species reported (5).

PARATHELIUM NYL.: *Bot. Ztg.* 20, 279 (1862)

MORPHOLOGY: *Thallus* crustose, uniform, epi-or endophloic, ecorticate. *Ascocarp* a perithecium; ostiolar canal more or less lateral; sometimes with a thalloid covering; paraphyses reticulate; asci cylindrical-clavate, bitunicate, usually thick walled, I−, 4-8 spored; ascospores ellipsoid to circular, transversely 3-10 septate, thin walled, brown. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on bark in humid forests. 1 species reported (?15).

PARMELIA ACH. *(sensu ampl.): Meth. Lich.* 153 (1803)
This very large generic aggregate is the subject of controversy. It has been divided by Hale (1974,a,b,c,d) and Esslinger (1978) into a great many segregates, which other workers may not accept. The segregates have been treated separately here, and may be found under the following names: *Bulbothrix, Hypotrachyna, Melanelia, Neofuscelia, Parmelia, Parmelina, Parmotrema, Pseudoparmelia, Relicina* and *Xanthoparmelia.*

PARMELIA ACH.: *(sensu Hale).*

MORPHOLOGY: *Thallus* foliose, lobed, radiate, appressed to somewhat ascending, both surfaces corticate; upper cortex of anticlinal hyphae, reticulately cracked or maculate; medulla woolly; lower cortex pale or dark, with simple or squarrose rhizines to the margin; with or without marginal cilia. *Ascocarp* an apothecium, sessile, laminal, disk concave, brown, circular; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (55 species) salazinic acid (28), lecanoric acid (10), gyrophoric acid (5), all species probably contain atranorin.

PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Widespread throughout the region except in arid or semi-arid areas. ?8 species reported (?60).

PARMELIELLA MULL. ARG.: *Mem. Soc. Phys. Hist. nat. Geneve* 16(2), 376 (1862).

MORPHOLOGY: *Thallus* crustose to squamulose or foliose; upper surface corticate; cortex paraplectenchymatous of anticlinal hyphae; medulla woolly; lower surface ecorticate; attached to the substrate by a well developed dark prothallus or by rhizoids. *Ascocarp* an apothecium, immersed to adnate, laminal; disk round; margin proper; hypothecium pale to brown; paraphyses unbranched; ascus clavate, unitunicate, I+, I+ tholus, 8 spored; ascospores ellipsoid, simple hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (1 species) no secondary lichen substances.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. 10 species reported (50).

PARMELINA HALE: *Phytologia* 28, 481 (1974b)

MORPHOLOGY: *Thallus* foliose, lobed, radiate, loosely appressed to the substrate; lobes sub-linear to irregular, corticate; cortex of anticlinal hyphae forming paraplectechyma; lower cortex usually black with simple or squarrose rhizines to the margin; margins of lobes with simple cilia at least in the axils. *Ascocarp* an apothecium, laminal, sessile; disk concave, round; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed, fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (46 species) atranorin (46), leucotylin (17), zeorin (17), secaleconic acid A (16), terpenes (15), gyrophoric acid (8), salazinic acid (7), galbinic acid (4), "horrescens" unknown (4), lecanoric acid (4), connorstictic acid (2), constictic acid (2), norstictic acid (2), fumarprotocetraric acid (1), lobaric acid (1), protocetraric acid (1), protolichesterinic acid (1), stictic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: In all states, especially on bark. 9 species reported (47).

PARMELIOPSIS (STIZ.) NYL.: *Syn. Lich.* 53 (1860)

MORPHOLOGY: *Thallus* foliose, appressed, irregularly lobed, upper and lower surfaces corticate; cortex of more or less anticlinal woven hyphae not forming paraplectenchyma; attached to the substrate by rhizines. *Ascocarp* an apothecium, laminal, sessile to adnate; disk round, concave; margin thalloid; hypothecium hyaline or brown; paraphyses rarely branched; ascus clavate, unitunicate, tholus I+ blue, 8 spored; ascospores ellipsoid to oblong, simple hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical, curved.
CHEMISTRY: (6 species) atranorin (5), divaricatic acid (3), thamnolic acid (2), usnic acid (2), protocetraric acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Victoria. 2 species reported (7).

PARMENTARIA FEE: *Essai Crypt.* 39 & 70 (1824)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic, ecorticate or with an amorphous cortex. *Ascocarp* a perithecium; aggregated; the ostiolar canals oblique to horizontal and fusing in a common opening; naked or immersed in thalline or stromatic warts; paraphyses reticulate; ascus clavate, unitunicate, I−, 1-8 spored; ascospores ellipsoid to oblong, muriform, brown, walls unequally thickened resulting in lenticular or rhombic locules. *Pycnidia* immersed; fulcrum exobasidial.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland and Victoria, in humid forests. 15 species reported (25).

PARMOTREMA MASS.: *Atti Ist. Veneto Sci. Ser 3(5),* 248 (1890)

MORPHOLOGY: *Thallus* foliose, lobed, radiate, loosely adnate to somewhat ascending, usually large; lobes broad, apically rotund with a distinct bare zone below the tips; upper and lower surfaces with a pallisade-plectenchymatous cortex, rhizines simple, often rather sparse. *Ascocarp* an apothecium; laminal, sub-stipitate to stipitate, often perforate, more or less round; disk concave, brown; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (106 species) atranorin (106), alectoronic acid (21), protocetraric acid (17), salazinic acid (17), protolichesterinic acid (14), usnic acid (12), rhodophyscin (10), gyrophoric acid (9), lecanoric acid (8), norstictic acid (7), cryptochlorophaeic acid (6), stictic acid (6), caperatic acid (3), olivetoric acid (2), vulpinic acid (2).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Widespread through humid and sub-humid areas, on bark, wood and rock. 26 species reported (110).

PECCANIA MASS.: *Atti Ist. veneto Sci. ser.* 3, 5, 335 (1860)

MORPHOLOGY: *Thallus* minutely fruticose of more or less branched lobes, forming small polsters; ecorticate; attached by rhizines. *Ascocarp* an apothecium, lateral to sub-terminal, constricted at the base; margin thalloid; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, 8-16 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum ?exobasidial; pycnospores ellipsoid to acicular.
CHEMISTRY: No data.
PHYCOBIONT: *Xanthocapsa.*
DISTRIBUTION: Western Australia, on calcareous substrates. ?1 species reported (14).

PELTIGERA WILLD.: *Flor. Berol. Prod.* 347 (1787)

MORPHOLOGY: *Thallus* foliose, spreading or somewhat ascending; upper and lower surfaces with a paraplectenchymatous cortex; upper surface with or without a tomentum; lower surface veined; attached to the substrate by bushy rhizoids. *Ascocarp* an apothecium, immersed on upper surface of specialized marginal lobes, emarginate; sometimes with a veil of cortical remains; hypothecium hyaline to brown; paraphyses unbranched; ascus cylindrical-clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored, ascospores oblong-ellipsoid to acicular, transversely 3-7 septate, hyaline to brown, thin walled. *Pycnidia* immersed with filiform fulcra; pycnospores filiform.

CHEMISTRY: (22 species) tenuiorin (16), dolichorrhizin (8), zeorin (6), methylgyrophorate (5), scabrosin B (4), phlebic acid B (3), gyrophoric acid (2), phlebic acid A (2), scabrosin A (2), evernic acid (1), methylevernate (1), 4-0-methylgyrophoric acid (1), methyllecanorate (1), methylorsellinate (1), triterpenes (1), usnic acid (1).
PHYCOBIONT: *Nostoc* or *Coccomyxa.*
DISTRIBUTION: On soil, in humid areas of all states. 14 species reported (30).

PELTULA NYL.: *Annls. Sci. nat. Bot. ser 3,* 20, 316 (1853)

MORPHOLOGY: *Thallus* squamulose to peltate or sub-fruticose, corticate at least on the lower surface; paraplectenchymatous throughout or with a woolly medulla; attached to the substrate by a small area of rhizoids or an umbilicus. *Ascocarp* an apothecium, immersed, frequently covering the entire squamule; with or without a proper exciple; hypothecium pale; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, many spored; ascospores minute, simple, hyaline, with a gelatinous sheath. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (6 species) no determined secondary lichen substances.
PHYCOBIONT: *Anacystis.*
DISTRIBUTION: On soil and rock, especially in arid and semi-arid areas of Queensland, New South Wales, Victoria, South Australia and Western Australia. 7 species reported (18).

PERTUSARIA D.C. in LAM. et D.C.: *Flor. Franc.* 319 (1805)

MORPHOLOGY: *Thallus* crustose, uniform to dwarf fruticose, ecorticate or corticate with a paraplectenchymatous cortex of anticlinal hyphae; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium immersed in a wart, often perithecium-like in appearance, sometimes several hymenia in a wart, hymenia globose or disk-like, with profuse gelatin; hypothecium pale, paraphyses strongly reticulate; asci clavate, unitunicate (but with layers), thick walled, I+ blue, tholus I+ blue, the exoascus bursting in layers at maturity, 1-8 spored; ascospores ellipsoid or oblong-ellipsoid, simple, hyaline, walls often heavily thickened and ridged, commonly very large. *Pycnidia* immersed in warts; fulcrum exobasidial; pycnospores cylindrical to acicular or filiform.
CHEMISTRY: (84 species) thiophanic acid (23), norstictic acid (15), lichexanthone (14), stictic acid (14), picrolichenic acid (7), 2-7 dichloronorlichexanthone (5), fumarprotocetraric acid (4), atranorin (3), 2-7 dichlorolichexanthone (3), lecanoric acid (3), salazinic acid (3), thamnolic acid (3), gyrophoric acid (2), physodalic acid (2), arthothelin (1), connorstictic acid (1), haemathamnolic acid (1), 2-0-methylperlatolic acid (1), 4-0-methylperlatolic acid (1), perlatolic acid (1), protocetraric acid (1), stenosporic acid (1), variolaric acid (1).
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: On wood, bark and rocks, throughout the region. 65 species reported (250).

PHAEOGRAPHINA MULL. ARG.: *Flora, Jena* 65, 398 (1882)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic, ecorticate or with a cortex of interwoven hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, elongate, often branched, adnate or immersed; disk narrow, proper exciple usually well developed; hypothecium pale to black; paraphyses unbranched; asci clavate, unitunicate, I−, usually 1-3 spored; ascospores oblong ellipsoid to elongate ellipsoid, large, muriform, brown,

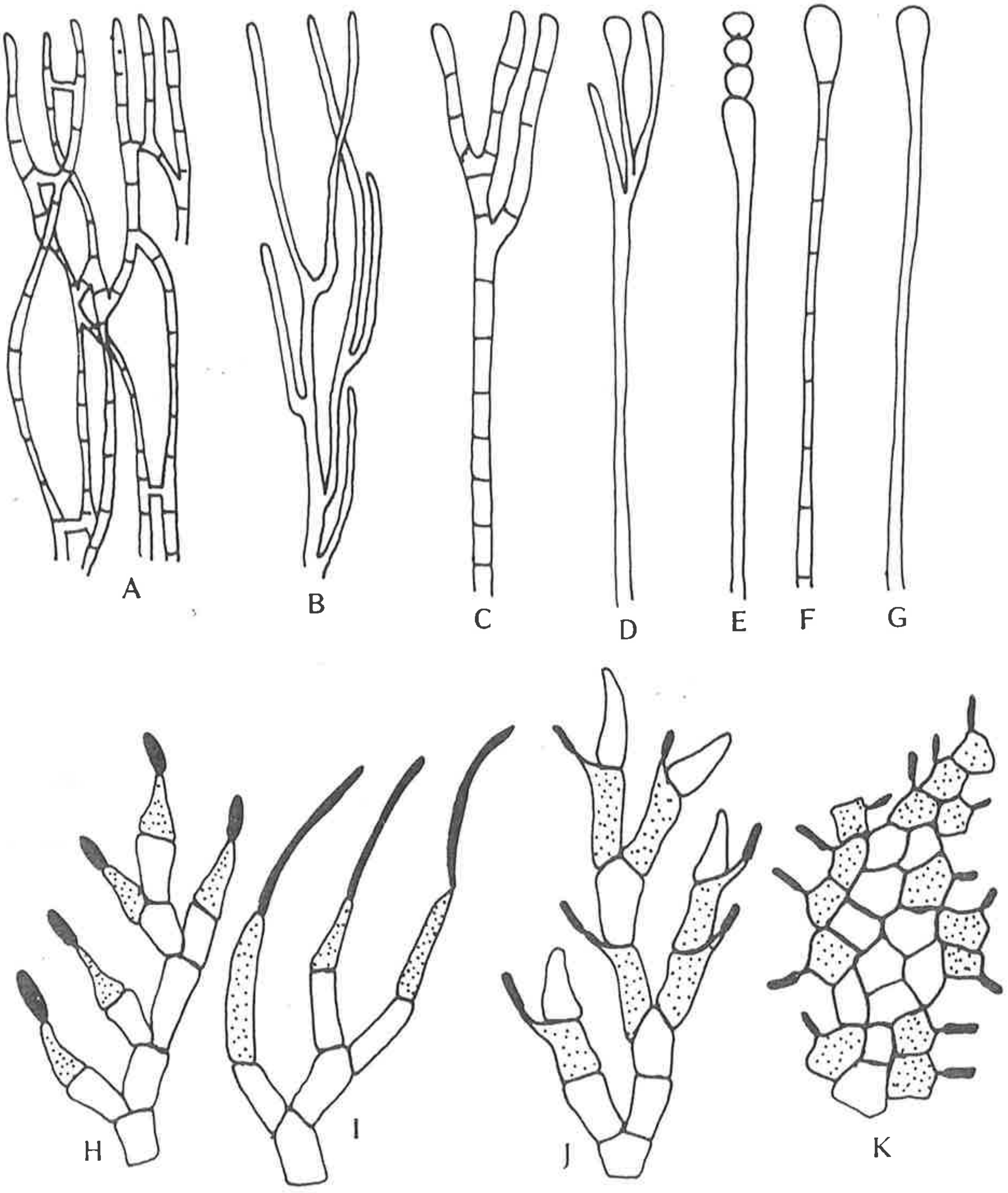

FIGURE 3 **Top:** Stylized variation in form of paraphyses and paraphysis-like structures: (A) reticulately branched, anastomosing, or net-like paraphyses, (B to D) variously branched paraphyses, (E to F) variations in unbranched paraphyses.
Bottom: Stylized pycnidial structures. (H and I) exobasidial fulcrum with pycnospores produced only by the terminal cells in a sequence, (H) shows ovoid pycnospores, (I) filiform pycnospores, (J and K) variants in the endobasidial form in which pycnospores are produced by cells other than terminal cells. (J) shows the bayonet-like form, and (K) the short celled form, both with bacilliform pycnospores. Pycnospores are shaded black, and the sterigmata producing them are stippled.

thin walled, I+ violet. *Pycnidia* rare, immersed; fulcrum exobasidial; pycnospores elongate, bacilliform.
CHEMISTRY: (7 species) norstictic acid (5), stictic acid (3).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On wood or bark, in Queensland and Victoria. 5 species reported (90).

PHAEOGRAPHIS MULL. ARG.: *Flora, Jena* 65, 336 (1882)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic; ecorticate or with a cortex of interwoven hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, immersed to sessile, elongate, often branched, disk narrow, proper exciple often black; thalloid exciple sometimes present; hypothecium pale to black; paraphyses unbranched; asci clavate, unitunicate, I− thick walled, 8 spored; ascospores transversely 3-many septate, brown, walls unequally thickened resulting in lenticular locules, I+ violet. *Pycnidia* rare, immersed; fulcrum exobasidial; pycnospores elongate or bacilliform.
CHEMISTRY: (4 species) norstictic acid (4).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On wood or bark, in Queensland, New South Wales and Victoria. 15 species reported (200).

PHAEOPHYSCIA MOBERG: *Symb. bot. upsal.* 12(1), 29 (1877)

MORPHOLOGY: *Thallus* foliose, lobed, to more or less fruticose; loosely adnate; upper surface paraplectenchymatously corticate, grey to brown; lower surface paraplectenchymatously corticate, usually dark brown or black; attached to the substrate by simple rhizines. *Ascocarp* an apothecium, laminal, sessile, disk round; thalloid exciple well developed, usually with rhizines on the lower surface; disk black or brown; hypothecium hyaline; paraphyses unbranched or somewhat branched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, 1 septate, brown, thick walled. *Pycnidia* immersed or partly immersed; fulcrum endobasidial; pycnospores minute ($<4\mu$m long) ellipsoidal.
CHEMISTRY: (13 species) skyrin (10), zeorin (7), atranorin (6), leucotylin (6), emodin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On bark, in Queensland, New South Wales and Victoria. 1 species reported (?13).

PHAEOTREMA MULL. ARG.: *Mem. Soc. Phys. Hist. nat. Geneve* 29(8), 10 (1887b)

MORPHOLOGY: *Thallus* crustose, uniform, granulose or warty, undifferentiated, or with a loose cortex; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, more or less immersed in the thallus or in fruiting warts; disk circular or elongate, punctiform; the proper exciple initially almost closing the disk but eventually cracking and falling away, leaving fragments around the more or less free disk with a thalloid margin; hypothecium hyaline; paraphyses unbranched; ascus clavate to broadly clavate, unitunicate, I− (but hymenial gel may be I+ blue) thick walled, 1-8 spored; ascospores oblong to fusiform, transversely 3-many septate, brown or black, walls unequally thickened resulting in lenticular locules. *Pycnidia* not known.
CHEMISTRY: (8 species) 4-0-demethylnotatic acid (3), hypoprotocetraric acid (3), psoromic acid (2), conpsoromic acid (1), constictic acid (1), stictic acid (1).

PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On bark, in humid forests of Queensland. 5 species recorded (30).

PHLYCTELLA KREMP.: *Verh. zool.-bot. Ges. Wein* 26, 452 (1876)

MORPHOLOGY: *Thallus* crustose, uniform, chinky or powdery, ecorticate, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed to adnate; disk round, concave to flat; thalloid margin often poorly developed, irregular; hypothecium hyaline to brown; paraphyses unbranched; asci clavate, unitunicate, I?, 1-8 spored; ascospores fusiform, transversely 3-many septate, walls unequally thickened to produce lenticular locules. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong, straight.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: On bark, in Victoria. 1 species reported (15).

PHYLLOPSORA MULL. ARG.: *Bull. Herb. Boissier* 2, app. 1, 11 & 45 (1894a)

MORPHOLOGY: *Thallus* minutely squamulose to much dissected foliose, upper surface corticate; attached to the substrate by a tomentum of rhizoids. *Ascocarp* an apothecium, sessile; disk round; margin proper; hypothecium pale to dark; paraphyses unbranched; asci cylindrical, unitunicate, I+, tholus I+blue, thin walled, 8 spored; ascospores oblong-ellipsoid to acicular, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical, straight.
CHEMISTRY: No data.
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: In humid forests of Queensland, Victoria and Tasmania. 4 species reported (35).

PHYSCIA (SCHREB.) TH. FR. em VAIN.: *Acta Soc. Fauna Flora fenn.* 7(1), 138 (1890)

MORPHOLOGY: *Thallus* foliose, lobed, loosely adnate; upper surface paraplectenchymatously corticate, pale to dark grey; lower cortex prosoplectenchymatous, white to pale brown; attached to the substrate by simple rhizines. *Ascocarp* an apothecium, laminal, sessile, disk round; thalloid exciple well developed, with rhizines on the lower surface; disk brown or black; hypothecium hyaline; paraphyses unbranched or somewhat branched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, 1 septate, brown, thick walled towards the apices. *Pycnidia* immersed; fulcrum endobasidial; pycnospores cylindrical, short ($>4\mu m$ $<10\mu m$ long).
CHEMISTRY: (13 species) atranorin (13), leucotylin (11), triterpenoids (11), zeorin (11).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Widespread on trees and rocks, especially in the southern half of Australia. 17 species reported (?120).

PHYSCIOPSIS CHOISY: *Bull. méns. Soc. linn. Lyon* 19, 20 (1950)

(*Physciopsis* Choisy is a synonym of *Hyperphyscia* Mull. Arg. p.10, (1894b)
MORPHOLOGY: *Thallus* foliose, lobed, closely adnate; upper surface paraplectenchymatously corticate, olive or brown; lower cortex prosoplectenchymatous if present, brown, often hard to detect; attached either directly or by very short indistinctly

delimited rhizines. *Ascocarp* an apothecium, laminal, sessile; disk round, brown to black; margin thalloid, without rhizines on the lower surface; hypothecium hyaline; paraphyses unbranched or somewhat branched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, 1(-3?) transversely septate, brown, walls thickened toward the apices. *Pycnidia* immersed, fulcrum endobasidial; pycnospores filiform (>10μm long).
CHEMISTRY: (3 species) no secondary lichen substances known.
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Throughout the region, but usually obscure. 2 species reported (10-15).

PHYSMA MASS.: *Neag. Lich.* 6 (1854a)

MORPHOLOGY: *Thallus* foliose, lobed, radiate, corticate; cortex paraplectenchymatous; attached to the substrate directly or by rhizines forming a tomentum. *Ascocarp* an apothecium, sessile or sub-stipitate; disk round, concave, margin thalline; hypothecium hyaline; paraphyses simple; ascus clavate, unitunicate, tholus I+, ascal gelatin I+ blue, 8 spored; ascospores ellipsoid to fusiform, simple, hyaline, thick walled, sometimes minutely verrucose. *Pycnidia* immersed; fulcrum exobasidial; pycnospores short, cylindrical or constricted in the centre.
CHEMISTRY: No data.
PHYCOBIONT: *Nostoc.*
DISTRIBUTION: On bark, in Queensland, New South Wales and Victoria. 4 species reported (10).

PILOPHORUS TH.FR.: *De Stereocaulis et Pilophoris Commentatio* 40 (1857)

MORPHOLOGY: *Thallus* granular crustose, warty to squamulose, ecorticate; undifferentiated; attached to the substrate by medullary hyphae; bearing well developed podetia; podetia upright, rarely branched, cylindrical, ecorticate, often granular-squamulose; sometimes with cephalodia; outer medulla loose and containing algae, inner medulla denser, of longitudinal hyphae, solid or hollow. *Ascocarp* an apothecium, apothecia single or aggregate, capitate or semi-globose; proper exciple dissappearing early; hypothecium dark; paraphyses unbranched; ascus narrow-clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid to oblong-ellipsoid, simple, hyaline, thin walled. *Pycnidia* adnate on tips of podetia; fulcrum exobasidial; pycnospores cylindrical or curved.
CHEMISTRY: (10 species) atranorin (9), zeorin (5), stictic acid (2), caperatic acid (1), constictic acid (1).
PHYCOBIONT: *Trebouxia,* cephalodia contain *Stigonema.*
DISTRIBUTION: New South Wales and Victoria. 2 species reported (10).

PLACOPSIS (NYL.) LINDSAY: *Trans. Linn. Soc. London* 25, 536 (1866)

MORPHOLOGY: *Thallus* crustose, with marginal lobes, corticate; cortex paraplectenchymatous; primary phycobiont commonly more or less displaced by internal cephalodia, with developed, apothecium-like external cephalodia. *Ascocarp* an apothecium, sessile; disk round, margin thalloid; hypothecium hyaline; paraphyses slender, branched, moniliform near the tip; ascus cylindrical, unitunicate, ?I−, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (12 species) gyrophoric acid (12), lecanoric acid (9), phenolics (1).
PHYCOBIONT: Initially *Trebouxia*-like, with internal and external *Stigonema* cephalodia.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania, on rocks or soil. 5 species reported (34).

PLACYNTHIUM (ACH.) GRAY: *Nat. Arr. Br. Pl.* 1, 395 (1821)

MORPHOLOGY: *Thallus* crustose or squamulose to foliose, irregularly lobed, sometimes with a developed hypothallus; well developed paraplectenchymatous upper cortex; poorly developed lower cortex; medulla more or less paraplectenchymatous. *Ascocarp* an apothecium, sessile; proper margin thin; hypothecium hyaline or dark; paraphyses thick, unbranched; ascus clavate, unitunicate, tholus I+, 8 spored; ascospores elongate or ellipsoid, transversely 2-8 septate, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Dichothrix.*
DISTRIBUTION: New South Wales. 2 species reported (25).

PLEUROTHELIOPSIS ZAHLBR.: *Cat. Lich. Univ.* 1, 512 (1922)

MORPHOLOGY: *Thallus* crustose, uniform; epi- or endophloic; ecorticate or with a cortex of periclinal hyphae. *Ascocarp* a perithecium opening by a more or less oblique ostiolar canal, usually clad in thalline material; paraphyses reticulate; asci cylindrical-clavate, bitunicate, usually thick walled, I−, 1-8 spored; ascospores muriform, brown, thin walled, locules angular. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on bark. 1 species reported (6).

PLEUROTREMA MULL. ARG.: *Bot. Jb.* 6, 388 (1885)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic; ecorticate. *Ascocarp* a perithecium, perithecia sessile or immersed; simple or compound; ostiolar canals oblique or prostrate; paraphyses reticulate; ascus cylindrical, bitunicate, thick walled, I−, 8 spored; ascospores oblong-ellipsoid to filiform, transversely 1-many septate, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On bark, in Queensland. 1 species reported (10).

POLYBLASTIOPSIS ZAHLBR.: *Pflanzenfamilien* 1, 67 (1903)

MORPHOLOGY: *Thallus* crustose, uniform, endo- or epiphloic, ecorticate. *Ascocarp* a perithecium-like pseudothecium or perithecium, immersed or sessile, with an erect ostiole; paraphyses reticulate; ascus bitunicate, thick walled, I−, 1-8 spored; ascospores oval to oblong, muriform, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trochisia* and other genera.
DISTRIBUTION: On bark or soil, in Queensland. 7 species reported (?18).

POLYCAULONIA HUE: *Exp. Antarct. Franc. Sci. Nat. Lich.* 8 (1908)

MORPHOLOGY: *Thallus* fruticose, erect or decumbent, dichotomous or irregularly branched, fully corticate, yellow. *Ascocarp* an apothecium, terminal, constricted at the base;

disk round, concave, orange; margin thalloid; hypothecium hyaline; paraphyses unbranched; asci cylindrical, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, polaribilocular, hyaline. *Pycnidia* terminal on axes; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (1 species) parietin.
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Tasmania. ?1 species reported (20).

PORINA MULL. ARG.: *Flora, Jena* 66, 320 (1883)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic, ecorticate. *Ascocarp* a perithecium, solitary, immersed or sessile; ostiole erect; paraphyses unbranched or little branched; ascus clavate, bitunicate, thin walled, I−, 8 spored; ascospores ellipsoid to acicular, transversely 1-many septate, hyaline, thin walled. *Pycnidia* immersed, fulcrum exobasidial; pycnospores bacilliform to filiform.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia, Phycopeltis.*
DISTRIBUTION: Queensland, New South Wales and Victoria in humid regions. 38 species reported (300).

POROCYPHUS KORB.: *Syst. Lich. Germ.* 425 (1855)

MORPHOLOGY: *Thallus* crustose, smooth to granular or minutely fruticose; attached by medullary hyphae; ecorticate; gelatinous. *Ascocarp* an apothecium, immersed, more or less closed by the thalloid margin, proper exciple pale and narrow; hypothecium hyaline; paraphyses fine, unbranched; ascus clavate, unitunicate, thin walled, 8 spored; ascospores ovoid to ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores short, oblong-ellipsoid.
CHEMISTRY: No data.
PHYCOBIONT: *Calothrix.*
DISTRIBUTION: On rocks, in Western Australia. 1 species reported (7).

PROTOBLASTENIA STEINER: *Verh. zool.-bot. Ges. Wein* 61, 47 (1911)

MORPHOLOGY: *Thallus* crustose, uniform, granular, yellow, ecorticate, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed or sessile; disk round, yellow; margin proper; hypothecium pale or dark; paraphyses unbranched; ascus clavate, unitunicate, thin walled, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (8 species) emodin (8), parietin (7), fallacinal (6), parietinic acid (6), teloschistin (6), erythroglaucin (5), xanthorin (4), usnic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On rocks and bark, probably in all states. ?3 species reported (11).

PSEUDEVERNIA ZOPF.: *Bei. Bot. Central.* 14, 124 (1903)

MORPHOLOGY: *Thallus* foliose, prostrate or ascending; lobes markedly recurved and channelled below; upper and lower surfaces paraplectenchymatous; lower surface often

becoming black, devoid of rhizines; lobes eciliate. *Ascocarp* an apothecium, stipitate; hypothecium pale; paraphyses unbranched or little branched; asci cylindrical, unitunicate, ?I+ blue, ?tholus I+ blue, 8 spored; spores ellipsoid, simple, hyaline. *Pycnidia* immersed, fulcrum ?endobasidial; pycnospores ?bacilliform.
CHEMISTRY: (5 species) atranorin (5), physodic acid (3), chloroatranorin (2), lecanoric acid (2), olivetoric acid (1), tetrahydroxy fatty acids (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Tasmania. 1 species reported (5).

PSEUDOCYPHELLARIA VAIN.: *Acta Soc. Fauna Flora fenn.* 7(1), 182 (1890)

MORPHOLOGY: *Thallus* foliose, lobed, radiate; both surfaces with a paraplectenchymatous cortex; medulla loose; attached to the substrate by rhizoids which often form a mat; lower surface broken by pseudocyphellae. *Ascocarp* an apothecium, sub-stipitate, marginal or laminal; disk round, usually concave; thalloid exciple; hypothecium pale or dark; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, 8 spored; ascospores oblong-fusiform to fusiform, transversely 1-several septate, hyaline becoming brown, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores short, straight, cylindrical.
CHEMISTRY: (44 species) calycin (21), pulvinic dilactone (21), tenuiorin (20), 7β-acetoxy-22-hydroxyhopane (19), constictic acid (16), stictic acid (16), 15α-22-dihydroxyhopane (12), norstictic acid (9), pulvinic acid (9), zeorin (7), durvillonol (5), durvilldiol (4), methylgyrophorate (3), gyrophoric acid (2), 4-0-methylgyrophoric acid (2), salazinic acid (2), atranorin (1) ergosterol (1), n-heptadecane (1), 4-0-methylbarbatic acid (1), methylevernate (1), methyllecanorate (1), methylorsellinate (1), 4-0-methylorsellinic acid (1), orsellinic acid (1), pannarin (1), protocetraric acid (1), usnic acid (1).
PHYCOBIONT: *Nostoc, Palmella* or *Trebouxia*-like.
DISTRIBUTION: In humid parts of Australia, on rock and bark. 43 species reported (200).

PSEUDOPARMELIA LYNGE: *Ark. Bot.* 13(13), 15 (1914)

MORPHOLOGY: *Thallus* foliose, lobed, radiate, adnate to the substrate; lobes linear irregular, corticate; cortex of anticlinal hyphae forming paraplectenchyma; lower cortex black to pale brown with simple rhizines to the margin; margins sometimes black rimmed, eciliate. *Ascocarp* an apothecium, laminal, sessile; disk concave, round; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (76 species) atranorin (55), protocetraric acid (25), usnic acid (20), divaricatic acid (9), stictic acid (8), salazinic acid (7), caperatic acid (5), constictic acid (5), gyrophoric acid (4), lecanoric acid (4), norlobaridone (3), protolichesterinic acid (3), neoloxodic acid (2), norstictic acid (2), perlatolic acid (2), physodalic acid (2), skyrin (2), barbatic acid (1), cryptochlorophaeic acid (1), 4-0-demethylbarbatic acid (1), evernic acid (1), fumarprotocetraric acid (1), obtusatic acid (1), sekikaic acid (1), succinprotocetraric acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Throughout Australia, especially on trees. 19 species reported (76).

PSEUDOPYRENULA MULL. ARG.: *Flora, Jena,* 66, 247 (1883)

MORPHOLOGY: *Thallus* crustose, uniform, endo- or epiphloic, undifferentiated, ecorticate. *Ascocarp* a perithecium, perithecia scattered or grouped, either naked or immersed; ostiole

erect; paraphyses reticulate; ascus clavate to cylindrical, bitunicate, I−, 8 spored; ascospores oblong to oblong-ellipsoid, transversely 3 or more septate, hyaline, walls unevenly thickened resulting in lenticular or angular locules. *Pycnidia* immersed; fulcrum exobasidial, pycnospores bacilliform, constricted in the middle.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland and Tasmania. 3 species reported (45).

PSORA HOFFM.: *Descr. adumb Lich.* 1, 37, (1790)

MORPHOLOGY: *Thallus* squamulose, corticate, attached to the substrate by medullary hyphae. Ascocarp an apothecium, sessile, disk round; margin proper; hypothecium pale or coloured, paraphyses branched or unbranched; asci cylindrical-clavate, unitunicate, tholus I+ blue, 8-spored; ascospores ellipsoid, simple, hyaline, thin-walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform.
CHEMISTRY: (3 species) lecanoric acid (1), norstictic acid (1), rhizocarpic acid (1).
PHYCOBIONT: *Trebouxia*-like.
DISTRIBUTION: On soil especially in drier areas. 7 species reported (50).

PSOROMA NYL.: *Mem. Soc. Sci. Nat. Cherbourg* 2, 5-16 (1855)

MORPHOLOGY: *Thallus* squamulose to foliose, more or less irregular; developed paraplectenchymatous upper cortex of anticlinal hyphae and a thin lower cortex of interwoven periclinal hyphae; attached to the substrate by a few rhizoids. *Ascocarp* an apothecium, laminal, adnate to sessile; thalloid margin; hypothecium hyaline; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores ellipsoid to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores short, cylindrical or constricted in the middle.
CHEMISTRY: (2 species) pannarin (1), zeorin (1).
PHYCOBIONT: *Myrmecia.*
DISTRIBUTION: In all humid parts of the region, on rock, soil and bark. 16 species reported (35).

PSOROMARIA NYL.: *Lich. N.Z.* 54 (1888)

MORPHOLOGY: *Thallus* squamulose to foliose, more or less irregular; developed paraplectenchymatous upper cortex of anticlinal hyphae and a thin lower cortex of interwoven periclinal hyphae; attached to the substrate by a few rhizoids. *Ascocarp* an apothecium, laminal, adnate to sessile; proper margin; hypothecium hyaline; paraphyses unbranched; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores ellipsoid to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores short, cylindrical or constricted in the middle.
CHEMISTRY: No data.
PHYCOBIONT: *Myrmecia.*
DISTRIBUTION: Tasmania. ?1 species reported (2?)

PYRENOPSIDIUM (NYL.) FORSS.: *Nova Acta R. Soc. Scient. Upsal. Ser 3,* 13, 39 & 59 (1885)

MORPHOLOGY: Thallus crustose, uniform, granular or areolate, gelatinous, ecorticate; of loose, much branched hyphae enmeshing algal cells; attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed to sessile, initially closed, later open, margin thalloid; disk often narrow; hypothecium hyaline to brown; paraphyses unbranched; ascus clavate, unitunicate, ?I+, 8 spored; ascospores oblong to globose, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores ellipsoid-oblong.
CHEMISTRY: No data.
PHYCOBIONT: Chroococcus.
DISTRIBUTION: On rock, in arid Western Australia. 1 species reported (8).

PYRENOPSIS NYL.: *Syn. Lich.* 1, 97 (1858)

MORPHOLOGY: Thallus crustose, uniform, granular to minutely fruticose, gelatinous, ecorticate, of hyphae enmeshing the phycobiont. *Ascocarp* an apothecium, immersed to sessile, initially closed, later open; thalloid exciple well developed; hypothecium pale to brown; paraphyses unbranched, often indistinct; ascus clavate, unitunicate, ?I+, 8-32 spored; ascospores oblong to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial, bushy; pycnospores oblong or rarely filiform and curved.
CHEMISTRY: No data.
PHYCOBIONT: Gloeocapsa.
DISTRIBUTION: Victoria and Tasmania. 2 species reported (40).

PYRENULA MASS.: *Ric. Lich. Crost.,* 162 (1852)

MORPHOLOGY: Thallus crustose, uniform, endo- or epiphloic; ecorticate. *Ascocarp* a perithecium, immersed or naked; ostiole erect; paraphyses fine, unbranched; ascus clavate, bitunicate, I−, 8 spored; ascospores ellipsoid to fusiform, transversely 3-7 septate, brown, walls unevenly thickened resulting in lenticular or rhomboidal locules. *Pycnidia* immersed; fulcrum exobasidial; pycnospores filiform, curved.
CHEMISTRY: (3 species) anthraquinoid (1), lichexanthone (1), parietin (1), phenolic (1).
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania, in humid regions. 35 species reported (190).

PYRGILLUS NYL.: *Syn. Lich.* 1, 168 (1860)

MORPHOLOGY: Thallus crustose, uniform, ecorticate. *Ascocarp* an apothecium, immersed to adnate, urn-like, disk narrow and flat; hypothecium pale; paraphyses thread-like; ascus thin walled, unitunicate, disintegrating into a mazaedium, 8 spored; spores oblong to elliptical, 1-3 septate, brown, walls unequally thickened to produce lenticular locules. *Pycnidia* immersed; fulcrum exobasidial; pycnospores filiform, curved.
CHEMISTRY: No data.
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: Queensland, in humid forests. 4 species reported (8).

PYXINE FR.: *Syst. orb.* 1, 267 (1825)

MORPHOLOGY: Thallus foliose, appressed, radiate, both surfaces corticate; the upper surface paraplectenchymatous of anticlinal hyphae, the lower of longitudinal hyphae; attached to the substrate by rhizines. *Ascocarp* an apothecium, sessile, laminal; margin sometimes with thalloid rim disappearing or retained, usually proper; hypothecium dark; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores oblong to ellipsoid, 1 septate, brown, walls thickened, lumina small. *Pycnidia* immersed; fulcrum endobasidial; pycnospores short, cylindrical.
CHEMISTRY: (32 species) unknown terpenoids (20), atranorin (16), lichexanthone (11), norstictic acid (7), dammarane derivatives (2), methylpyxinate (2), pyxinic acid (2), chiodectonic acid (1), chloroatranorin (1), diacetyl pyxinol (1), pyxinol (1), skyrin (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Queensland and New South Wales, especially near the coast. 11 species reported (35).

RAMALEA NYL.: *Flora, Jena* 49, 289 (1866)

MORPHOLOGY: Thallus squamulose to dwarfed fruticose, partly horizontal, tufted; both surfaces corticate; without rhizines; attached by hyphae. *Ascocarp* an apothecium, circular, lateral, stipitate; margin proper, hypothecium pale; paraphyses unbranched; ascus clavate, unitunicate, ?I+, 8 spored; ascospores acicular, simple or rarely 1 septate. *Pycnidia* immersed in the thallus; fulcrum exobasidial; pycnospores cylindrical, curved.
CHEMISTRY: (1 species) usnic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: On acid soils in heathlands, in Western Australia and Victoria. 1 species reported (3).

RAMALINA ACH.: *Lich. Univ.* 122 (1810)

MORPHOLOGY: Thallus fruticose, erect or pendulous, all surfaces corticate of anticlinal hyphae; strengthened by chondroid fibres of periclinal hyphae which may form a continuous ring; medulla sparse; attached to the substrate by a basal disk; commonly bilaterally flattened, sometimes dorsiventrally differentiated. *Ascocarp* an apothecium, terminal, sub-terminal, marginal or laminal; sessile or stipitate; concave; thalloid exciple; hypothecium pale; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, 8 spored; ascospores ellipsoid to fusiform, often curved, 1-3 septate, hyaline, thin walled. *Pycnidia* wholly or partly immersed in the thallus; fulcrum exobasidial, little branched; pycnospores bacilliform, straight.
CHEMISTRY: (85 species) usnic acid (74), salazinic acid (19), obtusatic acid (14), atranorin (11), norstictic acid (10), divaricatic acid (9), sekikaic acid (9), protocetraric acid (6), evernic acid (5), stictic acid (4), hypoprotocetraric acid (3), ramalinolic acid (3), chloroatranorin (2), stenosporic acid (2), boninic acid (4), bourgeanic acid (1), constictic acid (1), cryptochlorophaeic acid (1), 4-0-demethylbarbatic acid (1), 1-methyl-3,5 dichlorolecanorate (1), paludosic acid (1), perlatolic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: On bark and rocks, in all but the most arid parts of Australia. 41 species reported (200).

RELICINA HALE: *Phytologia* 28, 484 (1974b)

MORPHOLOGY: Thallus foliose; attached to the substrate by rhizines; with well developed upper and lower cortices, upper cortex pallisade plectenchyma; lower surface brown to black, rhizines simple or sparsely branched to squarrose or bushy and forming a tomentum; margins of lobes with bulbate cilia. *Ascocarp* an apothecium; sessile; margin thalloid, with or without a corona of sessile pycnidia, with or without bulbate cilia on the lower surface; disk round, flat or concave; hypothecium pale; paraphyses unbranched, capitate; asci cylindrical-clavate, unitunicate I+ blue, 8 spored; ascospores simple, ovoid to bicornute, thick walled. *Pycnidia* immersed in the thallus or sessile on apothecial margins; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (24 species) usnic acid (24), echinocarpic acid (6), atranorin (5), fumarprotocetraric acid (5), norstictic acid (4), salazinic acid (4), barbatic acid (3), 4-0-methyl barbatic acid (3), protocetraric acid (3), succinprotocetraric acid (3), diffractaic acid (2), stictic acid (2), alectoronic acid (1), caperatic acid (1), consalazinic acid (1), gyrophoric acid (1), "quintaria" unknown (1), protolichesterinic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Queensland and New South Wales, on rocks and on bark in humid forests. 8 species reported (24).

RHIZOCARPON LAM. ex LAM & DC.: *Flor. Franc.* 365 (1805)

MORPHOLOGY: Thallus crustose, uniform; ecorticate; often with a well developed prothallus; attached to the substrate by prothallial hyphae. *Ascocarp* an apothecium; immersed to sessile; disk more or less round, black; margin proper, black, disappearing; hypothecium dark; paraphyses usually reticulate; ascus clavate or inflated-clavate, unitunicate, I+, tholus I+ blue, 1-8 spored; ascospores irregular, muriform, brown, mucilagenous. *Pycnidia* immersed; fulcrum exobasidial; pycnospores cylindrical to acicular, straight or curved.
CHEMISTRY: (32 species) stictic acid (18), rhizocarpic acid (16), psoromic acid (11), gyrophoric acid (7), barbatic acid (4), norstictic acid (4), lecanoric acid (1), physodic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Queensland, New South Wales, Victoria, Tasmania and South Australia, on rocks in a wide range of habitats. 7 species reported (200).

RINODINA (ACH.) GRAY: *Nat. Arr. Br. Pl.* 448 (1821)

MORPHOLOGY: Thallus crustose to rarely squamulose, uniform or marginally lobed; ecorticate or with a paraplectenchymatous upper cortex; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, immersed to sessile; margin initially with a thalloid covering, later proper or emarginate; disk dark; hypothecium hyaline; paraphyses rarely branched; ascus clavate, unitunicate, thick walled, I+ blue, tholus I+ blue, usually 8 but up to 24 spored; ascospores transversely 1-3 septate, grey or brown, walls unevenly thickened resulting in small locules linked by an isthmus. *Pycnidia* immersed or prominent in warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (23 species) atranorin (15), norstictic acid (4), chloroatranorin (2), gyrophoric acid (2), lecanoric acid (2), zeorin (2), α-collatolic acid (1), fumarprotocetraric acid (1), phenolics (1), usnic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Queensland, Victoria, Tasmania, South Australia and Western Australia, on rock and bark. 14 species reported (200).

ROCELLA DC. apud LAM. & DC.: *Flor. Franc* ed 3, 2, 334 (1805)

MORPHOLOGY: *Thallus* fruticose, upright or pendant, branched, flat or terete; cortex of transverse hyphae; attached by a basal disk. *Ascocarp* an apothecium-like pseudothecium, round or somewhat irregular, sessile, lateral; margin thalloid or with a proper exciple; hypothecium black; paraphyses branched; ascus clavate, bitunicate, I –, 8 spored; ascospores oblong to fusiform, transversely several septate, hyaline, thin walled. *Pycnidia* immersed, lateral; fulcrum exobasidial; pycnospores bacilliform, curved.
CHEMISTRY: (37 species) erythrin (23), lecanoric acid (19), rocellic acid (9), mesoerythritol (6), portentol (3), acetylportentol (2), erythritol (2), lepraric acid (2), norstictic acid (2), tetrahydroxy fatty acids (2), aspicilin (1), ethyl orsellinate (1), galapagin (1), montagnetol (1), orcinol (1), picroerythrin (1), protocetraric acid (1), skyrin (1), zeorin (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On mangroves, in the tropics. 2 species reported (35).

SAGENIDIUM STIRT.: *Proc. Phil. Soc. Glasgow* 10, 305 (1877)

MORPHOLOGY: *Thallus* fruticose, branched, flat or terete, corticate, attached by a basal disk. *Ascocarp* an apothecium-like pseudothecium, sessile; without a margin; hypothecium black; paraphyses branched; ascus clavate, bitunicate, I –, 8 spored; ascospores hyaline, transversely several septate. *Pycnidia* not known.
CHEMISTRY: (4 species) atranorin (1), lecanoric acid (1), lepraric acid (1), protocetraric acid (1), schizopeltic acid (1).
PHYCOBIONT: Chlorophycean.
DISTRIBUTION: Tasmania, on ?maritime rocks. 1 species reported (4).

SAGIOLECHIA MASS.: *Geneac. Lich.* 11 (1854b)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, initially immersed, eventually sessile, round; proper margin thin, dark; thalloid margin sometimes disappearing; hypothecium dark; paraphyses simple; ascus clavate, unitunicate, I –, 8 spored; ascospores ellipsoid to fusiform, transversely 2-3 septate, hyaline, uniformly thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores short.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on calcareous rock. 1 species reported (2).

SARCOGRAPHA FEE: *Essai Crypt.* 35 & 58 (1824)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate or with a poorly developed cortex of periclinal hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, elongate or irregular; immersed in stroma which may be poorly developed; well developed proper exciple; hypothecium pale; hymenium gelatinous; paraphyses unbranched; asci oblong, unitunicate, I –, 8 spored; ascospores transversely 3-11 septate, brown, walls unequally thickened to produce lenticular locules. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform, curved.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales and Victoria, on bark. 7 species reported (70).

SARCOGRAPHINA MULL. ARG.: *Flora, Jena* 70, 425 (1887a)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate or with a poorly developed cortex of periclinal hyphae; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, elongate or irregular; immersed in raised stroma; proper exciple well developed, often with grooved labia; hypothecium pale or dark; hymenium gelatinous; paraphyses unbranched; asci oblong, unitunicate, I−, 4-8 spored; ascospores oblong to fusiform; muriform, brown. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: On bark, in Queensland. 1 species reported (8).

SARCOGYNE FLOT.: *Bot. Ztg.,* 9, 753 & 759 (1851)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, poorly developed; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, adnate to sessile or sub-stipitate, disk circular; margin thin, brittle, black, proper; hypothecium dark; paraphyses rarely branched, free; asci clavate, unitunicate, thick walled, I+ pale blue, tholus I+ blue, many spored; ascospores ellipsoid to globose, simple, hyaline, thin walled, minute. *Pycnidia* immersed in the thallus or in small warts; fulcrum exobasidial; pycnospores short-cylindrical.
CHEMISTRY: (2 species) no secondary lichen substances found.
PHYCOBIONT: *Myrmecia (+?Trebouxia).*
DISTRIBUTION: Victoria and Western Australia. 2 species reported (30).

SCHISMATOMMA MASS.: *Ric. Lich. Crost.* 55 (1852)

MORPHOLOGY: *Thallus* crustose, uniform; ecorticate; attached by medullary or prothallial hyphae. *Ascocarp* a round or irregular pseudothecium; with or without a poorly developed proper exciple; hypothecium black; paraphyses reticulate; ascus clavate, bitunicate, I−, 8 spored; ascospores fusiform or elongate-oblong, transversely 4-14 septate, hyaline, sometimes curved, locules sometimes of uneven size (one much larger), thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores bacilliform, sometimes curved.
CHEMISTRY: (8 species) lecanoric acid (3), atranorin (1), conpsoromic acid (1), erythrin (1), lepraric acid (1), norstictic acid (1), phenolics (1), psoromic acid (1), rocellin (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania, on bark and possibly leaves. 7 species reported (85).

SIPHULA FR.: *Syst. orb.* 238 (1825)

MORPHOLOGY: *Thallus* fruticose, upright or prostrate, attached to the substrate by rhizines, often forming turfy clumps or becoming almost coralloid, little branched, flat or terete, solid, corticate; cortex paraplectenchymatous. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (21 species) baeomycesic acid (6), squamatic acid (6), hypothamnolic acid (5), decarboxythamnolic acid (3), atranorin (2), chloroatranorin (2), porphyrilic acid (2), barbatic acid (1), norstictic acid (1), siphulin (1), siphulitol (1), usnic acid (1), zeorin (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On dry soils and alpine peats, in Queensland, New South Wales, Victoria, Tasmania, South Australia and Western Australia. 3 species reported (25).

SPHAEROPHORUS PERS.: *Ann. Bot. (Usteri)* 7, 23 (1794)

MORPHOLOGY: *Thallus* fruticose, caespitose, cylindrical or flattened, solid, with a well developed cortex; cortex paraplectenchymatous. *Ascocarp* an apothecium, terminal in capitate swellings, initially closed, later opening with a thalloid exciple irregularly torn from the centre exposing the almost globose hymenium; hypothecium hyaline; paraphyses fragile, thread-like; asci clavate, unitunicate, thin walled, 8 spored; asci and paraphyses disintegrate leaving the spores in a mazaedium; ascospores globose, simple, with a dark epispore. *Pycnidia* terminal; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (9 species) sphaerophorin (7), constictic acid (2), fragilin (2), isousnic acid (2), squamatic acid (2), stictic acid (2), thamnolic acid (2), hypothamnolic acid (1), protocetraric acid (1)
PHYCOBIONT: Chlorophyceae.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania, on bark or soil in humid regions. 3 species reported (9).

SPORASTATIA MASS.: *Geneac. Lich.* 9 (1845b)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate, poorly developed; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, immersed; disk circular; margin poorly developed to absent, if present thin and black, proper; hypothecium dark; paraphyses rarely branched, free; asci clavate, unitunicate, thick walled, I+ pale blue, tholus I+ blue, many spored; ascospores ellipsoid to globose, simple, hyaline, thin walled, minute. *Pycnidia* immersed in the thallus or in small warts; fulcrum exobasidial; pycnospores short-cylindrical.
CHEMISTRY: No data.
PHYCOBIONT: *Myrmecia (? + Trebouxia).*
DISTRIBUTION: On alpine rocks, New South Wales. 1 species reported (4).

SPOROPODIUM MONT. em. R. SANT.: *Symb. bot. Upsal.* 12, 509 (1952)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached by medullary or prothallial hyphae; prothallus often well developed especially at the margins. *Ascocarp* an apothecium, initially immersed, ultimately sessile; well developed proper exciple; hypothecium pale or dark; paraphyses branched and somewhat anastomosing; ascus clavate, unitunicate, thick walled, 1 spored; ascospore muriform, hyaline, thin walled. *Pycnidia* unknown.
CHEMISTRY: (4 species) pulvinic acid (2), pulvinic dilactone (2), vulpinic acid (2), calycin (1), 3-0-methyl-2,5,7-trichloronorlichexanthone (1), 2,5,7-trichloronorlichexanthone (1).
PHYCOBIONT: *?Trebouxia.*
DISTRIBUTION: Queensland and New South Wales, on leaves. 2 species reported (9).

SPILONEMA BORNET: *Mem. Soc. Sci. Nat. Cherbourg* 4, 226 (1856)

MORPHOLOGY: *Thallus* dwarf fruticose, of hyphae extending longitudinally within the algal sheath, undifferentiated. *Ascocarp* an apothecium, terminal on branches; disk flat to convex; exciple thin proper, soon disappearing; hypothecium brown; paraphyses unbranched, thick; asci oblong-clavate, unitunicate, I+, I+ blue tholus, 8 spores; ascospores oblong-ellipsoid, simple; hyaline. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Stigonema.*
DISTRIBUTION: On maritime rocks, Western Australia. 1 species reported (4).

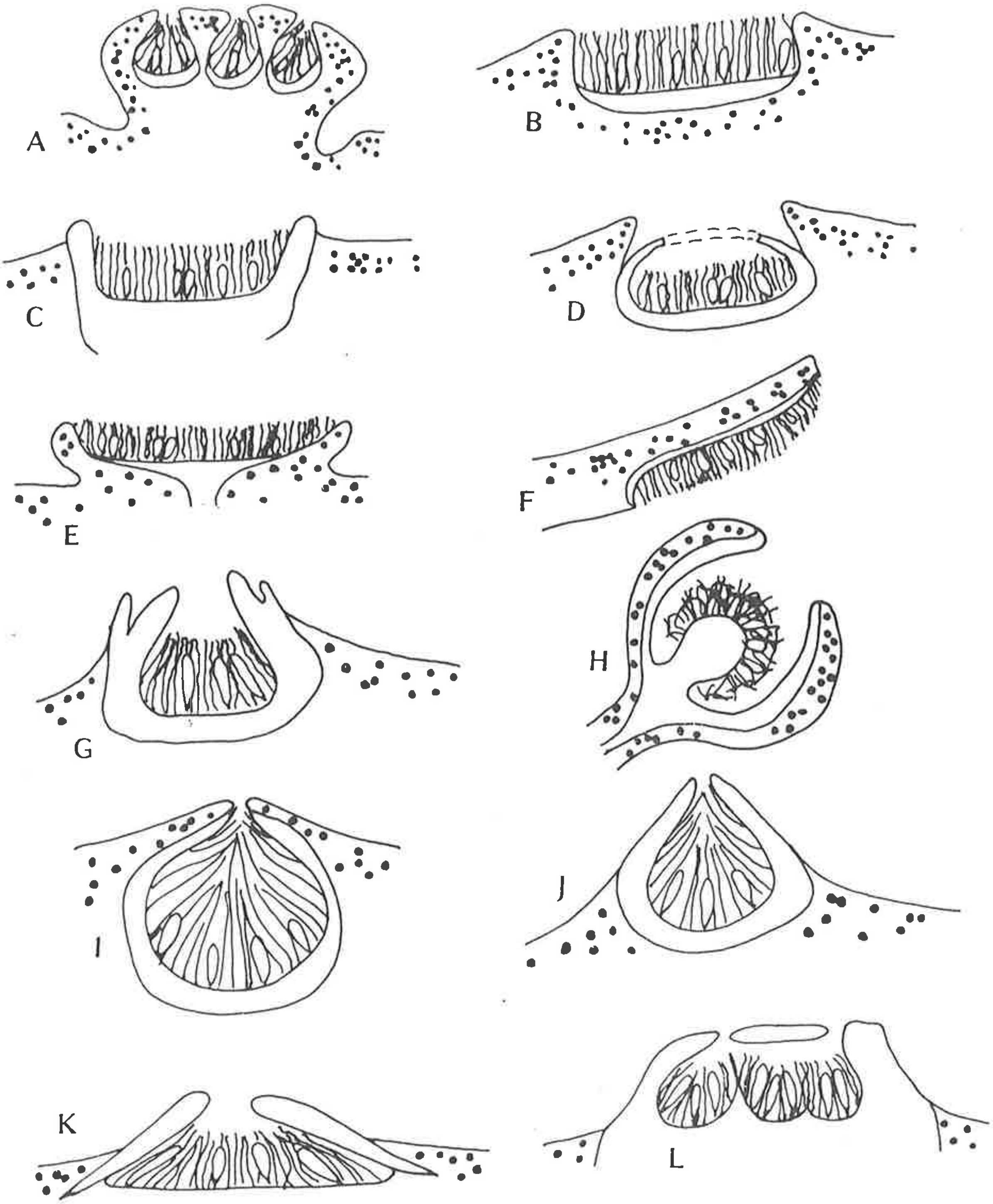

FIGURE 4 Variation in ascocarp structure and placement when viewed in section. (A) apothecia of *Pertusaria* immersed in thalloid warts; (B) immersed apothecium of *Aspicilia* showing the algal layer continuing below the hymenium, making this a thalloid margin (technically crypto-lecanorine); (C) apothecium of *Rhizocarpon*, which in contrast with *Aspicilia* does not have algae below the hymenium and therefore has a proper margin; (D) apothecium of *Thelotrema* showing the distinct proper and thalloid margins, with the originally closed proper covering dotted in; (E) sessile thalloid apothecium of *Caloplaca*; (F) apothecium of *Nephroma* on the lower surface of the lobe, apparently emarginate; (G) partly immersed apothecium of *Graphis* with grooved labia or margins; (H) apothecium of *Sphaerophorus* immersed in the tip of a lobe showing the central columella which supports the asci, etc.; (I) immersed perithecium of *Dermatocarpon*; (J) partly immersed perithecium of *Pyrenula*; (K) partly immersed dimidiate or conical perithecium-like pseudothecium of *Arthopyrenia*, in which no wall is formed below the ascocarp; (L) compound perithecium-like pseudothecium of *Mycoporellum*, showing several hymenia in a partly divided chamber. Paraphyses and paraphysis-like structures are represented by lines forming the hymenium, algae by black dots.

SQUAMARINA POELT: *Mitt. bot. Stamml. Munch.* 5, 19-20 (1958)

MORPHOLOGY: Thallus squamulose, attached to the substrate by medullary hyphae, cortex developed on both surfaces. *Ascocarp* an apothecium, round, sessile; thalloid margin thin; paraphyses unbranched; hypothecium pale; asci clavate, unitunicate, tholus I+ blue, 8 spored; ascospores oblong-ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed.
CHEMISTRY: (9 species) psoromic acid (7), usnic acid (5), parellic acid (2).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania. ?5 species reported (18).

STENOCYBE NYL.: *Bot. Not.* 84 (1854)

MORPHOLOGY: Thallus thin, crustose, poorly developed or absent. *Ascocarp* an apothecium terminal on a usually well developed stipe; at first closed by the exciple, but eventually opening; usually dark brown or black; paraphyses unbranched, slender; asci cylindrical, thick walled, unitunicate, 8 spored; ascospores ellipsoid to oblong-ellipsoid, 3-7 transversely septate, brown. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: ?Trebouxia-like or absent.
DISTRIBUTION: Tasmania. ?1 species reported (5).

STEREOCAULON SCHREB.: *Gener. Plant.* 768 (1791)

MORPHOLOGY: Thallus more or less crustose to squamulose, producing thalline pseudopodetia, the rudimentary horizontal thallus usually disappearing early; pseudopodetia solid, somewhat branched, fruticose in appearance, ecorticate, bearing cylindrical lateral ecorticate structures (phyllocladia) containing algae; cephalodia on pseudopodetia are irregularly globose. *Ascocarp* an apothecium, terminal on pseudopodetia; disk flat to convex, red-brown to black; exciple proper, soon disappearing; hypothecium hyaline; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores fusiform to acicular, transversely 3-7 septate, hyaline, thin walled. *Pycnidia* terminal or lateral, immersed; fulcrum exobasidial; pycnospores thread-like to cylindrical, straight or curved.
CHEMISTRY: (74 species) atranorin (56), lobaric acid (33), stictic acid (22), norstictic acid (16), porphyrilic acid (9), perlatolic acid (5), anziaic acid (4), α-methyl-ether-salazinic acid (3), miriquidic acid (3), salazinic acid (3), psoromic acid (2), tetrahydroxy fatty acids (2), thamnolic acid (2), colensoinic acid (1), constictic acid (1), divaricatic acid (1), fumarprotocetraric acid (1), lecanoric acid (1), parietin (1), β-setosterol (1), squamatic acid (1), ventosic acid (1).
PHYCOBIONT: Trebouxia with *Nostoc* or *Stigonema* cephalodia.
DISTRIBUTION: Queensland, New South Wales, Victoria and Tasmania, on soil in humid areas. 10 species reported (120).

STICTA SCHREB.: *Gener. Plant.* 768 (1791)

MORPHOLOGY: Thallus foliose, large, loosely adnate or ascending; both surfaces paraplectenchymatously corticate with anticlinal hyphae; internal cephalodia sometimes present below the upper cortex; attached to the substrate by short or long rhizoids; rhizoids sometimes almost forming a tomentum which may be more or less confined to a central

umbilicus-like area; lower cortex pierced by cyphellae. *Ascocarp* an apothecium, marginal or laminal, sessile to sub-stipitate, usually with a thalloid exciple; disk round, flat to concave; hypothecium pale or coloured; paraphyses unbranched; asci clavate to ovate-clavate, unitunicate, I+ blue, 8 spored; ascospores oblong-fusiform to acicular, transversely 1-7 septate, hyaline or brown, thin walled. *Pycnidia* warty, immersed, marginal or laminal; fulcrum endobasidial; pycnospores bacilliform or constricted in the middle.
CHEMISTRY: (13 species) pulvinic dilactone (2), stictalbin (2), stictinin (2), triterpenes (2), 7β-acetoxy-22-hydroxyhopane (1), anthraquinones (1), calycin (1), 15α,22-dihydroxyhopane (1), gyrophoric acid (1), lecanoric acid (1), norstictic acid (1), polyporic acid (1), stictic acid (1).
PHYCOBIONT: *Nostoc* or *Palmella* with *Nostoc* cephalodia.
DISTRIBUTION: Queensland, New South Wales Victoria and Tasmania, on rocks or bark in humid regions. 50 species reported (200).

STRIGULA FR.: *K. svenska Vetensk. Akad. Handl.* 1821, 323 (1821)

MORPHOLOGY: *Thallus* crustose, ecorticate, with minutely lobed margins; sub-cuticular. *Ascocarp* a perithecium, either naked or immersed in the thallus; erect; without hymenial algae; paraphyses unbranched; asci cylindrical or oblong-clavate, bitunicate, thin walled, I−, 8 spored; ascospores ellipsoid to fusiform, transversely 1-3 septate, hyaline, thin walled. *Pycnidia* protruding, convex; fulcrum exobasidial; pycnospores ellipsoid to fusiform; stylospores 1-9 septate, bacilliform or filiform.
CHEMISTRY: No data.
PHYCOBIONT: *Cephaleuros.*
DISTRIBUTION: Queensland and New South Wales, on leaves in rainforests. 7 species reported (12).

SYNALISSA FR.: *Syst. orb.* 297 (1825)

MORPHOLOGY: *Thallus* minutely fruticose, lobes erect, little branched, ecorticate, undifferentiated; composed of little branched hyphae in the algal gel; attached to the substrate by rhizines. *Ascocarp* an apothecium, terminal, immersed in the lobe tips; initially closed, later open with a thalloid margin; hymenium gelatinous; hypothecium hyaline to brown; paraphyses unbranched; asci clavate, unitunicate, thin walled, I+ blue, 8-32 spored; ascospores ellipsoid to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: No data.
PHYCOBIONT: *Gloeocapsa.*
DISTRIBUTION: Victoria, Tasmania, South Australia and Western Australia, on calcareous soils. ?2 species reported (5).

TAPELLARIA MULL. ARG. em R. SANT.: *Symb. bot. Upsal.* 12, 494 (1952)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate; attached to the substrate by medullary or prothallial hyphae. *Ascocarp* an apothecium, sessile or immersed; disk round with a well developed black proper exciple; hypothecium purple-brown; without epithecial algae; paraphyses richly reticulate, enveloping the asci; asci clavate, unitunicate thick walled, 1-8 spored; ascospores oblong, transversely septate or muriform, hyaline, large. *Pycnidia* rare, sessile or partly immersed, globose; fulcrum endobasidial; pycnospores bacilliform.

CHEMISTRY: (1 species) arthothelin (1), thuringione (1).
PHYCOBIONT: *?Trebouxia.*
DISTRIBUTION: Queensland, on leaves in humid forests. 1 species reported (8).

TELOSCHISTES NORM.: *Nytt. Mag. Naturv.* 7, 228 (1853)

MORPHOLOGY: *Thallus* fruticose or almost foliose, corticate on all surfaces; cortex of longitudinal agglutinate hyphae; usually without rhizines but often ciliate; attached to the substrate by rhizoidal hyphae. *Ascocarp* an apothecium, marginal or laminal; sessile; disk round, concave to flat, yellow or orange; margin thalloid; epithecium with algae; hypothecium pale; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores oblong-ellipsoid, polaribilocular, or sometimes 3 septate, thick walled, hyaline. *Pycnidia* globose; fulcrum endobasidial; pyncnospores bacilliform, straight.
CHEMISTRY: (11 species) parietin (11), teloschistin (7), emodin (6), fallacinal (6), parietinic acid (6), xanthorin (6), erythroglaucin (5), salazinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On bark and rocks, especially in the sub-humid and humid areas of the southern half of the region. 7 species reported (30).

THAMNOLIA ACH. ex SCHAER.: *Enum. lich. eur.* 243 (1850)

MORPHOLOGY: *Thallus* fruticose, upright or prostrate, more or less cylindrical, little branched, inflated, tapering to the ends; corticate on all surfaces; cortex paraplectenchymatous of anticlinal hyphae; unattached. *Ascocarp* not known. *Pycnidia* not known.
CHEMISTRY: (3 species) atranorin (1), baeomycesic acid (1), decarboxythamnolic acid (1), squamatic acid (1), thamnolic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On soils, in sub-alpine and alpine areas of Victoria, New South Wales and Tasmania. 3 species reported (3).

THELIDIUM MASS.: *Framment. lich.* 15 (1855)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate. *Ascocarp* a perithecium, sessile on the thallus; without algae in the hymenium; paraphyses gelatinizing; asci clavate or inflated, unitunicate, thick walled, I−, 8 spored; ascospores ellipsoidal to ovoid, transversely 1-3 septate, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Pleurococcus* and others?
DISTRIBUTION: Tasmania, on soil. ?1 species reported (100).

THELOTREMA ACH.: *Meth. Lich.* 130 (1803)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform; ecorticate or with a woolly poorly developed cortex; attached by medullary or prothallial hyphae. *Ascocarp* an apothecium, immersed to sessile in warts; disk round or elongate, punctiform or narrow; well developed proper exciple initially closed over the disk, later tearing and opening then disintegrating, leaving the disk free but surrounded by a thalloid margin; paraphyses unbranched; asci cylindrical-clavate, unitunicate, thick walled, I−, 8 spored; ascospores ellipsoid or oblong-ellipsoid, hyaline, muriform, wall thickness unequal resulting in spherical or lenticular locules.

Pycnidia, fulcrum exobasidial.
CHEMISTRY: (34 species) 4-0-methyldenotatic acid (6), psoromic acid (6), constictic acid (5), fumarprotocetraric acid (5), hypoprotocetraric acid (5), stictic acid (5), conpsoromic acid (4), 4-0-methylhypoprotocetraric acid (2), norstictic acid (2), protocetraric acid (2), salazinic acid (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, New South Wales, Victoria, Tasmania and Western Australia, on bark. 20 species reported (200).

THYREA MASS.: *Flora, Jena* 39, 210 (1856a)

MORPHOLOGY: *Thallus* foliose, monophyllous to entire, or sinuose and incised, attached at a central point; gelatinous; composed of hyphae ramifying through the algal gelatin; ecorticate. *Ascocarp* an apothecium, immersed to adnate; the disk deeply concave to flat, with a thick thalloid margin which may more or less close the disk; hypothecium hyaline to brown; paraphyses unbranched; ascus clavate, unitunicate, thin walled, ?I+, 8-24 spored; ascospores spherical to ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong.
CHEMISTRY: No data.
PHYCOBIONT: *Gloeocapsa.*
DISTRIBUTION: Western Australia, on (? calcareous) rocks or soil. ?1 species reported (20).

THYSANOTHECIUM MONT. et BERK.: *London J. Bot.* 5, 257 (1846)

MORPHOLOGY: *Thallus* granular to sub-squamulose; upper surface corticate; attached to the substrate by rhizoidal hyphae. *Ascocarp* an apothecium borne on podetia; podetia erect, usually unbranched, with a cortex, the medulla solid with longitudinal cords extending behind the hymenium, the algae in a sub-cortical layer; apothecia at first terminal with a raised proper margin, eventually lateral on bifacially flattened area without a developed margin and irregular in outline, often somewhat lobed; hypothecium pale; paraphyses little branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple or 1 septate, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: (3 species) divaricatic acid (3), usnic acid (2).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On charcoal and soil, throughout humid parts of southern Australia. 2 species reported (3).

TOMASELLIA MASS.: *Flora, Jena* 39, 283 (1856)

MORPHOLOGY: *Thallus* crustose, uniform, epi- or endophloic, ecorticate. *Ascocarp* a perithecium-like ascolocular pseudothecium, immersed in groups in stroma; ostiole apical, horizontal; paraphyses reticulate; ascus bitunicate, thick walled, I−, 8 spored; ascospores ovoid to acicular, transversely 2-16 septate, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on bark in humid forests. 4 species reported (23).

TONINIA MASS.: *Ric. Lich. Crost.* 107 (1852)

MORPHOLOGY: Thallus crustose to small squamulose or almost foliose or fruticose, sometimes inflated or lobed at the margin; cortex of periclinal hyphae; attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, sessile; disk round; margin proper, dark, often disappearing; hypothecium pale or dark; paraphyses unbranched; ascus clavate, unitunicate, thin walled, I+ blue, tholus I+ blue, 8 spored; ascospores oblong to acicular, transversely 1-7 septate, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores filiform or acicular, curved.
CHEMISTRY: (3 species) atranorin (2), norstictic acid (1), stictic acid (1).
PHYCOBIONT: Trebouxia.
DISTRIBUTION: Throughout the region, especially on soils from arid to alpine zones. 7 species reported (80).

TRAPELIA CHOISY: *Bull. mens. Soc. linn. Lyon.* 18, 112 (1949)

MORPHOLOGY: Thallus crustose to minutely squamulose, sometimes with a thin cortex, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, sessile to adnate, round; usually with a brown proper margin; hypothecium hyaline; paraphyses thin, often branched and reticulate; ascus clavate to cylindrical, unitunicate, thin walled, I−, 8 spored; ascospores ellipsoid, simple, hyaline. *Pycnidia* immersed; fulcrum exobasidial; pycnospores oblong to filiform.
CHEMISTRY: (2 species) gyrophoric acid (2), lecanoric acid (2).
PHYCOBIONT: Coccoid chlorophyceae.
DISTRIBUTION: New South Wales, Victoria, South Australia and Western Australia, on compacted earth. 1 species reported (12).

TREMOTYLIUM NYL.: *Bull. Soc. linn. Normandie Ser. 2,* 2, 513 (1868)

MORPHOLOGY: Thallus crustose, uniform, ecorticate; attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, immersed in stroma; disk irregular, narrow, concave; well developed proper exciple with a thalloid margin; paraphyses branched, reticulate; ascus clavate, unitunicate, 8 spored; ascospores ovoid to oblong, hyaline or brown, muriform, walls unevenly thickened resulting in globose locules. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: Trentepohlia.
DISTRIBUTION: Queensland, on bark. 2 species reported (6).

TRICHARIA FEE em. R. SANT.: *Symb. bot. Upsal.* 12(1), 376 (1952)

MORPHOLOGY: Thallus crustose, uniform; ecorticate or with a cartilaginous cortex; usually with black or white erect hairs. *Ascocarp* an apothecium, sessile; disk round with a proper margin; hypothecium hyaline; paraphyses reticulate; ascus clavate, unitunicate, thick walled, 1-8 spored; ascospores ovoid, transversely septate or muriform, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: Coccoid chlorophyceae.
DISTRIBUTION: Queensland, on leaves in humid forests. 1 species reported (10).

TRICHOTHELIUM MULL. ARG. em R. SANT.: *Symb. bot. Upsal.* 12(1), 266 (1952)

MORPHOLOGY: *Thallus* crustose, uniform, ecorticate. *Ascocarp* a perithecium, sessile; the ostiole surrounded by stiff horizontal bristles; paraphyses unbranched; ascus clavate, thin walled, the endoascus reduced to a thickening at the tip, I−, 8 spored; ascospores acicular, transversely many septate or muriform, thin walled. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: *Phycopeltis.*
DISTRIBUTION: Queensland, on leaves in humid forests. 1 species reported (7).

TRIMMATOTHELE NORM. ex BLOMBERG et FORSSELL: *Enum. Pl. Scand.* 100 (1880)

MORPHOLOGY: *Thallus* crustose, epi- or endophloic, uniform, ecorticate. *Ascocarp* a perithecium, sessile or partly immersed; ostiole erect, minute; paraphyses absent; without hymenial algae; asci obscure, unitunicate, thin walled, many spored; ascospores minute, ovoid or ellipsoid, simple, hyaline. *Pycnidia* not known.
CHEMISTRY: No data.
PHYCOBIONT: Coccoid chlorophyceae.
DISTRIBUTION: Queensland, on trunks of palms. 1 species reported (5).

TRYPETHELIUM SPRENG.: *Anleit. Kenn. Gewachse* 309 (1805)

MORPHOLOGY: *Thallus* crustose, uniform, epi-or endophloic; ecorticate or weakly corticate with periclinal hyphae. *Ascocarp* a perithecium; immersed in groups in stroma; paraphyses reticulate; asci cylindrical-clavate, bitunicate, I−, 8 spored; ascospores cylindrical to fusiform, transversely 3-17 septate, hyaline, walls unequally thickened resulting in lenticular or globose locules. *Pycnidia* immersed in stroma; fulcrum exobasidial; pycnospores cylindrical or constricted in the middle.
CHEMISTRY: (5 species) parietin (4), emodin (1), lichexanthone (2), norlichexanthone (1), secaleconic acid (1).
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on bark. 12 species reported (100).

TYLOPHORON NYL.: *Bot. Ztg.* 20, 279 (1862)

MORPHOLOGY: *Thallus* crustose or absent, effuse, ecorticate. *Ascocarp* an apothecium, initially immersed in thalline warts, later sessile, cylindrical or cup-shaped; disk open; proper and thalloid exciples present; hypothecium hyaline to dark, produced concially downwards; asci cylindrical, thin walled, unitunicate, disintegrating at maturity to release the spores in a mazaedium of ascal and hyphal fragments, 8 spored; ascospores globose to fusiform, 1 or 2 septate, hyaline to brownish, with a thickened wall. *Pycnidia* immersed; fulcrum exobasidial; pycnospores acicular, straight.
CHEMISTRY: No data.
PHYCOBIONT: *Trentepohlia.*
DISTRIBUTION: Queensland, on bark. 1 species reported (12).

UMBILICARIA HOFFM.: *Descr. adumbr. Lich.* 1, 9 (1789)

MORPHOLOGY: *Thallus* foliose, both surfaces corticate; cortex paraplectenchymatous attached by an umbilicus, although non-functional rhizines may be found on the lower surface; margins often markedly lacerate. *Ascocarp* an apothecium, sessile; sometimes in depressions or almost stipitate; surrounded by a proper margin; often with a gyrose disk; hypothecium brown; paraphyses unbranched; ascus clavate, unitunicate, I+ blue, ascal gelatin I+ violet, 1-8 spored; ascospores ellipsoid to oblong ellipsoid, simple to muriform; hyaline to brown. *Pycnidia* wart-like, fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (19 species) gyrophoric acid (18), umbilicaric acid (5), lecanoric acid (2), norstictic acid (1), stictic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: New South Wales, Victoria and Tasmania, on sub-alpine or alpine rocks. 7 species reported (45).

USNEA (HILL.) WIGG.: *Prim. fl. Holsat.* 90 (1780)

MORPHOLOGY: *Thallus* fruticose, erect or pendulous, corticate; cortex horny, brittle, of agglutinate hyphae; medulla woolly; central axis cartilaginous, solid or with a hollow centre, of longitudinal agglutinated hyphae; attached to the substrate by a basal disk; thallus straw-yellow to grey-green or red. *Ascocarp* an apothecium, lateral or terminal on branches; well developed thalloid margin; disk round, pale; hypothecium pale; paraphyses branched, agglutinate; asci clavate to cylindrical, untunicate, thick walled, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid to spherical, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum exobasidial; pycnospores fusiform to acicular.
CHEMISTRY: (135 species) usnic acid (131), salazinic acid (50), norstictic acid (37), stictic acid (20), barbatic acid (17), diffractaic acid (13), protocetraric acid (12), thamnolic acid (9), atranorin (6), constictic acid (6), psoromic acid (6), fumarprotocetraric acid (4), galbinic acid (4), caperatic acid (3), connorstictic acid (3), conpsoromic acid (2), decarboxythamnolic acid (2), barbatolic acid (1), chloroatranorin (1), divaricatic acid (1), evernic acid (1), lobaric acid (1), obtusatic acid (1), physodalic acid (1), squamatic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: On wood, bark and rock, in all states. 40 species reported (600).

VERRUCARIA WIGG.: *Prim. fl. Holsat.* 85 (1780)

MORPHOLOGY: *Thallus* crustose, often powdery; sometimes endolithic; ecorticate; prothallus may be prominent. *Ascocarp* a perithecium; immersed to sessile; ostiole punctiform or radially cracked, paraphyses disappearing early; without hymenial algae; asci ovoid to ovoid-clavate, unitunicate, thick walled, I−, 8 spored; ascospores oblong-ellipsoid to globose, simple, hyaline to brown, thin walled. *Pycnidia* immersed; fulcrum endobasidial; pycnospores acicular, straight or curved.
CHEMISTRY: (1 species) no characteristic lichen substances found.
PHYCOBIONT: *Myrmecia, Coccobotrys, Pleurococcus, Heterococcus, Pseudopleurococcus.*
DISTRIBUTION: Victoria, South Australia and Western Australia, on rock, 6 species reported (300).

XANTHOPARMELIA (VAIN.) HALE: *Phytologia* 28, 485 (1974b)

MORPHOLOGY: *Thallus* foliose, lobed, radiate, appressed to somewhat ascending; both surfaces corticate; lobes narrow, eciliate; attached to the substrate by simple rhizines; upper surface yellow-green. *Ascocarp* an apothecium, sessile, laminal; disk concave, brown, circular; margin thalloid; hypothecium pale; paraphyses branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, simple, hyaline, thin walled. *Pycnidia* immersed; fulcrum endobasidial, bayonet-like; pycnospores bacilliform.
CHEMISTRY: (51 species) usnic acid (51), salazinic acid (12), hypoprotocetraric acid (7), loxodin (7), norlobaridone (7), 4-0-methyldenotatic acid (6), norstictic acid (6), fumarprotocetraric acid (4), succinprotocetraric acid (4), connorstictic acid (3), lecanoric acid (3), stictic acid (3), alectoronic acid (2), atranorin (2), conpsoromic acid (2), notatic acid (2), protocetraric acid (2), psoromic acid (2), barbatic acid (1), constictic acid (1), diffractaic acid (1), 4-0-methylhypoprotocetraric acid (1), olivetoric acid (1), physodalic acid (1), "quintaria" unknown (1), rhizonic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Throughout the region, on rocks and soil. ?30 species reported (?100).

XANTHORIA (FR.) TH. FR.: *Nova Acta R. Soc. Scient. upsal. Ser 3,* 3, 166 (1861)

MORPHOLOGY: *Thallus* foliose, more or less appressed, lobed, radiate, golden-yellow; both surfaces corticate, paraplectenchymatous of anticlinal hyphae; attached to the substrate by rhizines. *Ascocarp* an apothecium, laminal, sessile; margin thalloid; disk round; hypothecium pale, paraphyses unbranched or little branched; ascus clavate, unitunicate, I+ blue, tholus I+ blue, 8 spored; ascospores ellipsoid, polari-bilocular, hyaline. *Pycnidia* immersed in thalloid warts; fulcrum endobasidial; pycnospores bacilliform.
CHEMISTRY: (14 species) parietin (14), fallacinal (11), teloschistin (11), emodin (10), parietinic acid (9), erythroglaucin (5), xanthorin (4), citeorosein (2), emodic acid (2), emodinal (1), erythroglaucinic acid (1).
PHYCOBIONT: *Trebouxia.*
DISTRIBUTION: Throughout the southern half of the region, on bark and rock, 2 species reported (15).

XYLOGRAPHA FR.: *Summ. veg. Scand.* 372 (1846).

MORPHOLOGY: *Thallus* crustose, little differentiated, attached to the substrate by medullary hyphae. *Ascocarp* an apothecium, sessile to immersed, minute (c.o. 1mm diam.), disk round to irregular; margin absent or little developed; hypothecium pale, paraphyses simple; asci with an apical wall thickening, I + blue then green, unitunicate, without an I + blue tholus, eight spored; ascospores simple, hyaline, thin walled. *Pycnidia* not known.
CHEMISTRY: (3 species) norstictic acid (2), atranorin (1), stictic acid (1).
PHYCOBIONT: Protococcoid.
DISTRIBUTION: On dead wood in Victoria. 1 species reported (5).

Aids for Species Determination

Few genera have been revised for the Australian region, and some worldwide revisions have been made using very little Australian material. To name a lichen to species therefore presents severe problems for many genera in most or all of Australia. The only regional lichen flora which is of use over a wide area is that of South Australia prepared by Filson and Rogers (1979), and that is incomplete. To assist with species identifications a list of handbooks and publications is provided below. The list has three sections: accounts of the lichen flora in some restricted areas of Australia, lichen floras from other regions which are likely to be useful and a list of other publications to help nomenclature within the named genera. Many lichens are cosmopolitan, or at least widespread within a climatic zone. Reference to a flora or revision from a similar climatic zone is therefore likely to assist in the naming of Australian collections. If the Australian material is of a different species from those covered in any given account of a genus, at least an idea of the characters useful in separating the species can be gleaned from the literature, as can an idea of the affinity of the material in hand.

1. REGIONAL ACCOUNTS OF THE AUSTRALIAN LICHENS

Filson R.B. and Rogers, R.W. (1979) *The Lichens of South Australia*, (Government Printer, Adelaide). A flora with keys to families, genera and species, descriptions, glossary, etc. Crustose genera are not usually treated at species level. Useful in western Victoria, western and central New South Wales and Western Australia as well as South Australia.

Rogers, R.W. (1974) "Lichens from the T.G.B. Osborn Vegetation Reserve at Koonamore in arid South Australia", *Trans. R. Soc. S. Aust.* 98, 113-23. Keys and descriptions of all species found in this small arid reserve. Useful throughout arid southern Australia.

Rogers, R.W. and Lange, R.T. (1972) "Soil surface lichens in arid and sub-arid south-eastern Australia. I. Introduction and floristics", *Aust. J. Bot.* 20, 197-213. Key to soil surface species, useful throughout arid southern Australia.

Stevens, G.N. and Rogers, R.W. (1979) "The macrolichen flora from the mangroves of Moreton Bay", *Proc. R. Soc. Qd.* 90, 33-49. Keys and descriptions of species with some plates, useful in mangroves from Sydney to Bundaberg, but of diminishing use beyond.

2. USEFUL FLORAS FROM OTHER REGIONS

Duncan, U.K. (1970) *Introduction to British Lichens* (Buncle, Arbroath). Useful, especially for crustose and alpine-sub-alpine genera.

Fink, B (1935) *The Lichen Flora of the United States* (Michigan U.P., Ann Arbor). A very dated account but still helpful especially in crustose genera.

Galun, M. (1970) *The Lichens of Israel* (Israel Academy of Sciences and Humanities, Jerusaleum). Keys and descriptions of species, well illustrated, good for Mediterranean climates.

Hale, M.E. (1969) *How to Know the Lichens* (Brown, Dubuque). Very helpful with foliose and fruticose genera; every species illustrated.

Martin, W. and Child, J. (1972) *Lichens of New Zealand* (Reed and Reed, Wellington). An incomplete illustrated account with keys to common species, of value especially in Victoria and Tasmania.

Poelt, J. (1969) *Bestimmungsschlussel Europaischer Flechten* (J. Cremer, Vaduz). Keys to genera and species, useful especially in cooler areas.

Vainio, E.A. (1890) "Etude sur la classification naturelle et la morphologie des Lichens du Bresil", *Acta Soc. Fauna Flora fenn.* 7(1) i-247, 7(2) 1-256. An account of tropical lichens still unsurpassed in breadth and detail. The text is in Latin, and is without keys, but the clarity of descriptions make the work usable in tropical and sub-tropical areas. It is likely to be shelved in libraries as a book *Lichens du Bresil* with the author listed as Wainio, an alternative spelling he sometimes used.

3. ACCOUNTS OF GENERA

Acarospora:	Magnusson (1929); Weber (1968).
Alectoria:	Brodo and Hawksworth (1977); Jorgensen (1972); Motyka (1964).

Anaptychia: Kurokawa (1962, 1973); Swinscow and Krog (1976a).
Athracothecium: Keissler (1937a); Muller-Argoviensis (1895).
Anzia: Galloway (1978) Bratt, Blackman and Cashin (1976).
Arctomia: Henssen (1969).
Arthonia: Redinger (1936a); Santesson (1952).
Arthopyrenia: Keissler (1937a).
Arthothelium: Redinger (1936a).
Aspicilia: Weber (1967a).
Aspidothelium: Santesson (1952).
Aulaxina: Santesson (1952).
Bacidia: Malme (1935); Santesson (1952), Zahlbruckner (1941).
Baeomyces: Thomson (1967).
Biatorella: James (1973); Magnusson (1935c).
Bombyliospora: Malme (1923).
Bottaria: Malme (1924); Muller- Argoviensis (1895).
Buellia: Imshaug (1955); Magnusson (1953); Malme (1928); Sheard (1964).
Bulbothrix:: Hale (1976b).
Byssoloma: Santesson (1952).
Calicium: Keissler (1937d); Tibell (1975).
Caloplaca: Alon and Galun (1971); Malme (1926); Wade (1965).
Campylothecium: Malme (1924).
Candelaria: Almborn (1966); Poelt (1974).
Candelariella: Hakulinen (1954).
Catillaria: Malme (1923); Santesson (1952).
Catinaria: Vainio (1922).
Cetraria: Esslinger (1973); Karnefelt (1977).
Cetrelia: Culberson and Culberson (1968).
Chaenotheca: Keissler (1937d); Tibell (1975).
Chondropsis: Bibby (1955)
Cladia: Filson (1970); Martin (1965).
Cladina: Ahti (1961); Thomson (1968).
Cladonia: Martin (1958); Thomson (1968).
Clathroporina: Keissler (1937a).
Coccocarpia: Arvidsson and Galloway (1979); Santesson (1952); Swinscow and Krog (1976b).
Coccotrema: Brodo (1973); Oshio (1968).
Coenogonium: Dodge (1933); Santesson (1952a); Vainio (1921).
Collema: Degelius (1954, 1974).
Coniocybe: Keissler (1937d).
Conotremopsis: Vezda (1977).
Crocynia: Hue (1924).
Cyphelium: Tibell (1971); Weber (1967b).
Dermatocarpon: Magnusson (1940); Swinscow and Krog (1975c); Zschacke (1933b).
Dermatina: Keissler (1937c); Reidl (1964).
Dictyonema: Parmasto(1978)
Dimerella: Lettau (1937); Santesson (1952).
Diplogramma: Muller Argoviensis (1891).
Diploschistes: Lettau (1937); Magnusson (1955).
Dirinaria: Awasthi (1975).
Dirinastrum: Muller Argoviensis (1893).

Echinoplaca:	Santesson (1952).
Endocarpon:	Magnusson (1940); Zschacke (1933b).
Enterographa:	Redinger (1936b, 1938); Santesson (1952).
Ephebe:	Henssen (1963a).
Erioderma:	Keuck (1977).
Evernia:	Bird (1974).
Fistulariella:	Bowler and Rundel (1977); Krog and Swinscow (1976b).
Fulgensia:	Poelt (1965).
Gylphis:	Redinger (1933).
Gomphyllus:	Frey (1933).
Graphina:	Hayward (1977); Nakanishi (1966); Wirth and Hale (1963, 1978).
Graphis:	See *Graphina*.
Gyalecta:	Malme (1934).
Gyalectidium:	Santesson (1952).
Gymnoderma:	Yoshimura (1973); Yoshimura and Sharp (1968).
Gymnographa:	Muller Argoviensis (1887)
Haematomma:	Culberson (1964).
Heppia:	Wetmore (1970)
Heterodea:	Filson (1978)
Heterodermia:	See *Anaptychia.*
Hypogymnia:	Elix (1980).
Hypotrachyna:	Hale (1975a); Hale and Kurokawa (1964); Krog and Swinscow (1979).
Icmadophila:	Frey (1933).
Laurera:	Malme (1924).
Lecanactis:	Lettau (1937).
Lecanora:	Imshaug and Brodo (1966); Poelt (1952, 1958).
Lecidea:	Hertel (1967, 1968, 1969b); Zahlbruckner (1941).
Lepraria:	Hue (1924).
Leprocaulon:	Lamb and Ward (1974).
Leptogium:	Dodge (1933); Sierk (1964).
Leptotrema:	Hale (1978).
Lichina:	Henssen (1963a).
Lobaria:	Jordan (1973); Yoshimura (1971).
Lopadium:	Kurokawa and Kashiwadani (1977); Santesson (1952).
Mallotium:	Awasthi and Akhtar (1977); Jorgensen (1975); Sierk (1964).
Maronea:	Magnusson (1934).
Mazosia:	Santesson (1952).
Medusulina:	Redinger (1933).
Megalospora:	Malme (1923).
Melanelia:	Esslinger (1977, 1978a).
Melanotheca:	Keissler (1937b); Malme (1924); Muller Argoviensis (1895).
Melaspilea:	Redinger (1936b); Wirth and Hale (1963).
Menegazzia:	Santesson (1943).
Micarea:	James and Coppins (1979); Vezda and Wirth (1976).
Microthelia:	Keissler (1937a); Muller Argoviensis (1895).
Mycoporellum:	Keissler (1937c).
Neofuscelia:	Esslinger (1977, 1978a).
Nephroma:	Wetmore (1960).
Neuropogon:	Lamb (1939).
Normandina:	Henssen (1976).

Ocellularia: Hale (1978).
Ochrolechia: Howard (1970); Verseghy (1962).
Opegrapha: Hayward (1977); Redinger (1936b, 1940); Santesson (1952).
Pannaria: Jorgensen 1978; Tavares (1965).
Pannoparmelia: Bratt *et al.* (1976); Galloway (1978).
Parathelium: Malme (1924).
Parmelia: Hale (1965); Hale and Kurokawa (1964).
Parmeliella: Dodge (1933); Malme (1925); Zahlbruckner (1941).
Parmelina: Hale (1976c).
Parmeliopsis: Hillman (1936).
Parmentaria: Malme (1924).
Parmotrema: Hale (1965b, 1974a).
Peltigera: Kurokawa *et al.* (1966); Murray (1960); Thomson (1950).
Peltula: Wetmore (1970).
Pertusaria: Dibben 1980; Erichsen (1935); Malme (1936b); Oshio (1968).
Phaeographina: See *Graphina.*
Phaeographis: See *Graphina.*
Phaeophyscia: Esslinger (1978b); Moberg (1977).
Phaeotrema: Hale (1978)
Physcia: Moberg (1977); Thomson (1963).
Physciopsis: Moberg (1977); Poelt (1965); Thomson (1963).
Physma: Hue (1905); Zahlbruckner (1941).
Pilophorus: Jahns (1970).
Placopsis: Lamb (1947).
Placynthium: Henssen (1963b); Weber (1977).
Pleurotrema: Malme (1924).
Polyblastiopsis: Keissler (1937a).
Porina: Malme (1929); Santesson (1952); Swinscow (1962).
Porocyphus: Henssen (1963a).
Pseudevernia: Hale (1968).
Pseudocyphellaria: Magnusson (1940); Zahlbruckner (1941).
Pseudoparmelia: Hale (1976a).
Psoroma: Malme (1925); Zahlbruckner (1941).
Psoromaria: Hue (1912).
Pyrenula: Keissler (1937a).
Pyxine: Imshaug (1957); Kashiwadani (1977); Swinscow and Krog (1975a).
Ramalina: Krog and James (1977); Krog and Swinscow (1976a).
Relicina: Hale (1975b).
Rhizocarpon: Malme (1923); Runemark (1956).
Rinodina: Sheard (1967).
Rocella: Darbishire (1898).
Sagenidium: Zahlbruckner (1941).
Sagiolechia: Vezda (1968).
Sarcographa: Redinger (1933).
Sarcogyne: Magnusson (1935b).
Siphula: Mathey (1971).
Sporastatia: Magnusson (1935a).
Sporopodium: Santesson (1952).
Spilonema: Henssen (1963a).
Stenocybe: Keissler (1937d).
Stereocaulon: Galloway *et al.* (1976); Lamb (1977, 1978).

Sticta: Zahlbruckner (1941).
Strigula: Santesson (1952).
Tapellaria: Santesson (1952).
Teloschistes: Filson (1969).
Thamnolia: Filson (1972).
Thelidium: Zschacke (1933a).
Thelotrema: Hale (1978).
Thysanothecium: Abbayes (1968); Galloway (1977).
Tomasellia: Keissler (1937b); Malme (1924).
Trapelia: Hertel (1969a).
Tricharia: Santesson (1952).
Trichothelium: Santesson (1952).
Trimmatothele: Zschacke (1933a).
Trypethelium: Keissler (1937b); Malme (1924).
Umbilicaria: Blackman *et al.* (1974); Kershaw (1961); Llano (1950, 1965).
Usnea: Motyka (1936-38); Swinscow and Krog (1974, 1975b, 1978).
Verrucaria: Swinscow (1968); Zschake (1933a).
Xanthoparmelia: Hale (1974b).
Xanthoria: Filson (1969).

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Glossary

acicular: long and needle shaped.

adnate: closely attached, the thallus close to the substrate, or the lower surface of the apothecium fused to the thallus.

aggregated: grouped together.

anastomosing: with numerous cross-connections (Fig. 3A).

anticlinal: at right angles to the surface.

apical: situated at the tip.

apothecium (apothecia): disk shaped fruiting body (ascocarp) of an ascomycetous fungus, whether lichenized or not (Figs 1 and 4).

appressed: closely pressed to the substrate.

arachnoid: cobweb-like in structure.

areole: a small part of a lichen thallus separated from the rest of the thallus by minute cracks.

areolate: consisting of a mosaic of areoles.

articulate: broken into jointed portions and so appearing rather like a crustacean's leg.

ascending: rising from the substrate.

ascus (asci): sac containing spores (Fig. 2A to C).

axis (axes): the main stem of a branched lichen, or in *Usnea*, the central cartilagenous core.

bacilliform: like a short rod.

basidia: inflated hyphal segments bearing basidiospores.

bicornute: curved and drawn into two points.

bilateral: concerning both sides.

bitunicate: ascal wall layers separating to show separate endoascus and exoascus. The fissitunicate ascus of some authors.

blastidia: small subsidiary locules in a thick-walled spore.

bulbate: with a bulbous swelling.

carbonaceous: black, opaque.

cephalodia: thallus structures containing a second phycobiont, usually a blue-green alga.

chondroid axis: the elastic, cartilagenous central core in the genus *Usnea.*

cilium (cilia): a hair-like growth on the margin or upper surface of lobes or on the margin of the apothecium.

clavate: club-shaped.

coccoid: organized in small, more or less spherical groups.

corona: crown-like radiating structure.

cortex: the outermost layer of the thallus which, if present, consists of compacted hyphae which may appear either fibrous or cellular.

crustose: thallus type forming a strongly adherent crust over the substrate: without a lower cortex or rhizines (Fig. 1C).

cupular: like a cup.

cymose: in a sequence one above the other, youngest at the top.

cyphella (cyphellae): a pore in the lower surface, lined with a pseudocortex.

dichotomous: branched into two equal portions, sometimes repeatedly.

ecorticate: without a cortex.

effigurate: without a defined form, grossly irregular (for example not ovoid).

endoascus: the inner layer of a bitunicate ascus.

endobasidial: a fulcrum type normally with short cells and producing pycnospores terminally. The endobasidial fulcrum usually produces bacilliform pycnospores (Fig. 3J and K).

endolithic: within rocks.

endophloic: within bark.

epiphloic: on bark.

epithecium: upper layer of the hymenium, above the asci (Fig. 1A and B).

erect: rising vertically from the substrate.

exciple: the layer surrounding the hymenium which sometimes develops into a distinct margin. A proper exciple has no algal component and is derived from apothecial tissue. A thalloid exciple has an algal component and is derived from the vegetative thallus (Fig. 1A and B).

exobasidial: a fulcrum type normally with long cells producing lateral pycnospores. The exobasidial fulcrum often produces markedly elongate or filiform pycnospores (Fig. 3H and I).

expanded: broadened or extended.

fenestrate: with small perforations.

filamentous: hair- or thread-like.

foliicolous: growing on leaves.

foliose: a thallus type usually with upper and lower cortices, dorsiventral, flat and somewhat leaf-like (Fig. 1E).

fruticose: a thallus form which is usually erect and rather bushy and shrub-like, commonly radially symmetrical but sometimes dorsiventral (Fig. 1F).

fulcrum: hypha giving rise to pycnospores (Fig. 3H to K).

fusiform: spindle-shaped.

gelatinous: like a jelly, slimy.

goniocysts: small aggregations of algae.

gyrose: in a more or less circular or spiral pattern.

heteromerous: a thallus form in which more or less distinct tissues are present.

homiomerous: a thallus form in which the algal and fungal components are uniformly dispersed.

hymenium: that part of the ascocarp composed of asci and paraphyses in a close arrangement (Fig. 1A and B).

hypha (hyphae): a filament of fungal cells.

hypothallus: a growth of undifferentiated mycelia, sometimes present as a distinct layer below or around a thallus.

hypothecium: the tissue in the apothecium immediately below the hymenium (Fig. 1A and B).

immersed: sunken into the thallus.

inflated: expanded, blown up, often hollow.

isidium (isidia): an outgrowth from the thallus with a cortex which serves as a vegetative dispersal unit.

labia: lateral lip-like structures.

lacerate: irregularly incised to form elongate strips, for instance finely lobed.

laminal: on the surface.

lax: loose, loosely woven.

lenticular: shaped like a lens (Fig. 2F).

leprose: a loose powdery mass of algal cells and fungal hyphae.

lirelliform: having a shape rather like the characters of Chinese writing.

mazaedium (mazaedia): a fruiting body in which ascus walls break down to leave an amorphous spore mass.

marginal: on the edge or margin rather than on the upper or lower surface.

medulla: an internal layer of loosely woven hyphae, between the algal layer and lower cortex.

moniliform: regularly constricted, like a string of beads.

muriform: with transverse and longitudinal walls (of spores) (Fig. 2G).

mycelial: made up of intertwined strands of hyphae.

obovoid: generally ovoid, but broader to the distal end.

ostiole: the narrow opening of a perithecium (Fig. 4I).

paraphysis (paraphyses): a specialized hyphal form, either simple or branched, in the hymenium. The term is here used in a broad sense to cover many structures similar to true paraphyses (Fig. 3A to G).

paraplectenchyma: a fungal tissue with a cellular structure superficially like parenchyma of vascular plants.

peltate: like a shield on a central stalk.

pendulous: hanging.

perforate: with holes through the thallus or into a central cavity.

periclinal: parallel to the surface.

perithecium (perithecia): a flask-shaped fruiting body immersed in the thallus with a single, terminal opening (Fig. 4I to K).

phycobiont: the algal component of a lichen.

plaque: like a small disk or plate.

plectenchyma: parenchyma-like tissue of tightly packed hyphae.

podetium (podetia): an erect portion of a thallus derived from tissue of apothecial origin, rising from a primary thallus and bearing apothecia.

polarilocular: referring to spores which are not-septate, but in which the wall thickens, almost dividing the cell into two polar compartments (Fig. 2J).

primary thallus: the first formed thallus which may later give rise to podetia (secondary structures).

proper exciple: an exciple formed from tissue of apothecial origin — without algae in the rim (Fig. 1B).

prosoplectenchyma: a fungal tissue with a cellular structure superficially like collenchyma of vascular plants.

prothallus: a purely fungal layer upon which an algal layer may later develop, commonly black, often found beneath crutose lichens.

pseudocyphella (pseudocyphellae): areas of the thallus in which the upper or lower cortex is missing and medullary hyphae come to the surface.

pseudoparenchymatous: having the appearance of parenchyma, that is isodiametric cells.

pseudopodetium (pseudopodetia): a podetium-like structure that has its origin in vegetative rather than reproductive tissue.

pseudothecium: the fruiting structure of an ascolocular ascomycete.

pycnidium (pycnidia): an often flask-shaped structure producing pycnospores.

pycnospores: the spore type produced in a pycnidium: the function of these is not known (Fig. 3H to K).

pyriform: pear-shaped.

regular: uniform, even, repeating.

reticulate: with a network of rides, lines or cracks on the surface (of a surface); like a net, anastomosing (of paraphyses) (Fig. 3A).

rhizines: a short branch of the thallus resembling a root.

rhizoid: hyphal structures on the lower surface anchoring the thallus.

scrobiculate: marked by shallow depressions.

septate: divided by a septum or wall (Fig. 2).

sessile: without a stem or stipe, sitting on the surface.

simple: unbranched (of paraphyses); non-septate (of spores).

soredium (soredia): a group of algal cells and hyphae, without a cortex, which functions as a vegetative reproductive unit.

squamule: a small scale-like thallus segment, with an upper cortex but lacking a lower cortex (Fig. 1D).

squamulose: a growth form composed of squamules.

squarrose: having numerous short laterals.

stellate: star-like.

sterigmata: spines on basidia which bear basidiospores.

stipe: a stalk that supports a fruiting body.

stipitate: elevated on a stipe.

striate: with parallel stripes or lines.

stroma: a compact mass of fungal tissue in which fruits are formed.

stylospores: large spores produced in pycnidia or similar structures.

terete: circular in cross-section.

terminal: ending the structure.

thalloid exciple: an exciple in which part of the vegetative thallus has grown up around the apothecium so that algae occur in the margin (Fig. 1A).

thallus: the lichen body, both alga and fungus.

tholus: a dome-like structure at the apex of many unitunicate asci.

tomentum: a dense woolly covering of hyphae.

trichotomous: branching equally into three, sometimes repeatedly.

truncate: cut short at the end.

umbilicate: with a point attachment at the centre of a thallus.

unitunicate: ascal wall not developing a distinct and separate endoascus and exoascus: the non-fissitunicate ascus of some authors.

urcelolate: shaped like an urn.

vermiform: like a worm, sinuous.

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LICHEN PHOTOBIONTS

R.W.Rogers

Introduction

The photobiont of a lichen is its photsynthetic component, providing the energy required to maintain the life and growth of the whole structure. While the structure of the lichen thallus is apparently determined by the fungal component in most species, it is clear that in some lichens the photobiont provides the basic structure, and in yet others, it is clear that the photobiont markedly influences thallus form (James & Henssen 1976). The photobiont is a member of the Chlorophyta (green algae) in about 90% of cases, and is one of the Cyanobacteria (blue-green algae) in about 10% of cases (Ahmadjian, 1967). Tschermak-Woess (1988) has reported that three lichens have a member of the Xanthophyta as photobiont and one doubtful case in which the photobiont is a member of the Phaeophyta.

LICHEN PHOTOBIONTS

Diversity of photobionts

Tschermak-Woess (1988) reported very fully on the diversity of photobionts in lichens. She recorded about 40 genera of photobiont from lichens, and listed about 100 species of photobiont that have been identified from lichens, although that number is quite incomplete. The most common lichen phycobiont by far is the genus *Trebouxia*, followed by *Trentepohlia*. Amongst the Cyanobacteria, *Nostoc* is the most common genus.

The photobiont may be constant within a lichen genus, as in the genus *Cladonia* in which all studies species contain a photobiont in the genus *Trebouxia*. In other cases the species of photobiont may vary geographically. A single lichen species may contain more than one photobiont, or even different photobionts at different stages of its life. In a number of genera of lichen (e.g. *Stereocaulon, Psoroma, Placopsis*), the thallus has a primary green algal photobiont, but develops characteristic structures called cephalodia which contain cyanobacteria as a photobiont. In a number of cases it appears that the thallus first develops with a cyanobacterial photobiont, and then replaces it with a chlorophytan photobiont (James & Henssen 1976). The process of replacement is apparently environmentally determined, and may be so delayed as to result in the formation of a peculiar and distinctive thallus form ascribed to the genus *Dendriscocaulon*. It is apparent, however, that thalli of *Dendriscocaulon* are only sterile cyanobacterial stages in the life of several species of *Sticta* and *Lobaria* which become fertile and produce apothecia following the adoption of a green photobiont. A strict interpretation of the *International Code of Botanical Nomenclature*, would, therefore, require that species of *Dendriscocaulon* be treated as synonyms of their fertile stages in *Sticta* or *Lobaria*, and *Dendriscocaulon* treated as a form genus for sterile thalli.

Nevertheless, the nature of the photobiont is highly characteristic for most groups of lichens, and is a useful device for lichen identification. Thus, while the photobiont in a lichen thallus is not strictly an attribute of a lichen-forming fungus, capacity to lichenise different photobionts is a characteristic of lichen-forming fungi.

Identification of photobionts

The determination of photobionts as either Chlorophyta (green algae) or Cyanobacteria (blue-greens) is usually a simple matter. The Chlorophyta produce a grass-green colouration within the thallus, often visible macroscopically and almost always visible under a dissecting microscope, whereas the Cyanobacteria produce a blue-black colouration which is similarly visible. If a thallus swells and becomes gelatinous when wet, the thallus probably contains a Cyanobacterial photobiont, although failure to swell and become gelatinous does not necessarily indicate the presence of Chlorophyta.

Chlorophyta

The nature of the chlorophytan photobiont is not commonly used as a key character, but the more common genera are easily separable. All of the Chlorophyta have a well-developed grass-green chloroplast and a nucleus. The Chlorophyta do not usually form a gelatinous sheath.

Cephaleuros occurs in foliicolous lichens, and is characterised by the formation of radiating and branched lines of cells beneath the cuticle of the leaf. Minute haustoria from the algae penetrate the leaf tissues, often causing a necrosis in the leaf.

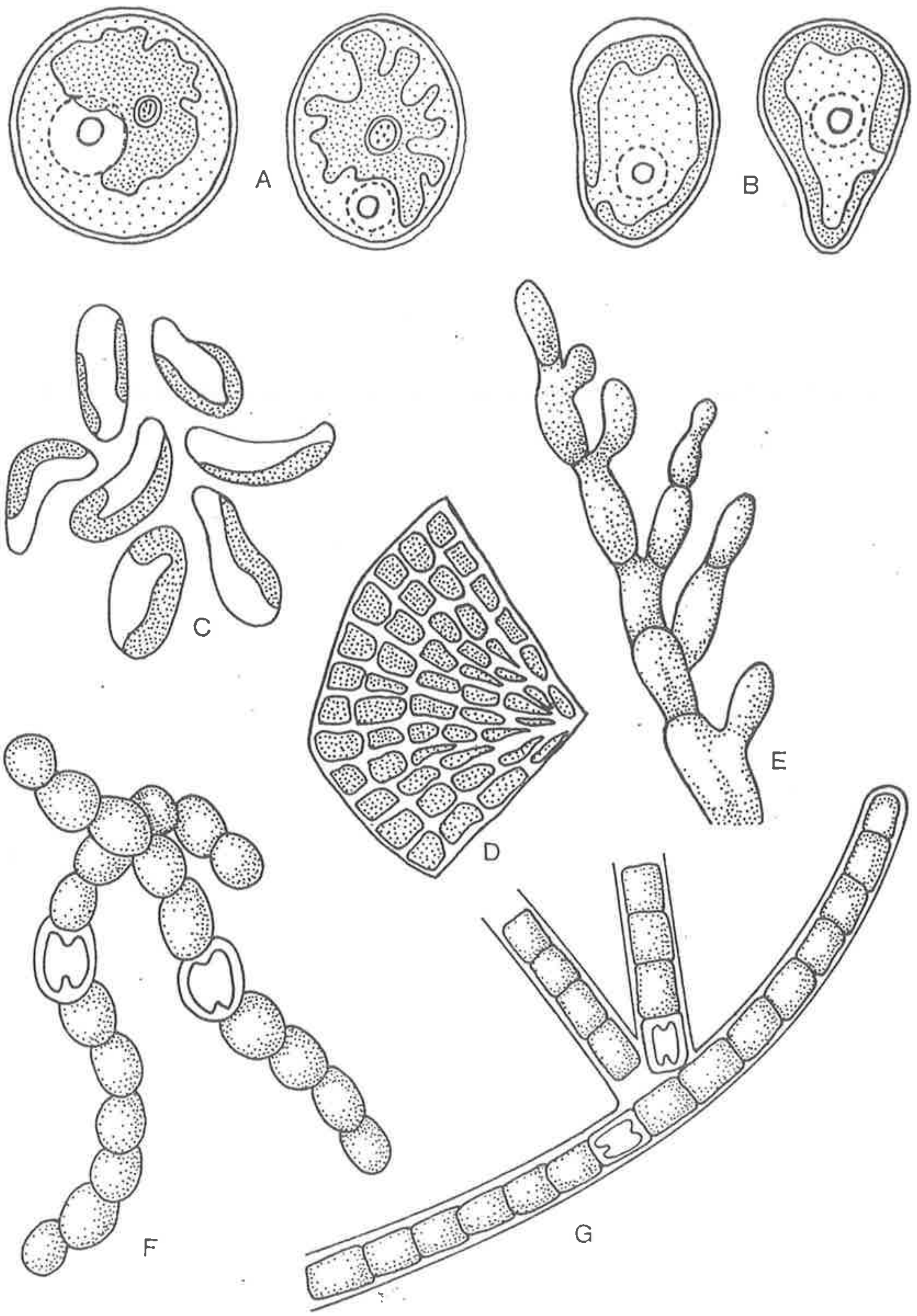

Figure 38. The most common types of photobiont found in lichen associations. **A**, *Trebouxia*. **B**, *Myrmecia*. **C**, *Coccomyxa*. **D**, *Phycopeltis*. **E**, *Trentepohlia*, **F**, *Nostoc*. **G**, *Scytonema*. Adapted by permission of V.Ahmadjian.

Coccomyxa is found in a diversity of lichens, especially (but not only) in the Peltigerales. The organism is unicellular, with kidney-shaped cells and a parietal chloroplast (Fig. 38C).

Myrmecia is found in a variety of crustose lichens, especially in the Verrucariaceae. It is characterised by irregular cells with a parietal chloroplast (Fig. 38B).

Phycopeltis is common in foliicolous lichens. It forms a flat disc with cells radiating from a central point, and is always supra-cuticular, and may form a peltate thallus (Fig. 38D).

Trebouxia is the most common lichen photobiont. It is single-celled, and the cells are more or less globose with a stellate chloroplast (Fig. 38A).

Trentepohlia is common in the Arthoniales, and often gives thalli in this order an orange colouration. *Trentepohlia* forms branched filaments within the thallus, and the green colour of the chloroplast may be masked by the production of an orange pigment. (Fig. 38E).

Cyanobacteria

The presence or nature of the cyanobacterial photobiont is often used as a key character. The cyanobacteria characteristically have no defined chloroplast or nucleus, and hence have an apparently uniform blue-green cytoplasm. The cyanobacteria in lichens commonly have a well-developed gelatinous sheath. The presence of heterocysts (distinctive thick-walled cells) in the Cyanobacteria is closely associated with capacity to fix atmospheric nitrogen.

Calothrix is often association with the Lichinaceae. It comprises single unbranched files of cylindrical cells with a single heterocyst at the base of each filament.

Gloeocapsa is a genus in which the cells are aggregated into small colonies within a gelatinous capsule. No heterocysts are formed.

Hyphomorpha is a filamentous thallus which is branched, may be several cells thick, and has no heterocysts. The genus has been recorded from only one lichen genus, *Spilonema*.

Nostoc is a single file of more or less globose cells joined into short chains with heterocysts present in the filaments, or terminal upon them. *Nostoc* is characteristically associated with large volumes of mucilage, and hence tends to be associated with homiomerous thalli, although it is not restricted to them (Fig. 38F).

Scytonema is filamentous with terminal or intercalary heterocysts. The filaments are commonly severely distorted within the lichen thallus (Fig. 38G).

Stigonema has a filamentous thallus which is branched and may be several cells thick, but without heterocysts. In some cases the lichen thallus consists simply of fungal hyphae ramifying through the encasing gelatine of the photobiont.

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A SYSTEMATIC ARRANGEMENT OF THE AUSTRALIAN LICHENS

R.W.Rogers & J.Hafellner

Introduction

The highly artificial taxonomic concepts of the nineteenth century lichenologist W.Nylander were carried into the twentieth century by A.Zahlbruckner and have dominated lichenology until recently. These systems of classification had the advantage of convenience, using the structure of the thallus, septation of spores, and form of the ascocarp as their basis. These characters are useful for keys, but tell little about phylogenetic relationships. These systems recognised that lichens are fungi, but maintained a separation between the systems of classification of lichenised and non-lichenised ascomycetes. A system of classification is more informative if it reflects the evolution of a group of organisms. The fact that this volume treats lichens as a group is a heritage of the artificial division between lichenised and non-lichenised fungi.

The incorporation of lichens into the classification system applied to the other fungi was a difficult process. Some lichens could easily be placed within orders and families created for non-lichenised fungi. In the ascomycetes, which contain most lichenised fungi, some groups consist almost entirely of lichens and other groups have very few. This meant that two independent and partly overlapping systems had to be integrated at a time of rapid development in taxonomic insight.

A major advance in lichen taxonomy came with the careful studies of Santesson (1952) who worked on the foliicolous lichens and applied contemporary approaches to ascomycete taxonomy to them. Henssen & Jahns (1974) presented a system of classification which took into account much of modern ascomycete taxonomy, especially studies in ontogeny of ascocarps. Poelt (1974) presented another system which placed more emphasis on the rowing body of information concerning the structure of asci. The relationships of the scomycetes with bitunicate asci (including lichenised taxa) were reviewed by Eriksson 1981), providing a workable, but still incomplete, taxonomy of that complex group. awksworth and Eriksson (1985, 1986, 1987) have attempted to integrate the ascomycetes nto a single broadly acceptable system. Their work has been influential in the evelopment of the system advanced here. The principles of classification adopted here, owever, are those enunciated by Hafellner (1988), and the orders used to accommodate he lichens are based on those accepted by Hafellner (1988) except that the order ichinales has been included.

he families adopted and the genera allocated to them have generally followed the reatments of Hawksworth and Eriksson, except that within the crustose taxa the less onservative system of Hafellner (1984) has been adopted.

he characters regarded as taxonomically important at higher levels include:

1. characters relating to the structure of the spore-bearing organs (asci or basidia) and the means of discharge (the apex of the ascus is of special significance in this context)
2. characters of the fruiting body, especially ontogeny, and nature and origin of sterile structures such as paraphyses
3. characters derived from the spores, including spore wall construction
4. pycnidial conidiomatal characteristics including mode of pycnospore development and form of pycnidial conidiomatum
5. secondary chemistry of the thallus
6. structure of the thallus and growth form.

Scope

he genera included in this classification are those in the checklist prepared by Filson 1988) but dubious records have been omitted. Additional records from the literature (up to ecember 1990), and unpublished identifications made by A.Henssen, T.Lumbsch, K.Kalb nd P.McCarthy have been included.

total of 18 orders in the Division Ascomycotina consisting of approximately 100 amilies and 2250 species and 18 and 7 species in the Divisions Deuteromycotina and asidiomycotina respectively are currently known to occur in Australia.

Arrangement

he sequence of orders in this classification is without taxonomic significance. Families e arranged alphabetically within orders, and genera are listed alphabetically within the ost appropriate family.

Systematic arrangement

he number before the decimal point indicates the order number, that after the decimal oint indicates the family. The number in parentheses is an estimate of the number of

A SYSTEMATIC ARRANGEMENT OF THE AUSTRALIAN LICHENS

species in that genus or family occurring in Australia according to McCarthy (1991).

Ascomycotina

1 Lecanorales Nannf.

1.1 Alectoriaceae (Hue) Tomaselli (1)
    1 *Alectoria* Link (1)
1.2 Bacidiaceae Walter Watson (62)
    1 *Bacidia* De Notaris (44)
    2 *Lecania* A.Massal. (10)
    3 *Toninia* A.Massal. (7)
    4 *Tylothallia* P.James & Kilias (1)
1.3 Biatoraceae A.Massal. ex Stizenb. (4)
    1 *Biatora* Fries *nom. cons.* (3)
    2 *Cliostomum* Fries (1)
1.4 Candelariaceae Hakulinen (10)
    1 *Candelaria* A.Massal. (1)
    2 *Candelariella* Müll. Arg. (6)
1.5 Cladiaceae Nyl.
    1 *Cladia* Nyl. (9)
1.6 Cladoniaceae Zenker (67)
    1 *Cladina* Nyl. (3)
    2 *Cladonia* Hill ex W.A.Weber *nom. cons.* (45)
    3 *Metus* D.J.Galloway & P.James (1)
    4 *Myelorrhiza* Verdon & Elix (2)
    5 *Neophyllis* F.Wilson (2)
    6 *Pycnothelia* (Ach.) Dufour (1)
    7 *Ramalea* Nyl. (1)
    8 *Thysanothecium* Mont. & Berkeley (3)
1.7 Coccocarpiaceae (Mont. ex K.Muller) Henssen (5)
    1 *Coccocarpia* Pers. in Gaudich. (8)
    2 *Spilonema* Bornet (1?)
1.8 Collemataceae Zenker (73)
    1 *Collema* W.A.Weber *nom. cons.* (19)
    2 *Leptogium* (Ach.) Gray (32)
    3 *Physma* A.Massal. (3)

- 4 *Ramalodium* Nyl. in Crombie (1)

1.9 Haematommaceae Hafellner em. R.W.Rogers & Hafellner (10)
- 1 *Haematomma* A.Massal. (10)

1.10 Heterodeaceae Filson (2)
- 1 *Heterodea* Nyl. (2)

1.11 Hypogymniaceae Poelt ex Elix (34)
- 1 *Hypogymnia* (Nyl.) Nyl. (12)
- 2 *Menegazzia* A.Massal. (22)

1.12 Lecanoraceae Fée emend. Hafellner (96)
- 1 *Bellemerea* Hafellner & Roux (1)
- 2 *Carbonea* (Hertel) Hertel (3)
- 3 *Clauzadeana* C.Roux (1)
- 4 *Lecanora* Ach. in Luyken (73)
- 5 *Lecidella* Körber emend. Hertel & Leuckert (7)
- 6 *Maronina* Hafellner & R.W.Rogers (1)
- 7 *Miriquidica* Hertel & Rambold (2)
- 8 *Protoparmelia* M.Choisy (3)
- 9 *Pyrrhospora* Körber (1)
- 10 *Rhizoplaca* Zopf (1)
- 11 *Tephromela* M.Choisy (3)

1.13 Megalariaceae Hafellner (3)
- 1 *Megalaria* Hafellner (3)

1.14 Pannariaceae Tuck. (62)
- 1 *Degelia* Arv. & D.J.Galloway (7)
- 2 *Erioderma* Fée (2)
- 3 *Fuscoderma* (D.J.Galloway & P.M.Jørg.) P.M.Jørg. & D.J.Galloway (2)
- 4 *Leioderma* Nyl. (3)
- 5 *Pannaria* Delise ex Bory (13)
- 6 *Parmeliella* Müll. Arg. (8)
- 7 *Psoroma* Ach. ex Michaux (12)
- 8 *Psoromidium* Stirt. (2)
- 9 *Siphulastrum* Müll. Arg. (2)

1.15 Parmeliaceae Eschw. (362)
- 1 *Anzia* Stizenb. *nom. cons.* (1)
- 2 *Bulbothrix* Hale (8)

3 *Canomaculina* Elix & Hale (1)
4 *Canoparmelia* Elix & Hale (11)
5 *Cetraria* Ach. in Luyken (3)
6 *Cetrelia* W.L.Culb. & C.F.Culb. (2)
7 *Chondropsis* Nyl. *nom. cons.* (2)
8 *Coelocaulon* Link (1)
9 *Flavoparmelia* Hale (13)
10 *Hypotrachyna* (Vain.) Hale (10)
11 *Imshaugia* S.F. Meyer (2)
12 *Karoowia* Hale (1)
13 *Melanelia* Essl. (4)
14 *Myelochroa* Elix & Hale (2)
15 *Neofuscelia* Essl. (18)
16 *Pannoparmelia* (Müll. Arg.) Darbish. (2)
17 *Paraparmelia* Elix & J.Johnson (39)
18 *Parmelia* Ach. *nom. cons.* (10)
19 *Parmelina* Hale (5)
20 *Parmelinella* Elix & Hale (1)
21 *Parmelinopsis* Elix & Hale (7)
22 *Parmeliopsis* (Nyl.) Nyl. (3)
23 *Parmotrema* A.Massal. (38)
24 *Platismatia* W.L.Culb. & C.F.Culb. (1)
25 *Pseudephebe* M.Choisy (1)
26 *Punctelia* Krog (5)
27 *Relicina* (Hale & Kurok.) Hale (18)
28 *Relicinopsis* Elix & Verdon (4)
29 *Rimelia* Hale (2)
30 *Xanthoparmelia* (Vain.) Hale (147)

1.16 Phyllopsoraceae Zahlbr. (8)
1 *Hypocenomyce* M.Choisy (4)
2 *Phyllopsora* Müll. Arg. (3)
3 *Physcidia* Tuck. (1)

1.17 Physciaceae Zahlbr. *nom. cons.* prop. (174)
(Pyxinaceae (Fries) Stizenb.)
1 *Buellia* De Notaris (53)

- 2 *Dimelaena* J.Norman (2)
- 3 *Diploicia* A.Massal. (1)
- 4 *Diplotomma* Flotow (1)
- 5 *Dirinaria* (Tuck.) Clements (9)
- 6 *Heterodermia* Trev. St. Léon (22)
- 7 *Hyperphyscia* Müll. Arg. (2)
- 8 *Orphniospora* Körber in Hertlaub & Lindeman (1)
- 9 *Phaeophyscia* Moberg (4)
- 10 *Physcia* (Schreber) Michaux (26)
- 11 *Physconia* Poelt (2)
- 12 *Pyxine* Fries (17)
- 13 *Rinodina* (Ach.) Gray (33)
- 14 *Rinodinella* H.Mayrhofer & Poelt (1)

1.18 Ramalinaceae Agardh (26)

- 1 *Ramalina* Ach. *nom. cons.* (26)

1.19 Scoliciosporaceae Hafellner (2)

- 1 *Scoliciosporum* A.Massal. (2)

1.20 Stereocaulaceae Chevall. (19)

- 1 *Stereocaulon* Hoffm. *nom. cons.* (19)

1.21 Umbilicariaceae Chevall. (8)

- 1 *Umbilicaria* Hoffm. (8)

1.22 Usneaceae Eschw. (33)

- 1 *Neuropogon* Nees & Flotow (3)
- 2 *Usnea* Hill ex Brown (30)

2 Families of uncertain affinity close to the Lecanorales

2.1 Acarosporaceae Zahlbr. (21)

- 1 *Acarospora* A.Massal. (12)
- 2 *Biatorella* De Notaris (4)
- 3 *Polysporina* Vezda (1)
- 4 *Sarcogyne* Flotow (3)
- 5 *Sporastatia* A.Massal. (1)

2.2 Agyriaceae Corda (1)

- 1 *Xylographa* (Fries) Fries (1)

2.3 Arctomiaceae Th.Fr. (1)

- 1 *Wawea* Henssen (1)

2.4 Brigantiaeaceae Hafellner & Bellemère (3)

- 1 *Brigantiaea* Trev. St. Léon (3)

2.5 Catillariaceae Hafellner (36)

- 1 *Austrolecia* Hertel (1)
- 2 *Catillaria* A.Massal. (35)

2.6 Catinariaceae Hale ex Hafellner (2)

- 1 *Catinaria* Vain. (2)

2.7 Crocyniaceae M.Choisy ex Hafellner (2)

- 1 *Crocynia* A.Massal. *nom. cons.* (2)

2.8 Ectolechiaceae Zahlbr. (9)

- 1 *Badimia* Vezda (1)
- 2 *Calopadia* Vezda (3)
- 3 *Loflammia* Vezda (1)
- 4 *Sporopodium* Mont. (4)

2.9 Heppiaceae Zahlbr. (1)

- 1 *Heppia* Naeg. in P.Hepp (1)

2.10 Hymeneliaceae Körber (5)

- 1 *Aspicilia* A.Massal. (4)
- 2 *Hymenelia* Krempelh. (1)

2.11 Lecideaceae Chevall. (73)

- 1 *Lecidea* Ach. (73)

2.12 Lithographaceae Poelt (1)

- 1 *Lithographa* Nyl. (1)

2.13 Lopadiaceae Hafellner (7)

- 1 *Lopadium* Körber *nom. cons.* (7)

2.14 Megalosporaceae Vezda ex Hafellner & Bellemère (16)

- 1 *Austroblastenia* Sipman (2)
- 2 *Megaloblastenia* Sipman (1)
- 3 *Megalospora* Meyen in Meyen & Flotow (13)

2.15 Micareaceae Vezda ex Hafellner (12)

- 1 *Micarea* Fries (9)
- 2 *Psilolechia* A.Massal. (3)

2.16 Miltideaceae Hafellener (1)

- 1 *Miltidea* Stirt. (1)

2.17 Mycobilimbiaceae Hafellner (1)

1 *Mycobilimbia* Rehm (1)

2.18 Phlyctidaceae Poelt in Ahmadjian & Hale (1)

1 *Phlyctella* Krempelh. (1)

2.19 Pilocarpaceae Zahlbr. (5)

1 *Byssoloma* Trev.St. Léon (2)

2 *Fellhanera* Vezda (3)

2.20 Porpidiaceae Hertel & Hafellner (17)

1 *Amygdalaria* J.Norman (1)

2 *Immersaria* Rambold & Hertel (1)

3 *Paraporpidia* Rambold & Pietschmann (3)

4 *Poeltiaria* Hertel (3)

5 *Poeltidia* Hertel & Rambold (1)

6 *Porpidia* Körber (7)

7 *Stephanocyclos* Hertel (1)

2.21 Psoraceae Fink (6)

1 *Eremastrella* S.Vogel (1)

2 *Protoblastenia* (Zahlbr.) Steiner (1)

3 *Psora* Hoffm. *nom. cons.* (4)

2.22 Rhizocarpaceae M.Choisy ex Hafellner (11)

1 *Rhizocarpon* Ramond ex DC. in Lam. & DC. (11)

2.23 Rimulariaceae Hafellner (3)

1 *Rimularia* Nyl. (3)

2.24 Roccellinastraceae Hafellner (2)

1 *Roccellinastrum* Darbish. (2)

2.25 Trapeliaceae Hertel *nom. cons.* prop. (15)

(Saccomorphaceae Elenkin)

1 *Placopsis* (Nyl.) Linds. (8)

2 *Placynthiella* Elenkin (2)

3 *Trapelia* M.Choisy (5)

2.26 Squamarinaceae Hafellner (2)

1 *Solenopsora* A.Massal. (2)

2.27 Tremoleciaceae Hafellner (2)

1 *Tremolecia* M.Choisy (2)

2.28 Vezdaeaceae Poelt & Vezda (2)

1 *Vezdaea* Tschermak-Woess & Poelt (2)

2.29 Genus of uncertain affinity in the Lecanorales (1)
  1 *Tapellaria* Müll. Arg. (1)

3 Teloschistales D.Hawksw. & Eriksson

3.1 Fuscideaceae Hafellner (3)
  1 *Fuscidea* V.Wirth & Vezda (2)
  2 *Maronea* A.Massal. (1)

3.2 Letrouitaceae Bellemère & Hafellner (12)
  1 *Letrouitia* Hafellner & Bellemère (12)

3.3 Teloschistaceae Zahlbr. (51)
  1 *Caloplaca* Th.Fr. *nom. cons.* (36)
  2 *Fulgensia* A.Massal. & De Notaris (3)
  3 *Teloschistes* J.Norman (8)
  4 *Xanthoria* (Fries) Th.Fr. *nom. cons.* (4)

4 Gyalectales Henssen ex D.Hawksw. & Eriksson

4.1 Gyalectaceae (A.Massal.) Stizenb. (17)
  1 *Coenogonium* Ehrenb. in Nees (9)
  2 *Dimerella* Trev.St. Léon (7)
  3 *Gyalecta* Ach. (1)

4.2 Thelenellaceae H.Mayrhofer (4)
  1 *Thelenella* Nyl. (4)

5 Pertusariales M.Choisy ex D.Hawksw. & Eriksson

5.1 Coccotremataceae Henssen (2)
  1 *Coccotrema* Müll. Arg. (2)

5.2 Pertusariaceae Körber ex Körber (48)
  1 *Ochrolechia* A.Massal. (9)
  2 *Pertusaria* DC. *nom. cons.* (39)

6 Peltigerales Walter Watson

6.1 Placynthiaceae E.Dahl *nom. cons.* (3)
  (Lecotheciaceae Körber)
  1 *Placynthium* (Ach.) S.F.Gray (2)
  2 *Polychidium* (Ach.) S.F. Gray (1)

6.2 Lobariaceae Chevall. (108)
  1 *Dendriscocaulon* Nyl. (1)
  2 *Lobaria* (Schreber) Hoffm. (19)
  3 *Pseudocyphellaria* Vain. (34)

  - 4 *Sticta* (Schreber) Ach. (54)

6.3 Nephromataceae Wetmore (5)

  - 1 *Nephroma* Ach. (5)

6.4 Peltigeraceae Dumort. (16)

  - 1 *Massalongia* Körber (1)
  - 2 *Peltigera* Willd. *nom. cons.* (15)

7 Ostropales Nannf.

7.1 Odontotremataceae D.Hawksw. & Sherwood (1)

  - 1 *Ramonia* Stizenb. (1)

7.2 Stictidaceae Fries (2)

  - 1 *Absconditella* Vezda (1)
  - 2 *Conotremopsis* Vezda (1)

8 Graphidales E.Bessey

8.1 Asterothyriaceae Walter Watson ex R.Sant. (6)

  - 1 *Gyalidea* Lettau (3)
  - 2 *Gyalideopsis* Vezda (3)

8.2 Graphidaceae Dumort. (102)

  - 1 *Cyclographina* Awasthi (2)
  - 2 *Diplogramma* Müll. Arg. (1)
  - 3 *Glyphis* Ach. (3)
  - 4 *Graphina* Müll. Arg. (19)
  - 5 *Graphinocarpon* Awasthi (1)
  - 6 *Graphis* Adans. (43)
  - 7 *Medusulina* Müll. Arg. (2)
  - 8 *Phaeographina* Müll. Arg. (5)
  - 9 *Phaeographis* Müll. Arg. (18)
  - 10 *Sarcographa* Fée (7)
  - 11 *Sarcographina* Müll. Arg. (1)

8.3 Thelotremataceae (Nyl.) Stizenb. (64) *nom. cons.*

  - 1 *Diploschistes* J.Norman (11)
  - 2 *Myriotrema* Fée (6)
  - 3 *Ocellularia* G.Meyer *nom. cons.* (18)
  - 4 *Thelotrema* Ach. (27)
  - 5 *Tremotylium* Nyl. (2)

9 Gomphillales Hafellner

9.1 Gomphillaceae Walter Watson ex Hafellner (13)
1 *Aulaxina* Fée (3)
2 *Calenia* (Müll. Arg.) em. R.Sant. (3)
3 *Echinoplaca* Fée (3)
4 *Gyalectidium* Müll. Arg. (2)
5 *Tricharia* Fée (2)
10 Caliciales E.Bessey
10.1 Caliciaceae Fée (18)
1 *Calicium* Pers. (15)
2 *Cyphelium* Ach. (3)
10.2 Coniocybaceae Reichb. (12)
1 *Chaenotheca* Th.Fr. (12)
10.3 Microcaliciaceae Tibell (2)
1 *Microcalicium* Vain. (not lichenised) (2)
10.4 Mycocaliciaceae Tibell (16)
1 *Chaenothecopsis* Vain. (not lichenised) (11)
2 *Mycocalicium* Vain. (not lichenised) (5)
10.5 Sclerophoraceae Tibell (1)
1 *Sclerophora* Chevall. (1)
10.6 Sphaerophoraceae Reichb. (12)
1 *Sphaerophorus* Pers. *nom. cons.* (12)
10.7 Sphinctrinaceae M.Choisy (3)
1 *Pyrgidium* Nyl. (not lichenised) (1)
2 *Sphinctrina* Fries (not lichenised) (2)
10.8 genera of uncertain position in the Caliciales (5)
1 *Heterocyphelium* Vain. (1)
2 *Nadvornikia* Tibell (1)
3 *Pyrgillocarpon* Nádv. in Tibell (1)
4 *Pyrgillus* Nyl. (1)
5 *Tylophoron* Nyl. ex Stizenb. (1)
11 Lichinales Henssen ex Eriksson & D.Hawksw.
11.1 Lichinaceae Nyl. (18)
1 *Ephebe* Fries (4)
2 *Lempholemma* Körber (2)
3 *Lichina* Agardh *nom. cons.* (3)

4 *Paulia* Henssen (1)

5 *Peccania* A.Massal. ex Arnold *nom. cons.* (1)

6 *Porocyphus* Körber (1)

7 *Pyrenopsis* Nyl. (3)

8 *Synalissa* Fries (2)

9 *Thyrea* A.Massal. (1)

11.2 Peltulaceae Budel (12)

1 *Peltula* Nyl. (12)

12 Pezizales E.Bessey

12.1 Schaereriaceae M.Choisy ex Hafellner (2)

1 *Schaereria* Th.Fr. *nom. cons.* (2)

13 Helotiales Nannf.

13.1 Baeomycetaceae Dumort. (8)

1 *Baeomyces* Pers. (7)

2 *Knightiella* Müll. Arg. (1)

14 Patellariales D.Hawksw. & Eriksson

14.1 Arthrorhaphidaceae Poelt & Hafellner (1)

1 *Arthroraphis* Th.Fr. (1)

15 Family of uncertain affinity near the Patellariales

15.1 Melaspileaceae Walter Watson (10)

1 *Melaspilea* Nyl. (10)

16 Arthoniales Henssen ex D.Hawksw. & O.Eriksson

16.1 Arthoniaceae Reichb. ex Reichb. (42)

1 *Arthonia* Ach. *nom. cons.* (29)

2 *Arthothelium* A.Massal. (12)

3 *Cryptothecia* Stirt. *nom. cons.* (1)

16.2 Chrysothricaceae Zahlbr. (2)

1 *Byssocaulon* Mont. (1)

2 *Chrysothrix* Mont. *nom. cons.* (1)

17 Opegraphales M.Choisy ex D.Hawksw. & O.Eriksson

17.1 Chiodectonaceae (19)

1 *Chiodecton* Ach. (19)

17.2 Lecanactidaceae Stizenb. (14)

1 *Lecanactis* Eschw. (5)

2 *Melampilidium* Stirt. ex Müll. Arg. (1)

- 3 *Sagenidium* Stirt. (1)
- 4 *Schismatomma* Flotow & Körber ex A.Massal. (7)

17.3 Opegraphaceae Stizenb. (24)

- 1 *Enterodictyon* Müll. Arg. (1)
- 2 *Enterographa* Fée (1)
- 3 *Opegrapha* Ach. *nom. cons.* (22)

17.4 Roccellaceae Chevall. (3)

- 1 *Roccella* DC. (2)
- 2 *Roccellina* Darbish. (1)

17.5 Genus of uncertain affinity within the Opegraphales

- 1 *Sagenidiopsis* R.W.Rogers & Hafellner (1)

18 Verrucariales Mattick ex D.Hawksw. & Eriksson

18.1 Verrucariaceae Eschw. (33)

- 1 *Agonimia* Zahlbr. (1)
- 2 *Catapyrenium* Flotow (3)
- 3 *Dermatocarpon* Eschw. (1)
- 4 *Endocarpon* Hedwig (10)
- 5 *Placidium* A.Massal. (1)
- 6 *Polyblastia* A.Massal. (1)
- 7 *Staurothele* J.Norman *nom. cons.* (1)
- 8 *Thelidium* A.Massal. (2)
- 9 *Verrucaria* Schrader *nom. cons.* (13)

19 Pyrenulales Fink ex D.Hawksw. & Eriksson

19.1 Acrocordiaceae Oksner *ad int.* (2)

- 1 *Acrocordia* A.Massal. (1)
- 2 *Pyrenocollema* Reinke (1)

19.2 Aspidotheliaceae Räsänen *ad int.* (1)

- 1 *Aspidothelium* Vain. (1)

19.3 Monoblastiaceae Walter Watson (2)

- 1 *Ditremis* Clem. (2)

19.4 Pyrenulaceae Rabenh. (83)

- 1 *Anthracothecium* Hampe ex A.Massal. (13)
- 2 *Bottaria* A.Massal. (1)
- 3 *Melanotheca* Fée (6)
- 4 *Parathelium* Nyl. (1)

- 5 *Parmentaria* Fée (14)
- 6 *Pleurotheliopsis* Zahlbr. (1)
- 7 *Pleurotrema* Müll. Arg. (1)
- 8 *Polyblastiopsis* Zahlbr. (8)
- 9 *Pyrenula* Ach. ex Luyken (38)

19.5 Strigulaceae Fries (11)

- 1 *Phylloporis* Clements (1)
- 2 *Raciborskiella* Höhnel (2)
- 3 *Strigula* Fries (8)

19.6 Trichotheliaceae (Müll. Arg.) Bitter & Schill. (58)

- 1 *Clathroporina* Müll. Arg. (9)
- 2 *Porina* Müll. Arg. *nom. cons.* (44)
- 3 *Trichothelium* Müll. Arg. (4)
- 4 *Zamenhofia* Clauzade & C.Roux (1)

19.7 Trypetheliaceae Eschw. (21)

- 1 *Campylothelium* Müll. Arg. (2)
- 2 *Cryptothelium* A.Massal. (1)
- 3 *Laurera* Reichb. (4)
- 4 *Polymeridium* (Müll. Arg.) R.C.Harris (1)
- 5 *Pseudopyrenula* Müll. Arg. (2)
- 6 *Trypethelium* Sprengel *nom. cons.* (11)

19.8 Genus of uncertain position in the Pyrenulales

- 1 *Asteroporum* Müll. Arg. (2)

20 Dothideales Lindau

20.1 Arthopyreniaceae Walter Watson (24)

- 1 *Arthopyrenia* A.Massal. (17)
- 2 *Mycomicrothelia* Keissler (not lichenised) (3)
- 3 *Tomasellia* A.Massal. (not lichenised) (4)

20.2 Lichenotheliaceae Henssen (7)

- 1 *Lichenothelia* D.Hawksw. (not lichenised) (7)

20.3 Mycoporaceae Zahlbr. (1)

- 1 *Mycoporum* G.Meyer (1)

20.4 Phragmopelthecaceae X.Filho (3)

- 1 *Mazosia* A.Massal. (3)

20.5 genera of uncertain position in the Dothidales (4)

1 *Mycoporellum* Müll. Arg. (3)
2 *Mycoporopsis* Müll. Arg. (1)

Deuteromycotina

21 Imperfect lichens

1 *Cystocoleus* Thwaites (1)
2 *Lepraria* Ach. *nom. cons.* (3)
3 *Leprocaulon* Nyl. (3)
4 *Leproloma* Nyl. ex Crombie (2)
5 *Lichenothrix* Henssen (1)
6 *Normandina* Nyl. (1)
7 *Siphula* Fries (6)
8 *Thamnolia* Ach. ex Schaerer *nom. cons.* (1)

Basidiomycotina

22 Basidiomycete lichens

22.1 Clavulariaceae (4)
  1 *Clavulinopsis* Overeem (1)
  2 *Multiclavula* R.Petersen (3)
22.2 Dictyonemataceae (2)
  1 *Dictyonema* Agardh (2)
22.3 Tricholomataceae (1)
  1 *Phytoconis* Bory (1)

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Chiodecton	17.1
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Cladia	1.5
Cladina	1.6
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Clavulinopsis	22.1
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Coccocarpia	1.7
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Coccotrema	5.1
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Coelocaulon	1.15
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Dirinaria	1.17
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Dothideales	20
Echinoplaca	9.1
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Enterodictyon	17.3
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Erioderma	1.14
Fellhanera	2.19
Flavoparmelia	1.15
Fulgensia	3.3
Fuscidea	3.1
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Glyphis	8.2
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A SYSTEMATIC ARRANGEMENT OF THE AUSTRALIAN LICHENS

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Graphis	8.2
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Imshaugia	1.15
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Knightiella	13.1
Laurera	19.7
Lecanactidaceae	17.2
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Lecania	1.2
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Lecanoraceae	1.12
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Megalosporaceae	2.14
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KEYS TO AUSTRALIAN LICHEN GENERA

R.W.Rogers

These keys to genera of Australian lichens have been prepared to aid identification. They are structured only to facilitate identification, and do not reflect the taxonomic system applied in this Flora. This means that they are 'artificial' keys in contrast to 'natural' keys which are intended to reflect classification.

The keys have been written to facilitate identification by those with little specialised knowledge of lichens (but who are prepared to learn the necessary language), and contain some redundancy. This allows the user to make some common errors and still arrive at the correct determination. They should not, therefore, be used to define the characteristics of a genus.

Foliose and fruticose genera can usually be identified from sterile material: species of other growth forms usually cannot. While the need for fertile material may cause some difficulty, it must be remembered that few keys to the genera of flowering plants allow identification of sterile material. The keys to genera of crustose lichens use spore septation as a first character, a very artificial attribute which was chosen for this role because it is clear cut. A consequence of the use of such artificial characters is that genera may appear in several sections of the key. In general, easily applied characters are used early in keys and more difficult ones later.

The lichen flora of Australia is still incompletely known, especially crustose genera from tropical regions, and it will be many years before the entire lichen flora is published. Characters used in the key to identify crustose genera have usually been chosen to allow identification of any species that fits within the generally accepted limits of a genus, not just those species known to occur in Australia.

Comments on the use of the key would be welcomed by the Executive Editor, Flora of Australia.

Key to artificial groups of lichens

1 Thallus shrub-like, ascending or pendulous, usually not flattened against the substratum, ; lobes or branches radially symmetrical or, if flattened, then similar on both surfaces

  2 Thallus shrubby with fungal and algal layers — **Group 1. FRUTICOSE LICHENS**

  2: Thallus of fungal hyphae ramifying in the gelatinous sheath of an algal filament — **Group 5: FILAMENTOUS LICHENS**

1: Thallus lobes and branches either dorsiventrally differentiated, usually strongly flattened on substratum, not ascending except at lobe tips or in secondary branches at centre of thallus, or crust-like with lower surface entirely adnate to substratum	
3 Thallus of well-defined, elongated lobes, adhering to substratum by specialised organs or only in restricted areas, usually with a well-developed lower cortex, although lower cortex sometimes missing or clothed in an indumentum	
4 Lower surface with well-developed rhizines; without distinct vein-like markings from which rhizines arise	**Group 2: FOLIOSE LICHENS I**
4: Lower surface apparently devoid of rhizines, or sparsely rhizinate at margins only, or tomentose, or on a spongy indumentum or prothallus, sometimes cyphellate, pseudocyphellate or with cyphellum-like pits or with distinct vein-like markings from which rhizines arise	**Group 3: FOLIOSE LICHENS II**
3: Thallus without well-defined lobes, usually without a lower cortex and mostly adhering to substratum over entire lower surface, although some small peltate scale-like thalli may have a lower cortex	
5 Thallus a mass of loosely tangled, cobwebby hyphae	**Group 6: BYSSOID LICHENS**
5: Thallus not a mass of loosely tangled hyphae	
6 Thallus of scale-like units which may or may not be corticate on both surfaces, not attached to substratum directly over entire surface but may be umbilicate or attached by rhizines or rhizoids	**Group 4: SQUAMULOSE LICHENS**
6: Thallus diffuse or continuous or areolate, sometimes with marginal lobes inseparable from substratum	
7 Ascospores simple	**Group 7: SIMPLE-SPORED CRUSTOSE LICHENS**
7: Ascospores septate or polarilocular	
8 Ascospores 1-septate or polarilocular	**Group 8: 1-SEPTATE SPORED CRUSTOSE LICHENS**
8: Ascospores with two or more transverse septa	
9 Ascospores transversely septate only	**Group 9: TRANSEPTATE SPORED CRUSTOSE LICHENS**
9: Ascospores with transverse and longitudinal septa	**Group 10: MURIFORM SPORED CRUSTOSE LICHENS**

Group 1: fruticose lichens
(and crustose lichens with fruiting bodies which may appear fruticose)

1 Thallus less than 1 cm tall when mature (including crusts bearing ascomata borne on a very thin stalk, and gelatinous species)	
2 Ascomata on ends of very thin black stalks arising from a crustose thallus; stalks less than 3 mm long	
3 Ascospores globose	CHAENOTHECA
3: Ascospores ellipsoidal	

4 Ascospores maturing in ascus

5 Apex of ascus uniformly thickened **MYCOCALICIUM**

5: Apex of ascus penetrated by a narrow canal visible in semi-mature asci **CHAENOTHECOPSIS**

4: Ascospores maturing in a mazaedium

6 Mazaedium pale green **MICROCALICIUM**

6: Mazaedium brown or black

7 Mazaedium pale brown **CHAENOTHECA**

7: Mazaedium black **CALICIUM**

2: Ascomata on more robust structures, for example truly fruticose thalli, podetia or pseudopodetia

8 Thallus yellow or orange, K+ purple (parietin)

9 Apothecia eciliate, terminal on short lobes **CALOPLACA**

9: Apothecia often ciliate, lateral on lobes **TELOSCHISTES**

8: Thallus grey, green, olive, or black, if K+ then not purple

10 Photobiont a cyanobacterium

11 Photobiont *Nostoc*

12 Photobiont confined to distinct zones in thallus

13 Thallus stalked, erect, coralloid at tips **DENDRISCOCAULON**

13: Thallus recumbent, dichotomously branched **POLYCHIDIUM**

12: Photobiont not confined to distinct zones in thallus

14 Ascospores simple **RAMALODIUM**

14: Ascospores septate

15 Thallus of tapering dichotomous lobes; found in Tas. rainforest **WAWEA**

15: Thallus of discrete, irregular lobes; widespread **COLLEMA**

11: Photobiont another cyanobacterium (not *Nostoc*)

16 Photobiont coccoid **SYNALISSA**

16: Photobiont filamentous

17 Photobiont *Calothrix*

18 Thallus cylindrical; sometimes marine **LICHINA**

18: Thallus flattened or irregular; never marine **POROCYPHUS**

17: Photobiont *Stigonema*, *Hyphomorpha* or *Scytonema*

19 Spores simple **SIPHULASTRUM**

19: Spores septate

20 Apothecial disc concave, immersed in tips of lobes **EPHEBE**

20: Apothecial disc convex, lateral or terminal

21 Ascoma terminal, with exciple **SPILONEMA**

21: Ascoma lateral, without exciple **POLYCHIDIUM**

10: Photobiont a chlorophyte (green alga)

22 Thallus entirely ecorticate, of fragile soredium-like particles over cartilage-like fibres, or thallus woolly and of loosely woven hyphae

23 Thallus woolly, of loosely woven hyphae **ROCCELLINASTRUM**

23: Thallus of soredium-like particles over cartilage-like fibres **LEPROCAULON**

22: Thallus robust, commonly at least partly corticate, not of loosely entangled hyphae

24 Thallus of decumbent anastomosing strands on arid, calcareous soils **ASPICILIA**

24: Thallus more or less erect, not of anastomosing strands; on diverse substrata

25 Thallus solid

26 Apothecia on expanded face of erect flattened podetia **THYSANOTHECIUM**

26: Apothecia not on expanded face of erect flattened podetia

27 Apothecia pink to pale brown, borne on ends of erect podetia arising from a basal crustose thallus **BAEOMYCES**

27: Apothecia black to brown, if on podetia then not arising from a basal crust; or thallus fruticose but sterile

28 Thallus yellow-green (usnic acid); apothecia clustered **RAMALEA**

28: Thallus white to grey, red-brown or black; apothecia not clustered

29 Thallus white or pale grey to grey-brown; sterile **SIPHULA**

29: Thallus dark brown; apothecia black **TONINIA**

25: Thallus hollow

30 Apothecia black

31 Apothecia in crowded, blackberry-like clusters 1–2 mm long; thallus growing on wood or bark **CLADIA**

31: Apothecia simple or distorted, but not crowded into clusters; thallus growing on soil, wood, or bark

32 Thallus growing on wood or bark **METUS**

32: Thallus growing on soil

33 Primary thallus inflated, without podetia; ascospores 7-septate **TONINIA**

33: Primary thallus crustose, bearing erect podetia; ascospores simple **PYCNOTHELIA**

30: Apothecia pale to dark brown or red

34 Primary thallus squamulose, bearing small, inflated, eperforate podetia **PYCNOTHELIA**

34: Primary thallus squamulose with perforate or eperforate podetia which are not inflated, or thallus truly fruticose

35 Thallus straw yellow to green, sometimes lacerate or perforate, without basal squamules; apothecia with exciple; disc buff to pale yellow-green **RAMALINA**

35: Thallus grey or straw yellow; axils perforate; basal squamules usually present; apothecia without exciple; disc brown or red **CLADONIA**

1: Thallus larger, the lobes more than 1 cm long when mature (including crusts and squamules which give rise to erect or procumbent podetia)

36 Thallus hollow

37 Thallus white, vermiform, without squamules **THAMNOLIA**

37: Thallus grey, straw yellow, green, brown, or black, not vermiform, with or without squamules

38 Thallus regularly perforate to central cavity, sometimes becoming lattice-like **CLADIA**

38: Thallus not perforate but sometimes irregularly fissured, or only the axils perforate

39 Thallus ecorticate, with a fine cobwebby surface when viewed with a hand lens **CLADINA**

39: Thallus at least partly corticate

40 Thallus inflated; apothecia buff, with a developed exciple **RAMALINA**

40: Thallus elongate; apothecia red, brown or black, without an exciple

41 Primary thallus crustose, persisting **METUS**

41: Primary thallus squamulose, sometimes not persisting **CLADONIA**

36: Thallus solid

42 Thallus cylindrical

43 Thallus with a central chondroid axis

44 Thallus yellow-green to green or red; apothecial disc buff to yellow-green **USNEA**

44: Thallus yellow with black annuli and black tips; apothecial disc black **NEUROPOGON**

43: Thallus without a central chondroid axis

45 Thallus with well-developed, though often sparse, pseudocyphellae **ALECTORIA**

45: Thallus without pseudocyphellae

46 Primary crustose thallus persistent; apothecia pink **BAEOMYCES**

46: Primary crustose thallus either never formed or not persisting; apothecia not pink

47 Thallus white or pale grey

48 Thallus with numerous phyllidia; cephalodia present; ascoma disc pale brown, pedicellate **STEREOCAULON**

48: Thallus without phyllidia or cephalodia; ascoma black, immersed **SPHAEROPHORUS**

47: Thallus brown, black, orange or straw yellow to green

49 Thallus red-brown to black

50 Branches thorny, 1–2 mm wide, loosely attached to substratum **COELOCAULON**

50: Branches smooth, less than 1 mm wide, closely attached to substratum **PSEUDEPHEBE**

49: Thallus straw yellow to green or orange

51 Apothecial disc black; on acid soils **RAMALEA**

51: Apothecial disc fawn or orange; on rocks, bark and wood

52 Apothecial disc orange; thallus K+ purple (parietin) **TELOSCHISTES**

52: Apothecial disc fawn; thallus K-, or K+ yellow or red **RAMALINA**

42: Thallus markedly flattened or irregular

53 Thallus of fragile soredium-like particles aggregated on cartilage-like strands **LEPROCAULON**

53: Thallus robust, not of soredium-like particles

54 Thallus white or pale grey to pink

55 Thallus with root-like rhizines immersed in soil, peat or moss **SIPHULA**

55: Thallus without root-like rhizines

56 Thallus strap-like, pendent; ascomata lateral on lobes; tropical maritime regions, especially on mangroves **ROCCELLA**

56: Thallus cylindrical to flattened, often coralloid branched; ascomata immersed in lobe tips; cool temperate forests **SPHAEROPHORUS**

54: Thallus straw yellow to green, orange or brown

57 Thallus yellow to orange, K+ purple (parietin) **TELOSCHISTES**

57: Thallus straw yellow to green or brown, not K+ purple

58 Thallus on rocks, bark or wood **RAMALINA**

58: Thallus on soil

59 Thallus of irregular, straw yellow to green podetia; medulla yellow **RAMALEA**

59: Thallus of flattened brown lobes; medulla white **CETRARIA**

Group 2: foliose lichens I

1 Margin of thallus ciliate

2 Cilia bulbate at base

3 Thallus grey, K+ yellow (atranorin) **BULBOTHRIX**

3: Thallus straw yellow to yellow-green, K- (usnic acid) **RELICINA**

2: Cilia not bulbate at base

4 Upper cortex brown **PHAEOPHYSCIA**

4: Upper cortex white, grey or straw yellow to green

5 Cilia sharply tapering at base, often forked **CANOMACULINA**

5: Cilia not markedly tapering at base; rarely forked

6 Rhizines dichotomously branched

7 Cortex K- **HETERODEA**

7: Cortex K+ yellow (atranorin)

8 Upper cortex of longitudinal hyphae; ascospores brown, 2-celled **HETERODERMIA**

8: Upper cortex plectenchymatous; ascospores hyaline, simple **HYPOTRACHYNA**

6: Rhizines simple or squarrose

9 Ascospores 2-celled; thallus with lobes 0.2–1.5 mm wide

10 Thallus K+ yellow (atranorin) **PHYSCIA**

10: Thallus K- (without atranorin) **PHAEOPHYSCIA**

9: Ascospores simple; thallus with lobes usually more than 2 mm wide

11 Lower surface covered by an indumentum; rhizines mostly on margins; apothecia marginal **HETERODEA**

11: Lower surface corticate; rhizines spread over lower surface; apothecia laminal

12 Lobe tips broadly rotund, with a broad naked zone below or with reticulately cracked young lobes

13 Upper cortex of young lobes reticulately cracked **RIMELIA**

13: Upper cortex continuous on young lobes **PARMOTREMA**

12: Lobe tips narrow, truncate to subrotund, with rhizines to tips; young lobes not reticulately cracked

14 Cilia evenly spread on lobe margins; lobes with truncate apices; rhizines furcate to weakly dichotomous **PARMELINOPSIS**

14: Cilia mainly in lobe axils; lobes with subrotund apices; rhizines simple

15 Lobes broad (5–10 mm); medulla K+ yellow turning red (salazinic acid) **PARMELINELLA**

15: Lobes narrow (1–6 mm); medulla K- **PARMELINA**

1: Margin of thallus eciliate

16 Upper surface of thallus bright yellow or yellow-orange

17 Thallus K+ purple (parietin); lobes more than 2 mm wide **XANTHORIA**

17: Thallus K-; lobes less than 1 mm wide **CANDELARIA**

16: Upper surface of thallus white, grey, brown or straw yellow to yellow-green

18 Apothecia on lower surface of lobe apices **NEPHROMA**

18: Apothecia on upper surface of lobes

19 Thallus brown or olive

20 Photobiont a cyanobacterium

21 Upper cortex tomentose **ERIODERMA**

21: Upper cortex smooth, wrinkled or roughened

22 Thallus heteromerous **PANNARIA**

22: Thallus homoiomerous **PHYSMA**

20: Photobiont a chlorophyte

23 Thallus blue with HNO_3, with neither pseudocyphellae nor soredia **NEOFUSCELIA**

23: Thallus either HNO_3- or red with HNO_3, with or without pseudocyphellae and soredia

24 Upper cortex pseudocyphellate **MELANELIA**

24: Upper cortex without pseudocyphellae

25 Ascospores simple, hyaline

26 Thallus grey-brown; cephalodia on upper or lower surface **PSOROMA**

26: Thallus tan to dark brown; cephalodia absent **MELANELIA**

25: Ascospores septate, brown

27 Lower cortex of interwoven hyphae; lobes 2–3 mm wide **PHYSCONIA**

27: Lower cortex paraplectenchymatous; lobes to 2 mm wide

28 Lobes usually 1–2 mm wide; conidia globose **PHAEOPHYSCIA**

28: Lobes often less than 0.5 mm wide; conidia acicular **HYPERPHYSCIA**

19: Thallus white, grey or straw yellow to yellow-green

29 Thallus straw yellow to yellow-green, on rocks or soil

30 Lobes narrow truncate **XANTHOPARMELIA**

30: Lobes subrotund **FLAVOPARMELIA**

29: Thallus white or grey, or if straw yellow to yellow-green then not on rocks or soil

31 Photobiont a cyanobacterium

32 Photobiont *Scytonema*

33 Apothecia without an exciple **COCCOCARPIA**

33: Apothecia with a well-developed exciple

34 Upper surface of thallus roughened, with or without isidia, without soredia **LEIODERMA**

34: Upper surface of thallus smooth, without isidia, with or without soredia **DEGELIA**

32: Photobiont *Nostoc*

35 Ascospores simple; apothecium with photobiont in exciple; rhizines white to blue-black; prothallus present **PANNARIA**

35: Ascospores septate; apothecium without photobiont in exciple; rhizines brown to black; prothallus absent **FUSCODERMA**

31: Photobiont a chlorophyte

36 Lower surface of thallus densely tomentose **PANNOPARMELIA**

36: Lower surface of thallus rhizinate only, not tomentose

37 Upper cortex pseudocyphellate

38 Ascospores septate; thallus lobes usually less than 2 mm wide **PYXINE**

38: Ascospores simple; thallus lobes usually more than 2 mm wide

39 Lower surface black; upper surface with linear or reticulate pseudocyphellae; some rhizines squarrose **PARMELIA**

39: Lower surface black to pale tan; upper surface with orbicular pseudocyphellae; all rhizines simple

40 Upper surface brown; rhizines sparse **CETRELIA**

40: Upper surface grey; rhizines common **PUNCTELIA**

37: Upper cortex without pseudocyphellae

41 Thallus umbilicate	**UMBILICARIA**
41: Thallus not umbilicate	
42 Rhizines dichotomously branched and prominent, usually protruding beyond lobe margin	
43 Spores simple	**HYPOTRACHYNA**
43: Spores septate	**HETERODERMIA**
42: Rhizines simple, squarrose or coralloid, usually not protruding beyond lobe margin	
44 Thallus lobes usually more than 5 mm wide, broadly rotund at tips; rhizines sparse or absent in a broad naked zone near lobe tips	
45 Rhizines dense near centre of thallus, absent from a broad marginal zone; pycnidia laminal	**PARMOTREMA**
45: Rhizines very sparse; pycnidia marginal	**PLATISMATIA**
44: Thallus lobes usually less than 3 mm wide, truncate or linear; rhizines extending to lobe tips	
46 Thallus UV+ gold (lichexanthone present)	**PYXINE**
46: Thallus UV- (lichexanthone absent)	
47 Lobes coalescing laterally	**DIRINARIA**
47: Lobes discrete	
48 Apothecia with a proper exciple only	
49 Thallus minutely laciniate; ascospores simple, hyaline	**MYELORRHIZA**
49: Thallus with linear lobes; ascospores septate, brown	**PYXINE**
48: Apothecia with a thalline exciple	
50 Ascospores septate	
51 Hypothecium dark; lower cortex which careful examination shows has no rhizines	**DIRINARIA**
51: Hypothecium pale; lower cortex which careful examination shows has at least sparse rhizines	**PHYSCIA**
50: Ascospores simple	
52 Thallus with cephalodia on upper or lower surface	**PSOROMA**
52: Thallus without cephalodia	
53 Upper cortex grey	
54 Margins ciliate	**CANOMACULINA**
54: Margins eciliate	**PARAPARMELIA**
55 Lower surface dark brown to black	
56 Lobes subrotund, black below	**CANOPARMELIA**
56: Lobes truncate, brown to black below	**PARAPARMELIA**
55: Lower surface white to pale brown	
57 Ascospores reniform; thallus without soralia	**PARMELIOPSIS**

57: Ascospores ellipsoidal; thallus sorediate **IMSHAUGIA**

53: Upper cortex straw yellow to green

58 Lower surface black **FLAVOPARMELIA**

58: Lower surface white or brown

59 Upper cortex pseudocyphellate **RELICINOPSIS**

59: Upper cortex without pseudocyphellae **PARMELIOPSIS**

Group 3: foliose lichens II

1 Lower surface of thallus with cyphellae or pseudocyphellae or cyphellum-like pits in an indumentum, or else with vein-like markings which bear rhizines

2 Lower surface of thallus with cyphellae or pseudocyphellae or cyphella-like pits on lower surface

3 Cyphella-like pits present as indentations in indumentum covering lower surface **HETERODEA**

3: Cyphellae or pseudocyphellae present as pores through lower cortex

4 Cyphellae present in lower cortex **STICTA**

4: Pseudocyphellae present in lower cortex **PSEUDOCYPHELLARIA**

2: Lower surface of thallus with vein-like markings

5 Apothecia terminal on digitate lobes **PELTIGERA**

5: Apothecia marginal, not on digitate lobes **ERIODERMA**

1: Thallus without cyphellae, pseudocyphellae, cyphellum-like pits in indumentum or vein-like markings

6 Rhizines sparse, restricted to margins or constrictions in thallus

7 Upper cortex grey, K+ (atranorin) **HETERODERMIA**

7: Upper cortex straw yellow to brown, K-

8 Lower surface with distinct bead-like patches of black indumentum **PANNOPARMELIA**

8: Lower surface glabrous or with continuous brown indumentum

9 Thallus isidiate, on rocks **ANZIA**

9: Thallus without isidia, on ground **HETERODEA**

6: Rhizines absent

10 Thallus umbilicate or attached by a holdfast

11 Thallus not gelatinous when wet, often large (1–10 cm wide)

12 Upper cortex tomentose **ERIODERMA**

12: Upper cortex glabrous

13 Ascoma an apothecium **UMBILICARIA**

13: Ascoma a perithecium **DERMATOCARPON**

11: Thallus gelatinous when wet, small (to 1 cm wide)

14 Photobiont *Nostoc*; ascospores septate **COLLEMA**

14: Photobiont *Calothrix* or else coccoid; ascospores simple

15 Photobiont *Calothrix* **POROCYPHUS**

15: Photobiont coccoid **THYREA**

10: Thallus neither umbilicate nor attached by a holdfast

16 Thallus with cephalodia on upper or lower surface

17 Thallus entirely of lobes **PSOROMA**

17: Thallus crustose in centre, the margins placodioid **PLACOPSIS**

16: Thallus without cephalodia

18 Thallus with an indumentum

19 Upper surface of thallus scrobiculate **LOBARIA**

19: Upper surface smooth or slightly irregular

20 Photobiont a chlorophyte **HETERODEA**

20: Photobiont a cyanobacterium

21 Photobiont *Scytonema* **ERIODERMA**

21: Photobiont *Nostoc*

22 Upper cortex one cell thick; indumentum on lower surface not protruding beyond margin of lobes; thallus gelatinous when wet **LEPTOGIUM**

22: Upper cortex several cells thick; indumentum on lower surface often protruding beyond margin of lobes; thallus not gelatinous when wet

23 Ascospores thin-walled; thallus not swelling greatly when wet **PANNARIA**

23: Ascospores thick-walled; thallus swelling greatly when wetted **PHYSMA**

18: Thallus glabrous below

24 Thallus yellow-gold, K+ purple (parietin) **TELOSCHISTES**

24: Thallus grey to brown, yellow-brown, straw yellow, yellow-green, green, olive, black, if K+ then not purple

25 Photobiont a chlorophyte

26 Thallus inflated and hollow, or medulla more than twice as thick as upper cortex and often loose and cobweb-like

27 Upper cortex pierced by holes to centre of thallus **MENEGAZZIA**

27: Upper cortex not pierced by holes

28 Thallus brown to green above, isidiate **MENEGAZZIA**

28: Thallus grey above, isidia absent **HYPOGYMNIA**

26: Thallus not inflated, solid; medulla less than twice as thick as upper cortex

29 Thallus free or loosely attached to soil

30 Thallus with cyphella-like pores on lower surface; apothecia marginal **HETERODEA**

30: Thallus without cyphella-like pores on lower surface; apothecia laminal

31 Thallus rolling into a ball when dry **CHONDROPSIS**

31: Thallus often markedly distorted, but not rolling into a ball when dry **XANTHOPARMELIA**

29: Thallus adnate on rock, wood or bark

32 Upper cortex densely tomentose **ERIODERMA**

32: Upper cortex glabrous

33 Thallus ascending from substratum

34 Lower surface yellow-brown or brown **CETRARIA**

34: Lower surface black

35 Thallus sorediate; soralia marginal on thallus; soredia powdery **CETRELIA**

35: Thallus usually not sorediate, but if sorediate then soralia laminal and soredia granular **PLATISMATIA**

33: Thallus adnate to substratum

36 Thallus olive or brown, always K- **HYPERPHYSCIA**

36: Thallus grey, yellow-green or straw yellow, or, if brown then K+ gold

37 Thallus yellow-green or straw yellow **XANTHOPARMELIA**

37: Thallus grey or brown

38 Lower surface naked; lobes usually coalescing laterally **DIRINARIA**

38: Lower surface sparsely rhizinate at margins; lobes remaining discrete

39 Thallus UV+ gold (lichexanthone) **PYXINE**

39: Thallus UV-

40 Apothecia with a proper exciple only **PYXINE**

40: Apothecia with a thalline exciple **PARAPARMELIA**

25: Photobiont a cyanobacterium

41 Upper surface of thallus with a long indumentum **DICTYONEMA**

41: Upper surface of thallus smooth or rugulose but not hairy

42 Thallus homoiomerous, gelatinous when wet

43 Ascospores with a thick wall and a gelatinous episporium **PHYSMA**

43: Ascospores thin-walled, without a gelatinous episporium

44 Thallus without a true cortex, instead with discrete swollen end-cells present at least in patches **COLLEMA**

44: Cortex of closely packed angular cells **LEPTOGIUM**

42: Thallus heteromerous, not gelatinous when wet

45 Apothecia with photobiont in exciple **PANNARIA**

45: Apothecia without photobiont in exciple

46 Upper surface of thallus minutely roughened **LEIODERMA**

46: Upper surface of thallus smooth **PARMELIELLA**

Group 4: squamulose lichens

1	Thallus dimorphic; ascomata terminal or lateral on podetia	
2	Podetia hollow	**CLADONIA**
2:	Podetia solid	
3	Podetia 1–2 mm; squamules lacerate	**NEOPHYLLIS**
3:	Podetia longer; squamules granular to bullate	
4	Apothecia pale brown to dark brown, on surface of flattened podetia	**THYSANOTHECIUM**
4:	Apothecia black, terminal on warty podetia	**RAMALEA**
1:	Thallus monomorphic; ascomata immersed in, or sessile on, squamules	
5	Primary photobiont a cyanobacterium	
6	Thallus heteromerous	
7	Apothecia immersed in thallus	
8	Asci 8-spored	**HEPPIA**
8:	Asci containing 16 or more spores	**PELTULA**
7:	Apothecia sessile	
9	Apothecium with photobiont in exciple	**PANNARIA**
9:	Apothecium without photobiont in exciple	
10	Ascospores simple	
11	Ascoma terminal; photobiont *Scytonema*	**SIPHULASTRUM**
11:	Ascomata laminal; photobiont *Nostoc*	**PARMELIELLA**
10:	Ascospores septate	
12	Ascoma pale	**MASSALONGIA**
12:	Ascoma black	**PLACYNTHIUM**
6:	Thallus homoiomerous	
13	Brown particles deposited in algal sheath	**PAULIA**
13:	Particles not deposited in algal sheath	
14	Gelatin surrounding photobiont red; thallus not umbilicate	**PYRENOPSIS**
14:	Gelatin surrounding photobiont hyaline; thallus umbilicate	**THYREA**
5:	Primary photobiont a chlorophyte, but *Nostoc* may occur in cephalodia	
15	Thallus of scattered, shell-like grey or greenish squamules, often with a roughened or sorediate margin	
16	Thallus C-	**NORMANDINA**
16:	Thallus C+ red (lecanoric acid)	**HYPOCENOMYCE**
15:	Thallus not of scattered shell-like squamules; colour various; sorediate margins rare	
17	Thallus attached by well-developed rhizines	
18	Thallus grey or white, sterile	**SIPHULA**
18:	Thallus brown to grey, with perithecia	**ENDOCARPON**
17:	Thallus variously attached but never by well-developed rhizines	

19 Ascoma a perithecium

20 Ascospores muriform

21 Photobiont present in hymenium **ENDOCARPON**

21: Photobiont absent from hymenium **AGONIMIA**

20: Ascospores simple

22 Thallus of loosely woven hyphae within a marine macroalgal thallus **TURGIDOSCULUM**

22: Thallus strongly paraplectenchymatous, not symbiotic with marine macroalgae **CATAPYRENIUM**

19: Ascoma an apothecium

23 Ascospores polarilocular or septate

24 Ascospores polarilocular **CALOPLACA**

24: Ascospores septate

25 Apothecium pink **KNIGHTIELLA**

25: Apothecium red-brown to black

26 Apothecia with photobiont in exciple **SOLENOPSORA**

26: Apothecia without photobiont in exciple

27 Thallus with fragile, overlapping, laciniate squamules **PHYSCIDIA**

27: Thallus of robust to bullate, entire squamules **TONINIA**

23: Ascospores simple

28 Cephalodia present on upper or lower surface

29 Apothecia with photobiont in exciple **PSOROMIDIUM**

29: Apothecia without photobiont in exciple **PSOROMA**

28: Cephalodia absent

30 Ascus with more than 32 spores

31 Thallus on rock or soil; apothecium immersed **ACAROSPORA**

31: Thallus on wood or bark; apothecium sessile **CANDELARIA**

30: Ascus 8-spored

32 Thallus K+ purple (parietin) **FULGENSIA**

32: Thallus if K+ then not purple

33 Thallus bright yellow or gold **CANDELARIA**

33: Thallus white to brown or pink

34 Apothecia on pedicel 1–4 mm long

35 Thallus with well-developed rhizines or a rhizinal mat **MYELORRHIZA**

35: Thallus without well-developed rhizines or a rhizinal mat **NEOPHYLLIS**

34: Apothecia sessile or immersed

36 Paraphyses reticulately branched **TRAPELIA**

36: Paraphyses simple

37 Thallus of overlapping scales or dissected lobules

38 Exciple of disc cobwebby; hypothallus clearly visible **PHYLLOPSORA**
38: Exciple of disc not cobwebby; hypothallus not visible **HYPOCENOMYCE**
37: Thallus of simple, more or less ovate scales
39 Upper cortex of closely packed pyramidal structures **EREMASTRELLA**
39: Upper cortex smooth or reticulately cracked **PSORA**

Group 5: filamentous lichens

1 Photobiont a chlorophyte
2 Thallus black **CYSTOCOLEUS**
2: Thallus white to green **COENOGONIUM**
1: Photobiont a cyanobacterium
3 Photobiont *Scytonema* **LICHENOTHRIX**
3: Photobiont *Stigonema* or *Hyphomorpha*
4 Apothecia emergent **SPILONEMA**
4: Apothecia deeply immersed **EPHEBE**

Group 6: byssoid lichens

1 Fruiting body a compound perithecium-like structures immersed in a stroma **CHIODECTON**
1: Fruiting body a simple globose or open apothecium, not aggregated in a stroma
2 Apothecia open, hymenium bright yellow or orange **COENOGONIUM**
2: Apothecia globose, hymenium white to black
3 Ascospores simple **ROCCELLINASTRUM**
3: Ascospores septate
4 Ascospores 1-septate **CROCYNIA**
4: Ascospores 3- or more septate
5 Ascospores 3-septate **SAGENIDIOPSIS**
5: Ascospores 5- or more septate
6 Ascospores 5- to 7-septate **SAGENIDIUM**
6: Ascospores 20- to 100-septate **CONOTREMOPSIS**

Group 7: crustose lichens with simple spores

1 Ascospores 16 or more per ascus
2 Photobiont a cyanobacterium

3 Hymenium containing photobiont cells **GONOHYMENIA**
3: Hymenium without photobiont cells **PYRENOPSIS**
2: Photobiont a chlorophyte
4 Thallus bright yellow
5 Apothecium sessile, not immersed **CANDELARIELLA**
5: Apothecium immersed **ACAROSPORA**
4: Thallus not bright yellow
6 Ascoma a perithecium **TRIMMATOTHELE**
6: Ascoma an apothecium
7 Apothecium sessile; exciple containing photobiont
8 Ascus with a distinct I+ external cap, but without a central axial body **MARONEA**
8: Ascus without an external I+ cap, but with a broad central axial body **MARONINA**
7: Apothecium immersed, or if sessile, then exciple not containing photobiont
9 Disc strongly gyrose, warty or grooved **POLYSPORINA**
9: Disc not gyrose, warty or grooved
10 Thallus endolithic; ecorticate **SARCOGYNE**
10: Thallus not endolithic; corticate
11 Apothecia immersed **ACAROSPORA**
11: Apothecia sessile, not immersed
12 Apothecium with pale exciple **BIATORELLA**
12: Apothecium with black exciple **SPORASTATIA**
1: Ascospores 1–8 per ascus
13 Photobiont a cyanobacterium
14 Photobiont *Nostoc*
15 Ascoma disc poriform or deeply immersed **LEMPHOLEMMA**
15: Ascoma disc not poriform, flat to convex **RAMALODIUM**
14: Photobiont *Calothrix* or coccoid
16 Photobiont filamentous (*Calothrix*) **POROCYPHUS**
16: Photobiont coccoid
17 Gelatin surrounding photobiont red **SYNALISSA**
17: Gelatin surrounding photobiont not red **PECCANIA**
13: Photobiont a chlorophyte
18 Ascoma a perithecium or similar closed structure
19 Spores more than 30 μm long; ascoma an immersed apothecium
20 Cephalodia not present **PERTUSARIA**
20: Cephalodia present **COCCOTREMA**
19: Paraphyses absent or gelatinising **VERRUCARIA**

18: Ascoma an apothecium or similar open structure

21 Ascospores brown at maturity

22 Thallus well-developed, corticate; photobiont present

23 Ascospores with an equatorial thickening, mid- to dark brown **ORPHNIOSPORA**

23: Ascospores with walls of uniform thickness, pale brown **FUSCIDEA**

22: Thallus ecorticate, commonly devoid of photobiont

24 Ascospores ellipsoidal **CHAENOTHECOPSIS**

24: Ascospores globose **CHAENOTHECA**

21: Ascospores hyaline at maturity

25 Cephalodia present on thallus

26 Thallus with marginal lobes **PLACOPSIS**

26: Thallus without marginal lobes **AMYGDALARIA**

25: Cephalodia not present on thallus

27 Ascospores more than 30 µm long

28 Ascospores sigmoid, attenuate **SARRAMEANA**

28: Ascospores ellipsoidal

29 Apothecial disc black **POELTIDEA**

29: Apothecial disc white to pale brown

30 Apothecium sessile, not immersed, with well-developed exciple containing photobiont **OCHROLECHIA**

30: Apothecium immersed, often in warts; exciple never containing photobiont **PERTUSARIA**

27: Ascospores less than 30 µm long

31 Apothecial disc red, pink, yellow or orange

32 Apothecial disc pink, sometimes on a tall pedicel **BAEOMYCES**

32: Apothecial disc red, yellow or orange, sessile or immersed

33 Apothecial disc K+ purple (parietin) **PROTOBLASTENIA**

33: Apothecial disc K-

34 Apothecium without photobiont in exciple

35 Apothecial disc yellow **PSILOLECHIA**

35: Apothecial disc red

36 Paraphyses branched and anastomosing; tholus uniformly I+ pale blue **MILTIDEA**

36: Paraphyses not branched and anastomosing; tholus I+ dark blue with an I+ pale blue axial body **PYRRHOSPORA**

34: Apothecium with photobiont in exciple

37 Thallus growing on calcareous earth; apothecial disc K+ purple **FULGENSIA**

37: Thallus growing on rock, wood, or bark; apothecial disc not K+ purple **CANDELARIELLA**

31: Apothecial disc cream, buff, brown or black

38 Ascospores released into a mazaedium **SCLEROPHORA**

38: Ascospores maturing in ascus

39 Ascoma without exciple even when young

40 Asci in locules surrounded by interthecial hyphae; hymenium without ascal gel **VEZDAEA**

40: Asci amongst paraphyses; ascal gel consolidating hymenium

41 Paraphyses branched and anastomosing; ascoma globular **MICAREA**

41: Paraphyses simple; ascoma ovoid to elongate **XYLOGRAPHA**

39: Ascoma with an exciple at least when young

42 Apothecial disc pale to dark brown, but not black

43 Thallus lobed or of minute squamules

44 Thallus of small squamules **TRAPELIA**

44: Thallus with marginal lobes

45 Thallus straw yellow (usnic acid) **KAROOWIA**

45: Thallus brown **PROTOPARMELIOPSIS**

43: Thallus with neither marginal lobes nor squamules

46 Tholus and internal cap well- or poorly developed, I- or with thin external I+ layer only

47 Tholus I-; apothecium immersed **ASPICILIA**

47: Tholus I- or with a thin I+ layer; apothecium sessile

48 Thallus C+ red **TRAPELIA**

48: Thallus C- **PLACYNTHIELLA**

46: Tholus or internal cap well-developed, I+ blue

49 Paraphyses reticulately branched and anastomosing **BIATORA**

49: Paraphyses sparsely branched

50 Ascal tip I+ dark blue, with an apical body

51 Thallus brown **PROTOPARMELIA**

51: Thallus white, grey or yellow **LECANORA**

50: Ascal tip I+ pale blue or with an external cap and an internal cap, but no apical body apparent

52 Hypothecium dark brown **LECIDEA**

52: Hypothecium pale **FUSCIDEA**

42: Apothecial disc black

53 Paraphyses simple, or branched only at tips; end-cells swollen

54 Asci cylindrical, apex not thickened **SCHAERERIA**

54: Asci clavate, apex thickened

55 Exciple entirely black **CARBONEA**

55: Exciple pale within

56 Tholus with a slight development of an I+ cap and ring structure **LECIDEA**

56: Tholus strongly developed, I+

57 Hypothecium hyaline or golden-brown **LECIDELLA**

57: Hypothecium black or purple **TEPHROMELA**

53: Paraphyses richly branched, often reticulate and anastomosing; end-cells not or only slightly swollen

58 Hypothecium dark brown

59 Apothecium immersed **IMMERSARIA**

59: Apothecium sessile, not immersed

60 Apothecial disc concentrically folded, usually umbonate **STEPHANOCYCLOS**

60: Apothecial disc not concentrically folded, flat or somewhat convex or rarely umbonate

61 Hymenial section I+ yellow to red; tholus I+ blue on flanks with an I+ blue central plug **RIMULARIA**

61: Hymenial section I+ blue; tholus I+ light blue with an I+ dark blue ring

62 Ascospores halonate **PORPIDIA**

62: Ascospores not halonate **PARAPORPIDIA**

58: Hypothecium colourless or pale brown

63 Apothecium adnate to, or immersed in, thallus, never constricted at base

64 Apothecium adnate to thallus but not immersed in it

65 Paraphysis shaft less than 3 µm wide **MIRIQUIDICA**

65: Paraphysis shaft 4–6 µm wide **AUSTROLECIA**

64: Apothecium immersed in thallus

66 Apothecium with photobiont in exciple; hymenium I- **CLAUZADEANA**

66: Apothecium without photobiont in exciple; hymenium I+ yellow to blue **IMMERSARIA**

63: Apothecium sessile, constricted at base

67 Hymenium I- **BIATORA**

67: Hymenium I+

68 Tholus I+ dark blue with an I+ light blue central axial body **TYLOTHALLIA**

68: Tholus I+ pale blue containing an I+ dark blue ring **POELTIARIA**

Group 8: crustose lichens with one-septate spores

1 Ascospores brown

2 Ascoma a perithecium or similar closed structure

3 Ostiole with star-like ornamentation **ASTEROPORUM**

3: Ostiole not ornamented	
4 Ascospore wall ornamented	**MYCOMICROTHELIA**
4: Ascospore wall plain	**MYCOPORELLUM**
2: Ascoma an apothecium or similar open structure	
5 Ascospores maturing in a mazaedium	
6 Ascoma on a stalk	**CALICIUM**
6: Ascoma sessile or adnate	
7 Ascoma with a developed corona	**NADVORNIKIA**
7: Ascoma without a corona	
8 Thallus K-	**PYRGIDIUM**
8: Thallus K+	
9 Photobiont *Trebouxia*; ascoma without distinct upper and lower chambers	**CYPHELIUM**
9: Photobiont *Trentepohlia*; ascoma with globose lower and conical upper chambers	**PYRGILLOCARPON**
5: Ascospores maturing in ascus	
10 Thallus with developed marginal lobes	
11 Apothecium with photobiont in exciple; ascospore wall thin	**DIMELAENA**
11: Apothecium without photobiont in exciple; ascospore wall unevenly thickened	**DIPLOICIA**
10: Thallus not lobed at margins	
12 Ascoma oblong to wildly irregular, lirellate	**MELASPILEA**
12: Ascoma globose or somewhat irregular,	
13 Ascospore wall unevenly thickened	**RINODINA**
13: Ascospore wall of uniform thickness	
14 Paraphyses reticulately branched and anastomosing	**RHIZOCARPON**
14: Paraphyses little-branched	
15 Ascospore ovoid, the wall more than 1 µm thick	**BUELLIA**
15: Ascospore cylindrical, the wall c. 0.5 µm thick	**RINODINELLA**
1: Ascospores hyaline	
16 Ascoma a perithecium or similar closed structure	
17 Ascoma with several fused chambers	**MYCOPORELLUM**
17: Ascoma simple	
18 Paraphyses gelatinising	**THELIDIUM**
18: Paraphyses persisting	
19 Paraphyses simple or rarely branched	
20 Aperture of ascoma fringed, crenulate or fissured	**RAMONIA**
20: Ascoma with a simple ostiole	**STRIGULA**
19: Paraphyses reticulately branched and anastomosing	
21 Ascospore with a warty episporium	

22 Ascospores uniseriate in ascus **ACROCORDIA**

22: Ascospores clumped or biseriate in ascus **ARTHOPYRENIA**

21: Ascospore not ornamented

23 Thallus subcuticular on lower surface of leaf **RACIBORSKIELLA**

23: Thallus rarely on leaves, never subcuticular

24 Ostiolar canals oblique or horizontal **PLEUROTREMA**

24: Ostiolar canals erect

25 Photobiont *Trentepohlia*-like; thallus usually on bark

26 Paraphyses not septate **DITREMIS**

26: Paraphyses septate **ARTHOPYRENIA**

25: Photobiont a cyanobacterium; thallus on rock **PYRENOCOLLEMA**

16: Ascoma an apothecium or similar open structure

27 Septum of ascospore pierced by a pore (polarilocular) or incompletely thickened

28 Ascospores less than 20 µm long **CALOPLACA**

28: Ascospores more than 20 µm long

29 Ascospore wall heavily thickened at apex, and unevenly thickened at septum **MEGALOBLASTENIA**

29: Ascospore wall not thickened at apex; septum of similar thickness to outer wall except for thin section in centre **MEGALARIA**

27: Septum of ascospore complete

30 Ascoma disc yellow

31 Exciple with photobiont **CANDELARIELLA**

31: Exciple absent or, if present, without photobiont

32 Ascus apex thickened; photobiont *Cystococcus* **ABSCONDITELLA**

32: Ascus apex not thickened; photobiont *Trentepohlia* **DIMERELLA**

30: Ascoma disc pale fawn to brown or black

33 Ascoma with a punctiform opening; aperture fringed, crenulate or fissured **RAMONIA**

33: Ascoma disc open

34 Ascoma lirellate (elongate, stellate, or irregular but not disc-like)

35 Paraphyses simple; ascus unitunicate

36 Apothecium pale to dark brown **MYCOBILIMBIA**

36: Apothecium black **MELASPILIEA**

35: Paraphyses reticulately branched and anastomosing; ascus bitunicate

37 Ascoma without exciple; ascus globose **ARTHONIA**

37: Ascoma with black exciple; ascus clavate **OPEGRAPHA**

34: Ascoma a round or somewhat distorted disc

38 Exciple developed, containing photobiont or with adhering thallus tissue

39 Thallus margin with developed lobes	SOLENOPSORA
39: Thallus margin not lobed	
40 Paraphyses reticulately branched and anastomosing	CALENIA
40: Paraphyses simple	
41 Thallus on leaves; ascoma ornamented with patches of adhering thallus tissue, often extending over disc	ASTEROTHYRIUM
41: Thallus not on leaves; ascoma without patches of adhering thallus tissue	LECANIA
38: Exciple either not developed or, if developed, photobiont absent	
42 Ascoma without an exciple	
43 Ascospores more than 30 µm long	MEGALOSPORA
43: Ascospores less than 30 µm long	
44 Asci in locules; not amongst paraphyses bound together by gelatine	VEZDAEA
44: Asci in a gelatinous hymenium	MICAREA
42: Ascoma with an exciple	
45 Photobiont a cyanobacterium	PLACYNTHIUM
45: Photobiont a chlorophyte	
46 Ascoma exciple black	TYLOTHALLIA
46: Ascoma exciple pale fawn to dark brown	
47 Epithecium interspersed with granules that dissolve in K	CLIOSTOMUM
47: Epithecium without granules	
48 Thallus on leaves	FELLHANERA
48: Thallus on other substrata	BIATORA

Group 9: crustose lichens with transeptate spores

1 Ascospores brown at maturity	
2 Fruiting body a perithecium or similar closed structure	
3 Ascomata clustered in groups or, if not clustered, each ascoma with several fused chambers	
4 Ascomata not clustered in groups, each ascoma a complex of fused chambers	MYCOPOROPSIS
4: Ascomata clustered in groups, sometimes fused at the ostiole	
5 Ascomata aggregated, but not in stromatic tissue; ostiole lateral	PARATHELIUM
5: Ascomata in groups in stromatic tissue; ostiole apical or lateral	
6 Perithecia radially arranged, prostrate or erect	PYRENASTRUM
6: Perithecia not radially arranged, erect	MELANOTHECA
3: Ascomata single, neither markedly clumped nor with fused chambers	
7 Photobiont *Phycopeltis*	MICROTHELIOPSIS

7: Photobiont *Trentepohlia*-like	
8 Ascoma pale, deeply cupular, deeply immersed in thallus	**MYRIOTREMA**
8: Ascoma dark, globose, with distinct ostiole	
9 Ascospore wall warty, but otherwise uniformly thick	**MYCOMICROTHELIA**
9: Ascospore wall smooth, thickened to produce lenticular lumina	**PYRENULA**
2: Fruiting body an apothecium or similar open structure	
10 Ascospores maturing in a mazaedium	
11 Ascoma pedicellate, with an undivided mazaedium; ascospore wall uniformly pigmented	**PYRGILLUS**
11: Ascoma sessile, the mazaedium divided into several locules; ascospore wall dotted with pigment	**HETEROCYPHELIUM**
10: Ascospores maturing in an ascus	
12 Ascoma pale, often deeply immersed in thallus	
13 Ascoma exciple lined with periphysoids	**THELOTREMA**
13: Ascoma exciple without periphysoids	**MYRIOTREMA**
12: Ascoma dark, not deeply immersed in thallus	
14 Ascomata grouped in stromatic tissue	**SARCOGRAPHA**
14: Ascomata single, not grouped in stromatic tissue	
15 Ascoma lirellate	**PHAEOGRAPHIS**
15: Ascoma discoid	
16 Ascospore wall thickened to produce lenticular locules	**RINODINA**
16: Ascospore with a uniformly thin wall	
17 Apothecial disc flat to convex; thallus on rocks	**DIPLOTOMMA**
17: Apothecial disc deeply concave; thallus on bark	**OCELLULARIA**
1: Ascospores hyaline at maturity	
18 Ascoma a perithecium, similar closed structure or deeply cupular	
19 Ascoma deeply cupular; asci in a hymenium	
20 Opening of disc punctiform and fringed, crenulate or fissured; ascus I+ blue	**RAMONIA**
20: Opening of disc simple; ascus I-	
21 Ascoma wall black	**OCELLULARIA**
21: Ascoma wall colourless or brown	
22 Ascoma exciple lined with periphyses	**THELOTREMA**
22: Ascoma exciple without periphyses	**MYRIOTREMA**
19: Ascoma with a distinct ostiole, or asci single in locules	
23 Ascoma a complex of fused chambers, or asci single in locules	
24 Asci single in locules; ascoma not well-developed	**STIRTONIA**
24: Asci in a developed hymenium; ascoma a complex of fused chambers	**MYCOPORELLUM**
23: Ascoma simple or chambers fused only at ostiole; asci in a hymenium	

25 Ascoma immersed in stromatic tissue
26 Ascospore with thick wall and lenticular locules **TRYPETHELIUM**
26: Ascospore with thin wall and cylindrical locules **TOMASELLIA**
25: Ascoma not immersed in stromatic tissue
27 Paraphyses becoming gelatinised **THELIDIUM**
27: Paraphyses persistent
28 Paraphyses simple or rarely branched
29 Ascoma with a corona of spreading bristles **TRICHOTHELIUM**
29: Ascoma not ornamented
30 Thallus isidiate **ZAMENHOFIA**
30: Thallus not isidiate
31 Ascospore lumina lenticular **PYRENULA**
31: Ascospore lumina cylindrical
32 Ascus with ocular chamber **STRIGULA**
32: Ascus without ocular chamber **PORINA**
28: Paraphyses reticulately branched and anastomosing
33 Ascospore lumina lenticular **PSEUDOPYRENULA**
33: Ascospore lumina cylindrical
34 Ascoma canal oblique or horizontal; ascomata sometimes compound **PLEUROTREMA**
34: Ascoma canal erect; ascomata never compound
35 Thallus subcuticular on underside of leaves **RACIBORSKIELLA**
35: Thallus rarely on leaves, never subcuticular
36 Ascospores with a warty episporium **ARTHOPYRENIA**
36: Ascospores with a smooth episporium
37 Hamathecium interspersed with oil globules; ascospore wall sometimes thickened with age **POLYMERIDIUM**
37: Hamathecium not interspersed with oil globules; ascospore wall not thickened with age **DITREMIS**
18: Ascoma an apothecium or similar open structure
38 Ascomata irregular to lirellate
39 Ascomata aggregated or with paired parallel hymenia
40 Ascomata with paired parallel hymenia **DIPLOGRAMMA**
40: Ascomata aggregated in stromatic tissue
41 Ascospore with thin wall and cylindrical lumina **ENTEROGRAPHA**
41: Ascospore with thick wall and lenticular lumina **GLYPHIS**
39: Ascomata neither aggregated nor with paired parallel hymenia
42 Ascospores I+ purple; paraphyses simple **GRAPHIS**
42: Ascospores I-; paraphyses reticulately branched and anastomosing
43 Ascospores clavate; ascus globose to pyriform **ARTHONIA**

43: Ascospores acicular to ellipsoidal; ascus clavate
44 Exciple of disc poorly developed, pale brown **ENTEROGRAPHA**
44: Exciple of disc well-developed, dark brown or black
45 Ascoma usually linear with only lateral exciples; ascus bitunicate, thick-walled **OPEGRAPHA**
45: Ascoma usually triangular or quadrangular with continuous exciples; ascus thin-walled **AULAXINA**
38: Ascomata disc-like to globose
46 Paraphyses simple or sparingly branched
47 Apothecium or thallus K+ purple (parietin) **LETROUITIA**
47: Neither apothecium nor thallus K+ purple
48 Exciple of disc cobwebby **BYSSOLOMA**
48: Exciple of disc not cobwebby
49 Thallus on leaves
50 Exciple bearing fragments of thallus **ASTEROTHYRIUM**
50: Exciple without thalline tissue
51 Exciple including large crystals; campylidia often present on thallus **BADIMIA**
51: Exciple without large crystals; campylidia absent **FELLHANERA**
49: Thallus on rock, wood or bark
52 Apothecium with photobiont in exciple **LECANIA**
52: Apothecium without photobiont in exciple
53 Ascospores ovoid
54 Ascospore septa markedly thickened **AUSTROBLASTENIA**
54: Ascospore septa thin **MYCOBILIMBIA**
53: Ascospores acicular or elongate
55 Photobiont a cyanobacterium **PLACYNTHIUM**
55: Photobiont a chlorophyte
56 Tholus well-developed, I+ blue **BACIDIA**
56: Tholus I- or absent
57 Ascospores 16 or more per ascus
58 Opening of apothecium fringed or fissured **RAMONIA**
58: Opening of apothecium without ornamentation **PACHYPHIALE**
57: Ascospores 8 or fewer per ascus
59 Ascospore with thick wall and a lenticular or angular lumen
60 Exciple black **OCELLULARIA**
60: Exciple pale
61 Periphysoids present on apothecial exciple **THELOTREMA**
61: Periphysoids not present on apothecial exciple **MYRIOTREMA**
59: Ascospore with thin wall and a cylindrical lumen

62 Ascus wall I+ blue; photobiont *Trentepohlia* or *Scytonema*

63 Disc punctiform, the exciple fringed, crenulate or fissured **RAMONIA**

63: Disc open, the exciple not ornamented **CRYPTOLECHIA**

62: Ascus wall I+ yellow to red-brown; photobiont *Cystococcus* **GYALIDEA**

46: Paraphyses reticulately branched and anastomosing, at least in epihymenium

64 Exciple of ascoma cobwebby **BYSSOLOMA**

64: Exciple of ascoma not cobwebby

65 Disc of ascoma red, sometimes masked by white or yellow pruina

66 Thallus on leaves, with campylidia **LOFLAMMIA**

66: Thallus on bark, without campylidia **HAEMATOMMA**

65: Disc of ascoma yellow, white, brown, or black

67 Disc bright yellow **CHRYSOTHRIX**

67: Disc white, brown or black

68 Ascospore with thickened septa and lenticular lumina **PHLYCTELLA**

68: Ascospore with uniformly thin wall and cylindrical lumina

69 Ascomata grouped in stromatic tissue **CHIODECTON**

69: Ascomata not grouped in stromatic tissue

70 Apothecial disc or exciple black

71 Apothecial exciple absent or poorly developed

72 Ascospores helically twisted **SCOLICIOSPORUM**

72: Ascospores straight or curved, but not helically twisted **MICAREA**

71: Apothecium with a well-developed exciple

73 Apothecia triangular or quadrangular **AULAXINA**

73: Apothecia round to irregular

74 Ascospores acicular

75 Thalline exciple present **SCHISMATOMMA**

75: Thalline exciple absent **LECANACTIS**

74: Ascospores ovoid or rod-shaped

76 Thalline exciple present **ROCCELLINA**

76: Thalline exciple absent

77 Thallus ecorticate, continuous **TAPELLARIA**

77: Thallus corticate, areolate **ARTHRORAPHIS**

70: Neither apothecial disc nor exciple black

78 Thallus sorediate **AUSTROBLASTENIA**

78: Thallus esorediate

79 Apothecium sessile or adnate, with a well-developed exciple

80 Exciple spreading laterally	ECHINOPLACA
80: Exciple well-defined	
81 Tholus I-; thallus with white or black bristles	TRICHARIA
81: Tholus I+; thallus without bristles	FELLHANERA
79: Apothecium immersed to adnate, with a poorly developed exciple	
82 Ascoma erumpent; ascus bitunicate	MAZOSIA
82: Ascoma immersed to sessile; ascus unitunicate	CALENIA

Group 10: crustose lichens with muriform spores

1 Mature ascospores brown	
2 Ascoma a perithecium or similar closed structure	
3 Ascoma a complex of fused chambers	MYCOPORUM
3: Ascoma of free chambers, or fused only at ostiole	
4 Ascomata immersed in stromatic tissue, often in groups	
5 Ostiolar canal erect	BOTTARIA
5: Ostiolar canal oblique to horizontal	PARMENTARIA
4: Ascomata not in stromatic tissue, not grouped	
6 Ostiolar canal erect	ANTHRACOTHECIUM
6: Ostiolar canal oblique to horizontal	PLEUROTHELIOPSIS
2: Ascoma an apothecium or similar open structure	
7 Ascoma lirellate (elongate, stellate or irregular)	
8 Paraphyses simple or sparsely branched	
9 Ascomata immersed in stromatic tissue	SARCOGRAPHINA
9: Ascomata not in stromatic tissue	PHAEOGRAPHINA
8: Paraphyses reticulately branched and anastomosing	
10 Ascoma immersed in stromatic tissue	TREMOTYLIUM
10: Ascoma not in stromatic tissue	ARTHOTHELIUM
7: Ascoma with a round or distorted disc	
11 Paraphyses branched and anastomosing	RHIZOCARPON
11: Paraphyses simple or sparsely branched	
12 Proper exciple black	
13 Thallus on bark; photobiont *Trentepohlia*	OCELLULARIA
13: Thallus on rock or ground; photobiont *Trebouxia* or *Protococcus*	
14 Apothecial disc flat to convex, adnate when mature	DIPLOTOMMA
14: Apothecial disc concave, immersed to adnate	DIPLOSCHISTES
12: Proper exciple pale brown or hyaline	
15 Exciple lined with periphysoids	THELOTREMA
15: Exciple without periphysoids	MYRIOTREMA

1: Mature ascospores hyaline

16 Ascoma a perithecium or similar closed structure

17 Ascoma a complex of fused chambers, or consisting of free chambers with a fused ostiole

18 Ascoma a group of free chambers with a fused ostiole **CRYPTOTHELIUM**

18: Ascoma a complex of fused chambers with multiple ostioles **MYCOPORELLUM**

17: Ascoma a free perithecium

19 Ascoma immersed in stromatic tissue **LAURERA**

19: Ascoma not immersed in stromatic tissue

20 Paraphyses becoming gelatinised **POLYBLASTIA**

20: Paraphyses persistent

21 Paraphyses simple or sparsely branched

22 Ostiole with a developed rim, or perithecial wall warty **ASPIDOTHELIUM**

22: Ostiole without a rim, perithecial wall smooth

23 Thallus on leaves **PHYLLOBATHELIUM**

23: Thallus on bark **CLATHROPORINA**

21: Paraphyses reticulately branched and anastomosing

24 Ostiole oblique **CAMPYLOTHELIUM**

24: Ostiole erect

25 Ascospores without a gelatinous sheath; ascoma wall pale at base **THELENELLA**

25: Ascospores with a gelatinous sheath; ascoma wall brown to olive **POLYBLASTIOPSIS**

16: Ascoma an apothecium or similar open structure

26 Apothecium immersed in stromatic tissue **TREMOTYLIUM**

26: Apothecium not immersed in stromatic tissue

27 Paraphyses strongly reticulately branched and anastomosing

28 Ascus globose, fissitunicate

29 Ascogenous areas white; interascal tissue not coherent **CRYPTOTHECIA**

29: Ascogenous areas usually black; interascal tissue somewhat coherent **ARTHOTHELIUM**

28: Ascus clavate, unitunicate

30 Ascoma linear or branched **CYCLOGRAPHINA**

30: Ascoma round or distorted

31 Ascoma immersed in thallus **GYALECTIDIUM**

31: Ascoma adnate or sessile

32 Tholus I-

33 Exciple of young apothecium consisting of radially spreading hyphae **ECHINOPLACA**

33: Exciple of young apothecium not consisting of radially spreading hyphae

Key to common, characteristically, sterile crusts

This key contains only a small selection of the genera which might be included, for all crustose lichens are sometimes found sterile. The genera included are either always sterile, are commonly found sterile, or contain common species which are always sterile.

1	Thallus vivid yellow	
2	Thallus ecorticate, of loosely woven hyphae	**CHRYSOTHRIX**
2:	Thallus corticate	**PERTUSARIA**
1:	Thallus white, grey or blue-green	
3	Thallus containing cartilaginous strands	**LEPROCAULON**
3:	Thallus without cartilaginous strands	
4	Thallus corticate	**PERTUSARIA**
4:	Thallus ecorticate	
5	Thallus deep green or deep blue-green when wet	**DICTYONEMA**
5:	Thallus white to grey or grey-green when wet	
6	Thallus a crust, bearing white soredia	**BAEOMYCES**
6:	Thallus of loosely woven hyphae, or a loose mass of soredium-like material	
7	Photobiont *Trentepohlia*; thallus of loosely woven hyphae, not sorediate; from *Nothofagus* forests	**BYSSOCAULON**
7:	Photobiont coccoid; thallus sorediate or loosely woven; widely distributed	
8	Thallus with poorly defined woolly lobes, dibenzofurans demonstrated by thin layer chromatography	**LEPROLOMA**
8:	Thallus without lobes, dibenzofurans not demonstrated by thin layer chromatography	**LEPRARIA**

34 Thallus with bristles; hyphophores needle-like	**TRICHARIA**
34: Thallus without bristles; hyphophores scale-like	**GYALIDEOPIS**
32: Tholus I+ blue	
35 Hypothallus present and woolly	**LASIOLOMA**
35: Hypothallus absent or poorly developed	
36 Epithecial algae present	**SPOROPODIUM**
36: Epithecial algae absent	
37 Thallus on mosses	**LOPADIUM**
37: Thallus on bark or leaves	
38 Apothecial disc black; thallus without campylidia	**AUSTROBLASTENIA**
38: Apothecial disc pink to red; thallus with campylidia	**LOFLAMMIA**
27: Paraphyses simple or sparsely branched	
39 Ascus bitunicate, globose to pyriform	
40 Ascoma immersed in stromatic tissue	**ENTERODICTYON**
40: Ascoma immersed or adnate on thallus	**MELAMPILIDIUM**
39: Ascus unitunicate, elongate	
41 Ascoma elongate or lirellate	
42 Ascoma in stromatic tissue	**MEDUSULINA**
42: Ascoma immersed in, or adnate on, thallus	**GRAPHINA**
41: Ascoma round or distorted	
43 Ascus wall and tholus I- or I+ brown	
44 Exciple black	**OCELLULARIA**
44: Exciple pale	
45 Exciple lined internally with periphysoids	**THELOTREMA**
45: Exciple without periphysoids	
46 Photobiont *Cystococcus*	**GYALIDEA**
46: Photobiont *Trentepohlia*	**MYRIOTREMA**
43: Ascus wall or tholus I+ blue	
47 Ascoma translucent when wet, initially immersed and opening by a pore, opening widely with age	**GYALECTA**
47: Ascoma opaque when wet, open, concave to convex	
48 Thallus K+ purple; ascospore wall often thickened in corners of lumen	**LETROUITIA**
48: Thallus K- or K+ yellow; ascospore wall not thickened in corners of lumen	
49 Thallus bearing campylidia	**CALOPADIA**
49: Thallus without campylidia	**BRIGANTIAEA**

34. **Rogers, R.W.** (1974). Lichens from the T.G.B.Osborn Vegetation Reserve at Koonamore in arid South Australia. *Transactions of the Royal Society of South Australia*, **98**, 113-124.

LICHENS FROM THE T. G. B. OSBORN VEGETATION RESERVE AT KOONAMORE IN ARID SOUTH AUSTRALIA

by R. W. ROGERS*

Summary

ROGERS, R. W. (1974).—Lichens from the T. G. B. Osborn Vegetation Reserve at Koonamore in arid South Australia. *Trans. R. Soc. S. Aust.* **98** (3), 113-123, 31 August, 1974.

The Koonamore Vegetation Reserve has a lichen flora of at least 38 species. The level of endemism (19% confined to Australian arid regions) is lower than that in other arid lands, but the total number of species is similar to that found in the arid lands of Asia and North Africa, and the percentage of foliose species is higher. It is possible that either the environment at Koonamore is less harsh than other areas with similar rainfall, or that Australian foliose species are more drought resistant than those from other areas. However, the broad species concept followed here, and the topography of the reserve also, tend to limit the number of crustose species. All soil-surface species occur more frequently on loamy soils than on sandy soils. It is suggested that *Collema coccophorus, Dermatocarpon lachneum, Endocarpon pusillum* and *Heppia lutosa,* the species most common on sand and most commonly occurring alone, are the pioneer species on the soil. Brief descriptions and a key to the species of lichens found on the reserve are appended.

Introduction

There have been a number of recent studies concerning lichens in arid southern Australia (Rogers 1971, 1972a, 1972b; Rogers & Lange 1971, 1972); however, these have dealt only with species growing on the soil.

The T. G. B. Osborn Vegetation Reserve at Koonamore (139°27′E, 32°15′S) was established in 1925 to study the regeneration of over-grazed arid shrubland, this work being summarised by Hall, Specht & Eardley (1964). Although it is only small (390 hectares), it has a vegetation representative of much of arid South Australia. The Reserve is located in an area where vegetation formations of the more arid, low, open shrublands to the north occur admixed with formations from the low woodlands to the south. The Reserve has a rainfall of only 182 mm per annum, and, using the criteria of Meigs (1953) is Arid.

The only report concerning lichens from the Reserve is in Osborn, Wood & Paltridge (1935). The collections were made by C. Barnard, and specimens sent to Kew for determination. Examination of the material retained as duplicates in the herbarium of the University of Adelaide (ADU) shows that some of the confusion in the discussion of lichens by Osborn, Wood & Paltridge was due to limited knowledge of lichens and their structure.

The "undetermined species of *Acarospora*" referred to as forming patches up to 8 cm in diameter is, in the specimens retained, mostly large colonies of *Diploschistes scruposus.* However, in a few cases, small, fertile thalli of *A. smaragdula* (rarely 2 cm in diameter) are present in the crust of *D. scruposus.* It is probable that similar material was sent to Kew, and the obviously fertile *Acarospora,* but not the often sterile *Diploschistes,* determined. Two of the three other soil-surface species discussed as being conspicuous because of their apothecia, are not so. *Lecidea decipiens* has small pink squamules with a white edge, and rarely, black marginal apothecia. Osborn, Wood & Paltridge apparently mistook the small thallus for an apothecium. Similarly, they confused the thallus of *Dermatocarpon hepaticum* with apothecia: *D. hepaticum* has immersed perithecia, not apothecia.

During 1965-1971 the Reserve was visited frequently by the author who collected specimens for lichen studies.

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*Botany Department, University of Queensland, St. Lucia, Qld. 4067.

The Lichen Flora

The soil lichens at Koonamore are a striking feature of the Reserve. Over much of the area the lichens form a continuous carpet, which is rich in species. Many of the small calcareous pebbles on the soil surface are completely encrusted with lichens, often with a variety of species on a pebble no more than 1 cm in diameter. Bark and wood of live or dead trees and shrubs supports a usually sparse growth of lichens.

From the collections made in 1965-1971, and from collections housed in the Botany Department, University of Adelaide, 38 species in 25 genera were determined by reference to the literature and herbarium material. These are listed in the Appendix. The flora is comparable in number of species to that found in south-western Africa (41 species; Doidge 1950), in Arizona (33 species; Fink 1909) and in the Negev (37 species; Galun & Reichert 1960).

Brief descriptions and a key to the species from the Reserve appear in the Appendix.

Biogeographic Considerations

Weber (1962) commented on the similarity of arid zone lichen floras from various continents. Rogers & Lange (1972) illustrated this by reference to the soil-surface lichens from all continents except South America.

In desert areas, the genera *Acarospora, Aspicilia, Buellia, Caloplaca, Collema, Dermatocarpon, Endocarpon, Heppia, Lecanora, Rinodina* and *Verrucaria* dominate the lichen floras. All these genera are crustose. The most common foliose genus is apparently *Physcia,* but *Parmelia, Teloschistes* and *Xanthoria* are also widespread. All of these genera are recorded in the Reserve although it is likely that the records for *Rinodina* and *Buellia* are based on identical material (see comment in species descriptions).

Literature was searched to see whether the species occurring at Koonamore grow in other deserts. Reports were placed into four regional groupings: North America (Fink 1909, Herre 1911, Rudolph 1953, Weber 1963), North Africa (Faurel, Ozenda & Schotter 1953), western Asia (Steiner 1921, Lamb 1936, Szatala 1957, Galun & Reichert 1960, Poelt & Wirth 1968), and southern Africa (Doidge 1950).

Of the 38 species found in the Reserve, four occur in each of the other four desert regions considered. These are *Acarospora schleicheri, Caloplaca murorum, Dermatocarpon lachneum* and *Lecidea decipiens.* A further four species, *Endocarpon pusillum, Parmelia pulla, Physcia stellaris* and *Toninia coeruleonigricans* occur in three of the four regions.

The seven taxa (19%) asterisked in Appendix II are endemic to Australia, with the exception of *Chondropsis semiviridis* and *Parmelia reptans,* which also occur in New Zealand. This is lower than the 30% endemism recorded by Faurel, Ozenda & Schotter (1953) for the Sahara, and similar to the endemism reported by Galun & Reichert (1960) for lichens from the Negev, Israel. Of the other species, 18 (48%) are also found in North American deserts, 14 (37%) in southern Africa, 11 (28%) in western Asian deserts, and 8 (21%) in the Sahara.

Comparison with floras from other arid lands (Table 1) indicates that the flora at Koonamore is unusually rich in foliose species. The most

TABLE 1

Life-form spectra for the lichen population in desert regions, with other South Australian spectra for comparison.

Location	% crustose and squamulose species	% foliose species	% fruticose species
Koonamore	58	42	0
Reno (Herre 1911)	75	25	0
Tucson (Fink 1909)	91	9	0
Negev (Galun and Reichert 1960)	91	6	3
Sahara (Faurel, Ozenda and Schotter 1953)	97	3	0
Arid South Australia*	75	23	2
Semi-Arid South Australia*	57	35	8
Temperate South Australia*	37	41	22
All of South Australia*	45	36	19

*Rogers, R. W. (1971) Unpublished Ph.D. thesis (University of Adelaide) Appendix I, pp. 183-186.

directly comparable area is that studied by Fink (1909) at Tucson. That area was somewhat larger with more diverse substrates and a slightly higher rainfall. The area studied by Herre (1911) at Reno included an altitudinal range of several thousand feet, also with a higher rainfall than Koonamore. Both of these areas were, however, poorer in foliose species. From Table 1 it is also evident that the Koonamore Reserve is relatively richer in foliose species than arid South Australia taken as a whole.

Renaut, Marrache & Trotet (1968) examined the use of lichen life-form spectra as indicators of aridity. With 42% foliose species, Koonamore would rate as sub-humid or perhaps semi-arid on their scale whereas it is classed as arid by use of climatic indices (Meigs 1953). At first this suggests that either the climate at Koonamore is less harsh in relation to its rainfall and temperature regime than other desert regions, or that southern Australian foliose lichens are more drought resistant than their counterparts elsewhere. However, the relatively high percentage of foliose lichens on the Koonamore Reserve may be due in part to the absence of outcropping rocks in the area. Two species absent from the Reserve, but which occur on rocky outcrops in the nearby Yunta and Waukaringa hills, are *Diploschistes gypsaceaus* (crustose) and *Heppia euploca* (squamulose). Another factor may be the broad species concept followed in naming the Koonamore lichens. While many taxonomists will not accept the revision of *Acarospora* subgenus *Xanthothallia* by Weber (1968), in which about 80 accepted species were reduced to two, his conclusion that the number of crustose lichens from arid areas is greatly inflated by description of environmental modifications as distinct taxa (Weber 1962) is sound. Apart from the genus *Acarospora*, the genera *Lecanora* and *Lecidea* have also been split to accommodate numerous environmental modifications. It is likely that other authors have followed rather narrow species concepts, increasing the total number and hence proportion of crustose species recorded from arid lands. This may also explain the similarity with the North American desert lichen flora, since both the present author and North American authors have followed a similar broad species concept.

Ecology of Soil Surface Species

To study the soil-surface lichens, 26 transects were randomly located in the physiographically diverse south-eastern half of the reserve. Along each transect, ten 15 cm by 20 cm quadrats were laid at random intervals between zero and ten metres apart, and the soil surface lichens within the quadrats listed. The soil type was classified into one of two categories, calcareous loam or sand.

Thirteen taxa occurred in more than ten of these quadrats; these are listed in Table 2, along with their frequency in loamy and sandy quadrats. Of the 260 quadrats, 67 were without lichens. Fifty-five of the quadrats without lichens were on sandy areas, 12 on loamy areas. Of the loamy quadrats 85% had lichens, whereas only 52% of the sandy quadrats did. The site with the greatest number of species (nine) was on loamy soil, whereas the richest site on sandy soil had seven species. The mean number of species on sandy sites bearing lichens was 3.5, significantly lower ($p<1\%$) than the mean of 4.3 on loamy sites with lichens.

If it is assumed that there is an increase in species diversity as a community develops towards its climax composition (Whittaker 1953), then it follows that species which tend to occur alone are more likely to be pioneer species than those which tend to occur only with others. From Table 2, it is apparent that *Collema coccophorus*, *Endocarpon pusillum*, *Dermatocarpon lachneum* and *Heppia lutosa* are the species most commonly occurring alone, or with few others. These species are therefore likely to be the pioneer species, occurring early in successional development on soil surfaces.

A number of sites on the reserve were discovered where lichen fronts were judged to be advancing on to previously uncrusted areas. This judgment was based on the presence of scattered squamules at a distance from a developed crust, the squamules becoming smaller and apparently younger as distance from the crust increased. *Dermatocarpon lachneum*, *Endocarpon pusillum* and *Heppia lutosa* were the species commonly found in such situations.

These observations, together with the observations of Rogers & Lange (1971) that *Collema coccophorus*, *Dermatocarpon lachneum*, *Endocarpon pusillum* and *Heppia lutosa* are the species least affected by trampling of sheep around waterholes, all point to the same group of species as the pioneers in lichen succession on arid soils in South Australia.

The distribution of lichen crusts in relation to shrub coverage was studied on Quadrat 100, an area of 100 m^2 of fine, calcareous soil on which regeneration of *Atriplex* spp. has been

TABLE 2

Frequency of soil-surface species on loamy soils and sandy soils from the Koonamore Vegetation Reserve, and the frequency with which these were either the only species in a quadrat, or were with only one other species.

Species	Frequency on loam	Frequency on sand	Number of occurrences alone	with one other
Acarospora smaragdula	9	0	0	0
Aspicilia calcarea (crustose)	54	22	1	2
A. calcarea (fruticose)	18	1	0	1
Chondropsis semiviridis	1	0	0	0
Collema coccophorus	55	49	14	16
Dermatocarpon lachneum	63	11	2	4
Endocarpon pusillum	43	35	3	15
Fulgensia subbracteata	24	12	0	1
Heppia polyspora	35	3	0	1
H. lutosa	30	18	1	6
Lecidea crystallifera	20	3	0	2
L. decipiens	66	19	0	2
Toninia coeruleonigricans	13	12	1	0

studied since 1925. On this quadrat it was possible in 1969 to find areas on which no perennial plant growth had been recorded in the past 44 years. These areas were without lichen growth. On areas with mature perennial shrub growth, a lichen crust had developed; the older the shrub stand, the more developed the lichen crust. A few areas were found in which the shrubs had virtually all died: in these the lichen crust remained intact. In yet other areas, young shrubs were starting to grow on areas quite devoid of lichen growth.

It is apparent from these observations that the lichen crust develops on fine calcareous soils only after a shrub cover has been established, thus stabilising the soil. However, it is also apparent that the lichens are able to prevent erosion of the soil once the shrub cover has disappeared. Lichen crusts thus increase the stability of desert soils: they cannot themselves stabilise an actively eroding surface.

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Appendix

1. KEY TO SPECIES

1\. Thallus fruticose—i.e. without dorsiventral differentiation 4

1\. Thallus foliose, squamulose or crustose—i.e. with dorsiventral differentiation 2

2\. Thallus foliose or squamulose either free from the substrate, or attached to it by rhizoids, but with a distinct lower surface 3

2\. Thallus crustose, attached to the substrate and inseparable from it, no lower surface discernible, or thallus absent 29

3\. Thallus foliose, i.e. of elongate, often branched lobes 7

3\. Thallus squamulose, i.e. of round to ovoid scales which may be crowded together 21

FRUTICOSE SPECIES

4\. Thallus gold to grey, on wood or bark .... *Teloschistes chysophthalmus*

4\. Thallus grey, black or dark olive green, on rock or soil 5

5\. Thallus grey, of anastomosing cylindrical lobes .... *Aspicilia calcarea*

5\. Thallus black or dark olive green, the lobes not anastomosing 6

6\. Thallus of cylindrical lobules or flattened lobes up to 5 mm high, forming a rosette *Collema coccophorus*

6\. Thallus of cylindrical lobes up to 2 mm high, the individuals densely packed to form an apparent crust .... *Synalissa symphorea*

FOLIOSE SPECIES

7\. Thallus black or dark olive green, gelatinous when wet .... *Collema coccophorus*

7\. Thallus not black nor gelatinous when wet .. 8

8\. Thallus bright yellow, gold or orange .. 9

8\. Thallus olive, grey, blue or yellow-green 11

9\. Thallus of minute, flattened, eciliate lobes (less than 1 mm broad), upper cortex K— .. *Candelaria concolor*

9\. Thallus of broader lobes, sometimes ciliate, upper cortex K+ burgundy 10

10\. Lobes eciliate, appressed to the substrate *Xanthoria ectanea*

10\. Lobes ciliate, ascending from the substrate *Teloschistes chrysophthalmus*

11\. Upper surface yellow green 12

11\. Upper surface grey, blue or olive 16

12\. Thallus rolling into a ball when dry, unrolling when wet .... *Chondropsis semiviridis*

12\. Thallus not rolling and unrolling 13

13\. On soil surfaces 14

13\. On rocks, wood or bark 15

14\. Thallus free on the surface, much distorted and convoluted .... *Parmelia convoluta*

14\. Thallus attached to the surface by rhizoids, lobes slightly convex, appressed .... *Parmelia reptans*

15\. On wood or bark .... *Parmelia ferax*

15\. On rocks .... *Parmelia* cf. *lineola*

16\. Thallus olive 17

16\. Thallus blue or grey 18

17\. Lobes 1 mm broad or less .... *Physciopsis syncolla*

17\. Lobes more than 1 mm broad .... *Parmelia pulla*

18\. Lobes more than 3 mm broad .... *Parmelia subalbicans*

18\. Lobes less than 2 mm broad 19

19\. Lobes with marginal soralia .. *Physcia albicans*

19\. Lobes esorediate 20

20\. Medulla K+ yellow .... *Physcia alba*

20\. Medulla K— .... *Physcia stellaris*

SQUAMULOSE SPECIES

21\. Phycobiont blue-green 22

21\. Phycobiont green 23

22\. Squamules elongate, margins granular but not thickened, forming a rosette .... *Heppia lutosa*

22\. Squamules ovoid or crenate, margins smooth, thickened, not forming a rosette *Heppia polyspora*

23. Squamules orange to red, often with a white margin .... *Lecidea decipiens*
23. Squamules brown, black, grey-green or grey 24
24. Squamules thin, pale grey-green, the margins curling up when dry .... *Cladonia* squamules
24. Squamules thicker, brown, black or grey, the margins not curling up when dry 25
25. Asci in perithecia immersed in the thallus 26
25. Asci in apothecia sessile on the thallus 28
26. Spores muriform, algae in the hymenium *Endocarpon pusillum*
26. Spores not septate, algae absent from the hymenium 27
27. On soil, squamules brown 2-3 mm across .... *Dermatocarpon lachneum*
27. On rock, squamules black less than 1 mm across .... *Dermatoparpon compactum*
28. Squamules pale grey or brown, epruinose, the upper surface deeply cracked, giving a crystalline appearance, apothecia small in relation to the squamules .... *Lecidea crystallifera*
28. Squamules dark grey or black, often pruinose, the upper surface shallowly cracked, apothecia large in relation to the squamules .... *Toninia coeruleonigricans*

CRUSTOSE SPECIES

29. Thallus or apothecia yellow or orange 30
29. Thallus and apothecia devoid of orange or yellow coloration 34
30. Thallus with small but distinct marginal lobes 31
30. Thallus without distinct marginal lobes or thallus absent 32
31. Thallus smooth, orange to orange brown .... *Caloplaca murorum*
31. Thallus mealy, very pale yellow when dry becoming bright yellow when wet .... *Fulgensia subbracteata*
32. On rocks or soil, spores more than 64 per ascus .... *Acarospora schleicheri*
32. On wood, spores 8 per ascus 33
33. Apothecia bright yellow, thallus absent or only a prothallus present .... *Candelariella antennaria*
33. Apothecia dull orange, thallus of greyish areoles .... *Bombyliospora domingense* var. *aurantiaca*
34. Crust black, of minute squamules or minute fruticose individuals closely packed 35
34. Crust white to brown, sometimes areolate or granular, but not squamulose or fruticose individuals 36
35. Thallus gelatinous when wet, individuals minutely fruticose about 0.1 mm diameter, asci in apothecia .... *Synalissa symphorea*
35. Thallus not gelatinous when wet, individuals squamulose, asci in perithecia .... *Dermatocarpon compactum*
36. Spores 64 or more per ascus 37
36. Spores less than 16 per ascus 38
37. Thallus brown, without marginal lobes, usually one apothecium per areole, on rock .... *Acarospora cervina*
37. Thallus grey, with distinct marginal lobes, apothecia usually several per areole, on soil and rock .... *Acarospora smaragdula*
38. Asci in perithecia, thallus virtually indistinguishable from the substrate .... *Verrucaria* cf. *calciseda*
38. Asci in apothecia, thallus quite distinct 39
39. Apothecia immersed or adnate on the thallus 40
39. Apothecia sessile on the thallus 42
40. Apothecia 3 mm or more in diameter .... *Diploschistes ocellatus*
40. Apothecia less than 2 mm diameter 41
41. Spores black or brown .... *Diploschistes scruposus*
41. Spores hyaline .... *Aspicilia calcarea*
42. Spores black or brown .. *Buellia subalbula*
42. Spores hyaline .... *Lecanora sphaerospora*

II. DESCRIPTIONS OF THE SPECIES

Acarospora cervina (Ach.) Mass. 1852:28.

Lecanora cervina Ach. 1814:188.

Thallus of small (1–2 mm broad) brown squamules with white margins, usually scattered but occasionally compacted. Apothecia immersed, pruinose, usually one per squamule. Spores many (>100) per ascus, non-septate.

Occasional on small calcareous pebbles. Specimen examined*: *Rogers*, 24.iii.1969.

Acarospora schleicheri (Ach.) Mass. 1852:27.

Urceolaria schleicheri Ach. 1810:332.

Thallus of minute (<1 mm diam.) sulphur yellow squamules, usually scattered, but sometimes becoming areolate. Apothecia immersed, one per squamule. Spores many (>100) per ascus, non-septate.

Rare, found only on silicious pebbles at Koonamore, but may also occur on compacted soil. Specimen examined: *Womersley*, 6.vi.1946.

Acarospora smaragdula (Wahlenb.) Mass. 1852: 29.

Endocarpon smaragdulum Wahlenb. apud Ach. 1803:29.

Thallus of small (1–2 mm in diam.), chalky white to brown squamules, forming plaques up to 2 cm in diam. Apothecia immersed, sometimes pruinose, one to five per squamule, a well developed exciple concolourous with the thallus. Spores many (>100) per ascus, non-septate.

Common on calcareous soil surfaces, often with *Diploschistes scruposus*. Specimens examined: *Barnard*, 12.xii.1927: Anon., May 1943: *Eardley*, June 1946: *Rogers*, 20.xi.1967.

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* Specimens cited as *Rogers* are in the author's private herbarium, all others in the herbarium of the University of Adelaide (*ADU*).

Aspicilia calcarea (L.) Mudd 1861:161.

Lichen calcareus L. 1753:1140.

Thallus white to greyish, either crustose or more or less fruticose; if crustose then areolate, if fruticose the lobes cylindrical, pseudocyphellate, anastomosing, 0.5-1.0 mm thick. Apothecia known only on crustose forms, immersed with a crenate margin, the disc densely pruinose. Spores 2-8 per ascus, non-septate.

Virtually any calcareous pebble on the reserve has the crustose form on it somewhere. The fruticose form is less common but occurs most often at the junction of pebbles and soil. Both forms also occur on calcareous soil alone. Numerous intergrades have been observed on the reserve. Specimens examined: Anon., May 1948; *Rogers*, 8.xii.1967.

Bombyliospora domingensis (Pers.) Zahlbr. var. *aurantiaca* Zahlbr., in Magnusson & Zahlbruckner 1945:32.

Thallus an obscure yellow-grey crust covering extensive areas on old wood. Apothecia orange, <1 mm in diam., very numerous, sessile, convex. Spores 8 per ascus, usually 5 septate.

Very common on dead, decorticate twigs, especially of *Cassia* spp. and *Eremophila* spp., where entire branches may be covered. Specimens examined: *Barnard*, 12.xii.1927; *Rogers*, 5.xi.1967.

Buellia subalbula (Nyl.) Muell. 1880:79.

Lecidea subalbula Nyl. 1868:516.

Thallus a white, areolate crust forming patches up to 5 cm in diam. Apothecia black, up to 1 mm in diam., numerous, sessile, convex, with a false white exciple disappearing early in development. Spores 8 per ascus, black, septate.

Very common on calcareous pebbles. Specimens examined: Anon., June 1946; Anon., May 1948; *Rogers*, 24.iii.1969.

Although the material has not been examined it is likely that specimens determined at Kew as *Rinodina diffractella* Muell. for Osborn, Wood & Paltridge (1935), was identical with the material here called *B. subalbula*. The two species are very similar according to their descriptions, each having a thalloid exciple when young, which disappears with age, hence confusion about the appropriate genus for the material. The species differ, however, in that there are slightly larger spores (12–12.6 x 5.7–6 μm) in *B. subalbula* than in *R. diffractella* (7–10 x 4–4.5 μm).

Caloplaca murorum (Hoffm.) Th. Fr. 1871:170.

Lichen murorum Hoffm. 1784:63.

Thallus crustose, areolate at the centre, sometimes with distinct marginal lobes 1–2 mm long, or the thallus of verrucose squamules, light orange-brown. Apothecia sessile, the disc orange to rusty brown, the exciple concolourous with the thallus. Spores 8 per ascus, polari-bilocular.

On siliceous rocks, not common. Specimens examined: *Womersley*, 6.vi.1946; Anon., May 1948.

Candelaria concolor (Dicks.) Stein in Cohn 1879: 84.

Lichen concolor Dicks. 1793:18.

Thallus yellow, minutely foliose, lobes 0.1–0.5 mm broad, c. 1 mm. long, forming rosettes or spreading irregularly, the margins irregularly granular. Fertile specimens have not been found in South Australia. According to Osborn, Wood & Paltridge (1935) this species is uncommon, but forms extensive patches on twigs. This species has not been relocated by recent collectors despite careful examination of the area.

Record: *Barnard*, 12.xii.1927 (not seen).

Candelariella antennaria Ras. 1939:137.

Thallus missing. Apothecia sessile on the substrate, the disc and exciple greenish yellow. Spores 8 per ascus, non-septate. Paraphyses septate, sometimes branched.

A common but obscure species occurring admixed with *Bombyliospora domingense* var. *aurantiaca* on wood. Specimens examined: *Rogers*, 22:ix.1969; *Rogers*, 14.1.1971.

**Chondropsis semiviridis* (F. Muell. ex Nyl.) Nyl. ex Cromb. 1880:397.

Parmeliopsis semiviridis F. Muell ex Nyl. 1885: 57.

Thallus foliose, green above, pale yellow-brown below, lobes 3–5 mm broad, strictly dichotomously branched, rolling into a ball when dry, lying flat when wet. Apothecia extremely rare, sessile, disc brown, exciple concolourous with the thallus. Spores 8, non-septate.

At Koonamore this species has lobes approaching 5 mm wide, possibly the broadest form found in Australia. Common on soil surfaces in scattered patches. Barnard apparently did not find this distinctive species on the reserve in 1927. Specimens examined: Anon., May 1942; *Barrien*, ?1944; *Rogers*, 29.xi.1968.

Cladonia sp.

Scattered squamules grey green above, white below, without podetial development.

Very rare on shaded soil under *Heterodendrum*. Specimen examined: *Rogers*, 8.xii.1967.

Collema coccophorum Tuck. 1862:385.

Thallus a rosette of deep olive to black crenate lobes 2–3 mm long, much convoluted, sometimes with cylindrical lobules, gelatinous when wet. Apothecia not common, about 1 mm broad, the disc and exciple concolorous with the thallus. Spores 8 per ascus, once septate.

Infrequent, on calcareous or sandy soil. Specimen examined: *Rogers*, 8.xii.1967.

Dermatocarpon compactum (Mass.) Lettau 1912: 52.

Placidium compactum Mass. 1856:32.

Thallus of minute (0.2–0.3 mm) squamules packed together forming a dark brown plaque. Perithecia opening by pores, spores 8 per ascus, non-septate.

Common, but inconspicuous on calcareous pebbles. Specimen examined: *Rogers*, 9.ix.1969.

Dermatocarpon lachneum (Ach.) Smith 1911:270.

Lichen lachneus Ach. 1798:140.

Thallus of tan to dark brown squamules 1–2 mm across, initially ovate, entire, plane to slightly convex but becoming crenate and distorted with age. The rhizoids of this species remain fine, permitting it to be distinguished from the coarse rhizined *Endocarpon pusillum*. Perithecia opening by pores. Spores 8 per ascus, non-septate.

Common and conspicuous on calcareous soil, superficially like *Endocarpon pusillum*. Specimens examined: *Barnard*, 12.xii.1927; *Rogers*, 20.xi.1967.

Diploschistes ocellatus (Vill.) Norm. 1853:232.
Lichen ocellatus Vill. 1789:988.

Thallus an extensive white crust of smooth, chalky areoles up to 1 mm broad. Apothecia poorly developed or absent on the reserve, but sessile with a thick thalloid exciple and a black, flat disc. Spores 8 per ascus, black, muriform.

A rare, but quite striking lichen on calcareous soil in deeply shaded sites. Specimens examined: Anon., May 1942; *Eardley*, June 1946; *Rogers*, 2.v.1969.

Diploschistes scruposus (Schreb.) Norm. 1853:232.
Lichen scruposus Schreb. 1771:133.

Thallus an extensive floury grey or white crust with areoles <1 mm across. Apothecia very common, immersed, c. 0.5 mm in diam., the disc black. Spores 8 per ascus, black, muriform.

Common on calcareous soils. Specimens examined: *Barnard*, 12.xii.1927; *Eardley*, June 1946; *Rogers*, 20.xi.1967.

Endocarpon pusillum Hedw. 1789:56.

Thallus of brown, usually crenate, squamules with extensive rhizoidal and stolon development below. Perithecia immersed, opening by a black pore on the upper surface. Spores usually 2 per ascus, black, muriform.

Common on calcareous soils and firm sands, easily confused with *Dermatocarpon lachneum*. Specimen examined: *Rogers*, 20.xi.1967.

Fulgensia subbracteata (Nyl.) Poelt 1961, no. 137.
Lecanora subbracteata Nyl. 1883:534.

Thallus crustose, somewhat granular, very pale yellow when dry, bright yellow when wet, the margins showing minute lobes. Apothecia adnate, rare, the exciple colored like the disc, deep rusty brown. Spores 8 per ascus, non-septate.

Rare, on sandy and calcareous soils. Specimen examined: *Rogers*, 2.v.1969.

Heppia lutosa (Ach.) Nyl. 1885:45.
Collema lutosum Ach. 1814:309.

Thallus squamulose grey-green to olive, squamules forming small rosettes (5 mm in diam.) the margins granular. Apothecia immersed, usually one per squamule, disc red. Spores 8 per ascus, non-septate.

Common on calcareous soils. Specimen examined: *Rogers*, 4.vii.1969.

Heppia polyspora Tuck. 1882:115.

Thallus squamulose, tan to olive, squamules 1–4 mm in diam., round or crenate with a thickened margin. Apothecia usually one per squamule, immersed, the disc red. Spores many (>32) per ascus, non-septate.

Common, but very obscure on sandy and calcareous soils. Specimen examined: *Rogers*, 4.vii.1969.

*_Lecanora sphaerospora_ Muell. 1892:196.

Thallus crustose, white to grey, areolate, areoles up to 1 mm in diam. Apothecia sessile with a white margin, usually crenate, the disc grey, at first flat then becoming markedly convex. Spores 8 per ascus, non-septate.

Very common on calcareous pebbles. Specimens examined: *Rogers*, 8.xii.1967; *Rogers*, 30.vi.1969.

*_Lecidea crystallifera_ Tayl. 1847:148.

Thallus of grey-brown squamules 1–3 mm broad, entire to crenate or somewhat lacerate, the upper surface sculptured into a mass of pyramid-like solid angles, giving it a crystalline appearance. Apothecia not found at Koonamore, but sessile, flat to convex, the disc dark grey to black. Spores 8 per ascus, non-septate.

Very common on calcareous soils. Specimen examined: *Rogers*, 20.xi.1967.

Lecidea decipiens (Hoffm.) Ach. 1803:80
Psora decipiens Hoffm. 1794:68.

Thallus of pink squamules 1–7 mm broad, the margins or the whole thallus white pruinose, the squamules entire to crenate or lacerate, often markedly concave at the centre with deflexed margins. Apothecia rare, marginal, sessile, the disc black, markedly convex. Spores 8 per ascus, non-septate.

One of the most common and obvious lichens on soil in the reserve. Specimens examined: *Barnard*, 12.xii.1927; Anon., 1.ix.1932; *Eardley*, June 1946; *Rogers*, 20.xi.1967.

*_Parmelia convoluta_ Kremph. 1880:337.

Thallus yellow-green above, foliose; the lower surface light brown, sparsely rhizinate, usually concealed within the rolled and convoluted lobes, the older lobes often rugose above, up to 5 mm broad. Apothecia very rare, sessile, the disc brown, the margin yellow green.

This species is separated from the very similar *P. australiense* by the presence of salicinic acid (medulla K+ yellow becoming red) whereas *P. australiense* lacks salicinic acid and is therefore K— (Kurokawa 1969). Mixed populations have been found in some places, but all Koonamore material examined is *P. convoluta*.

Common, lying free on the soil surface. Specimens examined: *Barnard*, 12.xii.1927; Anon., May 1942; *Rogers* 20.xi.1967; *Rogers*, 17.v.1969.

*_Parmelia ferax_ Muell. 1886:257.

Thallus yellow-green above, foliose, the lower surface black, sparsely rhizinate, lobes 0.5–1.5 mm broad, margins crenate, branching irregular. Apothecia common, margin colored like the thallus, the disc brown. Spores 8 per ascus, non-septate.

Parmelia ferax may be confused with *P. rutidota*, but it has a more rugose thallus, has no K+ acids, and produces physodalic not protocetraric acid (Kurokawa 1967).

Common on dead twigs and bark of trees. Specimens examined: *Barnard*, 12.xii.1927; Anon., May 1942; *Womersley*, 6.vi.1946; *Rogers*, 20.xi.1967.

Parmelia cf. *lineola* Berry 1941:77.

Thallus yellow-green above, foliose, the lower surface pale to dark brown, closely adnate to the substrate, lobes 2–5 mm broad, sub-dichotomous, the upper surface becoming rugose and cracking. Apothecia not seen.

The subgenus *Xanthoparmelia* to which this material belongs is complex and poorly understood. Absence of isidia and soredia, and presence of salicinic acid, place this species close to *P. lineola*, a western North American species.

Rare on quartzitic pebbles. Specimens examined: *Womersley*, 6.vi.1946; Anon., May 1948; *Rogers*, 21.xi.1967.

Parmelia pulla (Schreb.) Ach. 1814:206.

Lichen pullus Schreb. 1771:131.

Thallus dark olive or brown above, foliose, the lower surface dark, lobes 1.5–3.0 mm broad, sparsely rhizinate, the margins crenate, branching irregular. Apothecia rare, the margin concolorous with the thallus, disc dark brown. Spores 8 per ascus, non-septate.

Rare, on deeply shaded calcareous soils and rocks. Specimens examined: *Womersley*, 6.vi.1946; Anon., May 1948.

**Parmelia reptans* Kurok. in Baker *et al.* 1973:137.

Thallus yellow-green above, foliose, forming rosettes 1–3 cm in diam., more or less dichotomously branched, lobes linear, 0.7–2.0 mm broad, lower surface pale brown with long black rhizoids. Apothecia unknown.

Very similar to *P. amphixantha* Muell., however *P. reptans* tends to have wider lobes (*P. amphixantha* up to 1 mm) and has fumaprotocetraric, succinprotocetraric and usnic acids (Pd+ yellow turning crimson) whereas *P. amphixantha* has norstictic, stictic and usnic acids (Pd+ yellow) (Baker *et al.* 1973).

On soil, usually in deep shade. Specimens examined: *Barnard*, 12.xii.1927; *Eardley*, June, 1946.

**Parmelia subalbicans* Stirt. 1877-78:254.

Thallus grey-blue, foliose, light brown below, lobes 1.5–4.0 mm broad, sparsely rhizinate, the margins irregular, branching sub-dichotomous. Apothecia common, the margin concolorous with the thallus, disc brown. Spores 8 per ascus, non-septate.

Very common on bark and dead twigs, usually with *P. ferax*. Specimens examined: Anon., May 1942; *Womersley*, 6.vi.1946; *Rogers*, 20.ix.1967.

Physcia alba (Fée) Muell. 1887:12.

Parmelia alba Fée 1824:125.

Thallus grey-blue, foliose, forming distinct rosettes, closely adnate, lobes up to 3 mm broad, without soredia or isidia, pale below. Apothecia common, the margin concolorous with the thallus, disc brown, usually pruinose. Spores 8 per ascus, once septate, brown. Cortex K+ yellow, Pd+ yellow, Medulla K+ yellow, Pd+ yellow.

Rare on the bark of trees. Easily confused with *P. stellaris* in the field. Specimens examined: Anon., May 1948.

Physcia albicans (Pers.) Thoms. 1963:88.

Parmelia albicans Pers. 1811:17.

Thallus blue to somewhat olive, foliose, forming distinct rosettes, closely adnate, lobes 1–4 mm broad, contiguous to the margin with ascendent labriform soralia; pale below, becoming dark. Apothecia rare, spores 8 per ascus, once septate, brown. Cortex K+ yellow becoming red, Pd—; medulla K+ yellow becoming red, Pd—.

Rare, found on the bark of *Casuarina cristata*. Specimens examined: Anon., May 1948; *Rogers*, 20.xi.1967.

Physcia stellaris (Ach.) Nyl. 1856:307.

Parmelia stellaris Ach. 1803:209.

Thallus blue-grey, foliose, forming rosettes or extended patches, not closely appressed, lobes 0.5–1.5 mm broad, without isidia or soredia, pale below. Apothecia common, the margin coloured like the thallus, the disc brown, often bluish pruinose. Spores 8 per ascus, once septate, brown. Cortex K+yellow, Pd—; medulla K—, Pd+ yellow brown.

On the bark of trees, not common. Specimen examined: *Rogers*, 20.xi.1967.

Physciopsis syncolla (Tuck.) Poelt 1965:30.

Physcia syncolla Tuck. in Nyl. 1858:428.

Thallus brown, foliose, forming extensive patches, closely adnate, lobes about 1 mm broad, dark below. Apothecia up to 1.5 mm broad, the margin concolorous with the thallus, the disc brown, sometimes pruinose. Spores 8 per ascus, once septate, brown.

Obscure, but in extensive patches on the bark of *Acacia aneura*. Specimen examined: *Rogers*, 20.xi.1967.

Synalissa symphorea (Ach.) Nyl. 1856:264.

Lichen symphoreus Ach. 1798:135.

Thallus dark olive-green to black, minutely fruticose, packed into patches up to 3 cm in diam., individual thalli 1 mm high, less than 1 mm in diam., branched, the lobes tightly packed, somewhat nodulate. Apothecia up to 0.2 mm in diam., more or less immersed in the tips of the upright lobes. Spores usually 8 per ascus, non-septate.

A very inconspicuous species on calcareous soil. Specimen examined: *Rogers*, 20.xi.1967.

Teloschistes chrysophthalmus (L.) Th. Fr. 1861:51.

Lichen chrysophthalmus L. 1771:311.

Thallus gold to grey, foliose, forming a shrubby clump, the lobes 0.5–2.5 mm broad with long marginal fibrils, with neither isidia nor soredia. Apothecia common, pedicellate, up to 6 mm in diam., with fibrils on the margin, concolorous with the thallus. Spores 8 per ascus, septate.

On twigs of bushes and bark of trees. Specimens examined: *Barnard*, 12.xii.1927; Anon., May 1942.

Toninia coeruleonigricans (Lightf.) Th. Fr. 1871: 336.

Lichen coeruleonigricans Lightf. 1777:805.

Thallus of dark grey, small (1 mm in diam.) inflated, reticulately cracked, usually blue-pruinose squamules. Apothecia often larger than the squamules, the margin and the disc both black, often pruinose. Spores 8 per ascus, fusiform, once septate.

Common on calcareous and sandy soils. Specimens examined: *Barnard*, 12.xii.1927; Anon., May 1942; *Womersley*, 6.vi.1946; Anon., May 1948; *Rogers*, 30.iv.1969.

Verrucaria aff. *calciseda* DC. in M. Lam. & DC. 1805:317.

Thallus a whitish crust, almost indistinguishable from the substrate, smooth, somewhat powdery. Perithecia immersed in pits in the thallus, showing as sunken black spots barely 0.1 mm in diam. Spores 8 per ascus, 24 μm by 12 μm, non-septate, hyaline.

An extremely obscure species on calcareous pebbles, appearing to be a pitted limestone surface unless carefully examined. Specimen examined: Anon., June 1946.

Xanthoria ectanea (Ach.) Räs. ex R. Filson 1969: 83.

Parmelia parietina var. *ectanea* Ach. 1810:464.

Thallus forming a golden rosette, foliose, adnate to the substrate, the lobes smooth, up to 2.5 mm broad, the margin raised then deflexed. Apothecia common, about 2 mm in diam. Spores 8 per ascus, septate.

Rare on twigs of *Lycium australe*. Specimens examined: Anon., May 1942; *Rogers,* 30.iv.1969.

35. **Rogers, R.W.** (1977). The 'City Effect' on lichens in the Brisbane area. *Search*, **8**, 75-77

The 'City Effect' on Lichens in the Brisbane Area

R.W. Rogers
Botany Department, University of Queensland, St Lucia

Lichen populations in the Brisbane area reflect the level of industrial activity in their environment. Some species and genera show enhanced development in industrial areas, others are less developed or absent entirely from such areas. This is probably a response to degree of air purity.

The adverse effect of cities on lichen populations has been known by lichenologists for a long time, the earliest record perhaps being Nylander (1866) who commented on the deterioration of the lichen flora in the Luxembourg Gardens, Paris. Since that time a great amount of work has been done on the phenomenon, exploring not only the patterns found in lichen distribution around cities, but the causation of the patterns. In almost every case air pollution has been cited as the cause. Hawksworth and Rose (1970) have concluded that sulphur dioxide has caused major changes in the lichen flora of England and Wales, a conclusion reached by other workers for many other areas (LeBlanc and Rao, 1973). A number of studies (Hawksworth, 1973) have used lichen populations as the basis for mapping air purity. Chronic sulphur dioxide concentrations as low as 30 micrograms per cubic metre have been shown to cause changes in lichen populations, even excluding the most pollution-sensitive species (Hawksworth and Rose, 1970).

The vast preponderance of studies has, however, been carried out in the cool temperate regions of Europe and North America, around point sources of pollution, or in heavily polluted industrial cities (Hawksworth, 1973). It was uncertain whether a similar effect could be detected in a subtropical city such as Brisbane, which has a diffuse industrial complex and relatively little heavy industry.

During 1975 lichens were collected from the trunks of 343 trees in the Brisbane City Council area in such a way that at least five trees were examined in each of 49 arbitrarily defined grid units. Each location from which a collection was made was classified as industrial or non-industrial on the basis of current land use. The lichens collected were returned to the laboratory, determined, and distribution patterns examined.

The frequency of industrial sites in each grid unit was calculated, and was then smoothed by averaging the proportion of industrial sites in each unit and all those adjoining it (usually eight others). These smoothed valued were mapped (Figure 1). This technique tended to block up a simple pattern across the whole area, at the expense of detail, allowing only large-scale patterns to emerge. From Figure 1 it is apparent just how diffuse industrialisation is in the Brisbane area, although it must be noted that most of the heavy industry is grouped about the mouth of the Brisbane River where there are two oil refineries and a large chemical industry.

The lichen flora on tree trunks proved to be unexpectedly rich in species. Over 150 species have been determined to date, with a number of groups not yet subject to detailed investigations. For a comparison it is interesting to compare the data of Moore (1968) for the lichen flora of Florida with the present study. For selected taxa the number of species found in this study (followed by Moore's figures in parentheses) are *Parmelia* 40 (39), *Pyxine* 7 (4), *Dirinaria* 5 (4), *Anaptychia* 2 (6), *Physcopsis* 2 (3), *Physcia* 4 (6). In order to avoid complications which could result from a taxon occurring only on a single tree species, and the distribution pattern thus reflecting that of the tree, only those lichen taxa which occurred on a range of widely distributed trees are considered here.

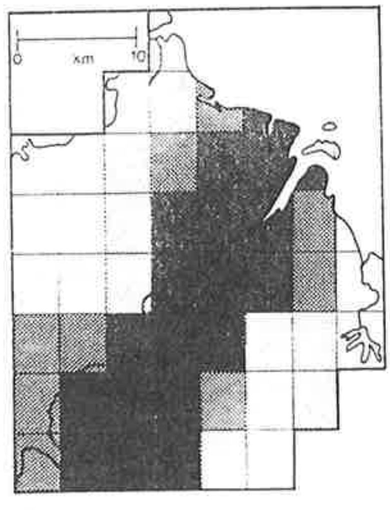

FIGURE 1
Smoothed frequency of industrial activity at sites examined within each grid unit. Shading (from dark to white) represents more than 20%, 10-19%, 0.1-9% and 0% industrial sites respectively.

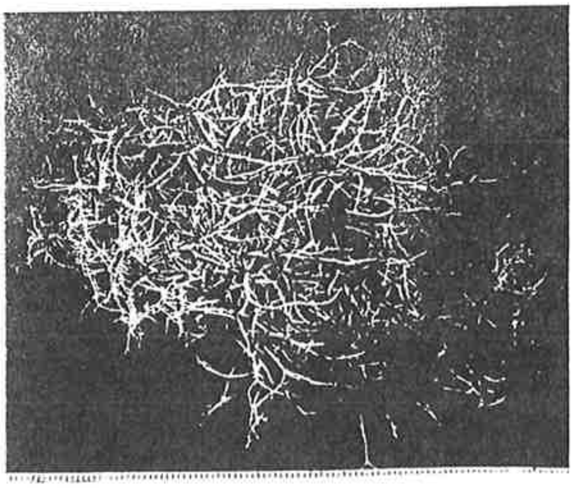

FIGURE 2
A well developed specimen of *Usnea arida* Motyka, a fruticose species collected from the rural, western margin of the study area. The small scale divisions are millimetres.

Fruticose species (Figure 2), which are notoriously sensitive to air pollution, were absent from most of the urban areas except for the coastal strip (Figure 3). Two foliose species which show typical but contrasting patterns are *Pyxine endoleuca* (Muell. Arg.) Vain., which apparently occurs only in the urban areas, and *Parmelia rudecta* Ach. which only occurs outside the urban zone (Figure 4). *Parmelia tinctorum* Nyl., by contrast, occurred throughout the entire area studied, but was markedly less frequent in urban areas than in rural areas. The frequency of *P. tinctorum* (percentage of trees examined bearing a specimen of the species) was calculated for each grid area and then smoothed and mapped (Figure 5). It was also noted that individuals of *P. tinctorum* from polluted areas were generally much smaller than those from a rural environment, their growth apparently being stunted (Figure 6).

It was apparent that most species in the genus *Parmelia* were adversely affected by the city, but that the closely appressed species (Figure 6) in the genera *Dirinaria, Pyxine, Physcopsis,* and *Physcia* (all Physciaceae) were apparently favoured by the city. The mean number of species in both of these groups was therefore calculated for each grid unit, and these values were then smoothed and mapped (Figures 7 & 8).

There is a striking relationship between the distribution patterns mapped for the various lichen taxa and the distribution of industrial sites and urban areas: that the relationship survives the heavy smoothing is testimony to its strength; but there is no apparent relationship with climatic variation in the Brisbane region. Information concerning distribution patterns on a small scale, due to either topography or industrial activity, is necessarily lost in the smoothing process. One particular piece of information lost concerns the Darra area in the south-west of the study zone. In this area the lichen populations are reduced to a very low level in a restricted area around a cluster of industrial sites including brick kilns and a cement works. Although very few species survive in this area, the smoothing quite eliminates any indication of this from the maps, while the geographically more extensive industrial activity in the area around the mouth of the Brisbane River is strongly reflected in the maps.

These patterns are in accord with those found in the many studies done elsewhere. The larger, more prominent fruticose and foliose species have, by and large, disappeared from urban regions; only the smaller, more closely appressed species thrive, some of which are apparently favoured by the urban environment. Variation in either light intensity or air purity might be invoked to explain the pattern. Trees in the urban area are usually isolated and have trunks exposed to full sun. Those in the rural area around Brisbane are commonly in more or less natural forest stands in which light intensity on trunks would be reduced somewhat, although the canopy is generally very diffuse. Sulphur dioxide in the air in the Brisbane area is sufficiently concentrated to be expected to influence the lichen flora. The mean daily sulphur dioxide levels, averaged over the five-year period June 1970 – June 1975 (Anon, 1970/1 - 1974/5), show a range from 17 to 45 micrograms per cubic metre (Figure 9): a range which has been found to cause quite marked changes in the lichen flora elsewhere (Hawksworth, 1973). The enhancement of some species populations in the urban areas may therefore be due to removal of competing, but pollutant sensitive, species, or to the provision of nutrients in the air that are normally in short supply, or both.

The presence of fruticose taxa (*Ramalina* and *Teloschistes*) in the coastal belt in close proximity to heavy industrial activity at the Brisbane River mouth is not necessarily incompatible with an air-purity hypothesis for control of the distribution of these taxa. The fruticose growth forms were found only in mangrove populations, which were downwind from the industrial areas. The prevailing winds are from the south-east in the summer when the lichen thalli

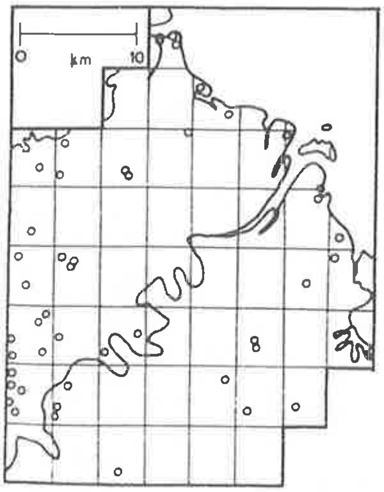

FIGURE 3

Sites at which fruticose lichens *(Ramalina, Teloschistes* and *Usnea)* were found.

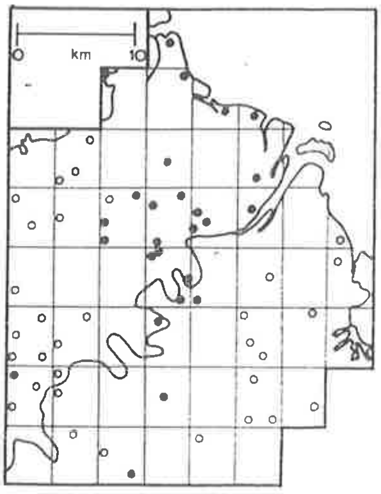

FIGURE 4

Sites at which *Parmelia rudecta* (○) and *Pyxine endoleuca* (●) were found.

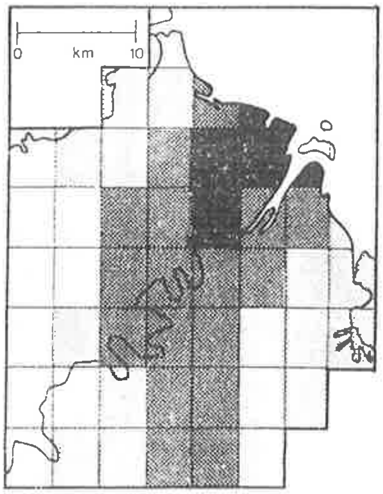

FIGURE 5

Smoothed frequency of occurrence of *Parmelia tinctorum* within each grid unit. Shading (from dark to white) represents frequencies of less than 30%, 30-39%, 40-49%, and more than 50% respectively.

are likely to be moist and therefore most susceptible to damage from sulphur dioxide (Coker, 1967). In the winter and spring, when westerly winds are common and might be expected to carry pollutants into these areas, the lichen thalli are likely to be air-dry, and so will not absorb sulphur dioxide so readily.

While the light and air-purity hypotheses are not mutually exclusive, on the basis of world experience the latter appears the more likely to explain the patterns observed.

These results demonstrate a city effect on lichen populations in a diffuse sub-tropical city. The pattern is quite marked even using very crude quantitative analysis. If it can be demonstrated by field and laboratory studies that air quality, or more specifically sulphur dioxide, causes the pattern, then a simple and relatively cheap method for estimating air purity could be established in the Brisbane area, thus augmenting data available from the few monitoring stations in the region.

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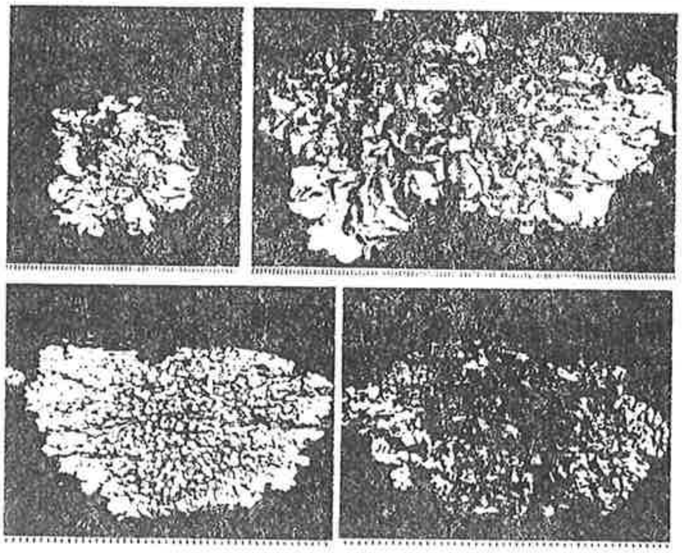
FIGURE 6

Top: specimens of *Parmelia tinctorum* (a large foliose species) from an inner city area (left) and a rural area (right), showing the reduced size of specimens from urban areas. Bottom: specimens of small closely adnate foliose species from urban areas. Left — *Dirinaria applanata* (fee) Awasthi; right — *Pyxine endoleuca*. The scale divisions are millimetres.



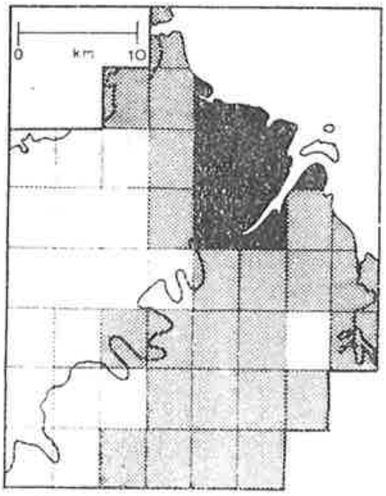


FIGURE 7

Smoothed number of Parmelia species occurring within each grid unit. Shading (from dark to white) represents 1-2.9, 3-4.9, 5-6.9, and more than 7 species respectively.

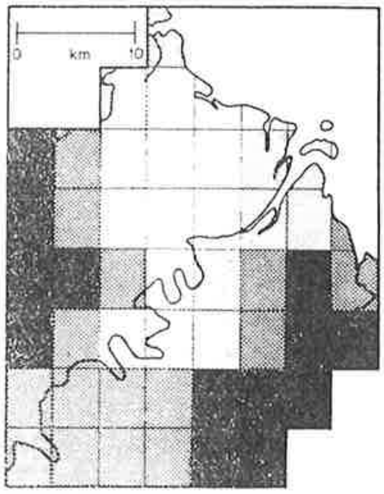


FIGURE 8

Smoothed number of Physcioid species occurring within each grid unit. Shading (from dark to light) represents less than 7, 7-8.5, 8.6-9, and more than 9 species respectively.

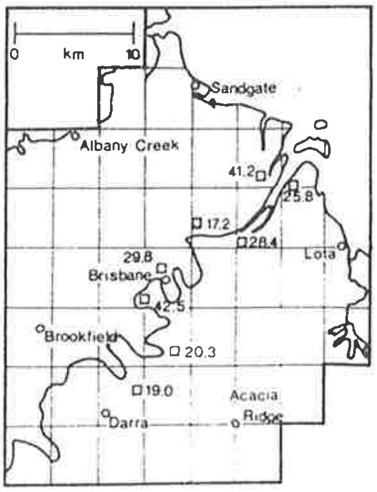


FIGURE 9

Mean daily aerial sulphur dioxide concentrations for all available years at all stations in the study area.

36. **Rogers, R.W. & Guymer, G.** (1993). Lichen collections in Brisbane, Queensland, Australia. *Taxon* **42**, 719-721.

HERBARIA AND INSTITUTIONS

Edited by Patricia K. Holmgren & Noel H. Holmgren[1]

Lichen collections in Brisbane, Queensland, Australia

R. W. Rogers[2] & G. P. Guymer[3]

Summary

Rogers, R. W. & Guymer, G. P.: Lichen collections in Brisbane, Queensland, Australia. – *Taxon* 42: 719-721. 1993. – ISSN 0040-0262.

The lichen collection from the University of Queensland Herbarium (BRIU) has been consolidated with that in the Queensland Herbarium (BRI). The collection numbers over 20,000 packages, and is rich in tropical and subtropical material. Types collected by Shirley and Bailey and described by Stirton, Müller Argoviensis, and Shirley are to be found in the collection.

History

Lichen collections have been made in Queensland by a number of workers over an extended time span. Noteworthy among the early collectors were John Shirley and F. Manson Bailey, whose efforts in the nineteenth century resulted in the description of very large numbers of species from tropical Australia by James Stirton of Glasgow and J. Müller (Argoviensis) of Geneva. Shirley also described some new species himself. While Shirley's collections are widely dispersed with some in the Glasgow Museum (GLAM) and the Natural History Museum (BM) (Rogers, 1981), many are located in the collections long held in the Queensland Herbarium (BRI). Similarly, collections by Bailey are scattered in Geneva (G) and in BM but with many in Brisbane.

The lichen collection received little attention in the first 70 years of this century, but accumulated some materials as exchange, and as occasional collections.

Lichenological activity commenced at the University of Queensland in 1971, when R. W. Rogers brought a small collection with him to the Botany Department (BRIU), and continued with lichen studies. Rogers and his students built up this collection over the period 1971 until 1992. It has now been transferred to BRI. The transfer took place following a cessation of lichen taxonomy by Rogers and Nell Stevens in the department, and under pressure of space within the Botany Department. A consequence of the transfer of the BRIU collections is a single relatively large and quite rich collection in BRI where the collections earlier held in BRIU are now housed in more appropriate space and have full professional curation from a

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[1] New York Botanical Garden, Bronx, New York 10458-5126, U.S.A.

[2] Botany Department, The University of Queensland, Queensland 4072, Australia.

[3] Queensland Herbarium, Meirs Road, Indooroopilly, Queensland 4068, Australia.

skilled professional staff. The security of the collection is now guaranteed. The exact number of collections transferred is uncertain, but approximates 20,000 packages. When added to the approximately 2000 historical collections housed previously in BRI, this makes a significant bulk of herbarium specimens.

Collectors

The BRI material was largely collected by Shirley and Bailey in the second half of the nineteenth century. Their collections were extensive, both in terms of total numbers and of area covered. These historically important collections were augmented in the early part of this century by material which appears to be an exsiccate from Vienna, and includes much Australian material collected by Edward Cheel of Sydney Herbarium.

The Botany Department Herbarium contained the major portion of collections by Rogers, Stevens, and C. Scarlett. Some smaller but significant contributions came from J. Conran and P. Merrotsy. An incomplete set of W. A. Weber's exsiccatum was included in the transfer.

The collection now assembled in BRI, therefore, includes materials both from historically significant collectors as Shirley and Bailey, as well as recent workers.

Contents

The collection is rich in material from a number of genera revised at the Botany Department in recent years. These include *Haematomma* (Rogers, 1982, 1985), *Pyxine* (Rogers, 1986a, b), *Ramalina* (Stevens, 1982, 1983, 1986, 1987), and *Usnea* (Rogers & Stevens, 1988; Stevens, 1991a, b). There are substantial collections of lichens from mangrove habitats, discussed by Stevens & Rogers (1979) and Stevens (1979). In addition, a large collection of urban corticolous lichens was accumulated and reported on in relation to air pollution by Rogers (1977) and Scarlett (1990).

The collection is therefore particularly rich in such genera as *Dirinaria*, *Haematomma*, *Heterodermia*, *Pyxine*, *Ramalina*, *Usnea*, and in the foliose *Parmeliaceae* of tropical regions. Collections from rainforests are also present.

It is planned to have the specimen label data of the collection available on the Queensland Herbarium computer database (HERBRECS) by early 1994.

Types

The collections made by Shirley and Bailey were not all well curated in the first half of this century, and, because of the tropical climate of Brisbane, some suffered. The practice of mounting collections in albums, often on both sides of the page, caused further damage to materials. Almost all the material which appears to be the collection of Shirley was mounted in such volumes, and was without annotations except a species name. Shirley's collections apparently described by Stirton and the Bailey collections tend to have more information with them. Some of these collections have been repackaged in recent years to improve accessibility.

It is not always clear whether the specimens in BRI are duplicates or materials returned by Stirton or Müller Argoviensis. Types of species described by Shirley, Stirton, and Müller Argoviensis may be present in the collection.

As a matter of policy holotype material was not retained in the BRIU collection, but was usually lodged in the Melbourne Herbarium (MEL). A number of isotypes of material described by J. Hafellner, G. Rambold, R. W. Rogers, G. N. Stevens, and A. Vězda are included, together with isotypes distributed by W. A. Weber.

The consolidated collection, therefore, is quite rich in isotype material, but also contains holotype and lectotype material for some species described by Stirton and Müller. Taxonomists revising material from tropical regions or for Australia are likely to find these collections a valuable asset, and are encouraged to take advantage of their availability.

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Austrobaileya 1(5): 502-510 (1982)

TYPIFICATION OF THE SPECIES OF LICHENS DESCRIBED FROM AUSTRALIAN SPECIMENS BY JAMES STIRTON.

By Roderick W. Rogers

Botany Department, University of Queensland.

Abstract

During the nineteenth century James Stirton published 103 lichen names as new species from the Australian continent (excluding Tasmania). One of these was invalidly published. Type specimens have been located for 82 of the taxa, and the nature of the material – holotype, lectotype or syntype, designated. The types are in three herbaria, British Museum (Natural History) London, Glasgow Museum and Art Gallery, and the Queensland Herbarium, Brisbane.

INTRODUCTION

James Stirton described over 100 new lichen taxa from Australia. Working from Glasgow he received material from all parts of the tropical and subtropical world. He received his Australian material mostly through F. M. Bailey, the Colonial Botanist for Queensland.

Most of the species described by Stirton he published himself, but a number of Australian taxa were published in works by F. M. Bailey. The standard of the publication is regrettably low: in many cases no type specimen is indicated, and in some no collector, location or date is indicated. When specimens are matched with the descriptions it is apparent that errors occurred in transcribing information in notes with the specimen to the publication. This means that no Holotype can be designated for most of the Australian material, and that designation of a Lectotype is necessary.

In 1977/78 the collections in the British Museum (Natural History) (BM) and Glasgow Museum and Art Gallery (GLAM) were searched for Stirton types from continental Australia. The annotations were copied, and a set of the annotations lodged with the Melbourne Herbarium (MEL). Brisbane herbarium (BRI) has been searched for types also.

The Stirton collection was divided after his death, and distributed to GLAM and to BM. No logic in the distribution of taxa is apparent from the Australian collections in the herbaria. Some Stirton types were sent back to F. M. Bailey in Brisbane (BRI). The collections in GLAM are usually better than the others, with more complete labels and more material, however, this is not universally true. It appears that the GLAM material has not been disturbed since it came to the museum. The BM collections, however, have been stuck on to sheets often with many other specimens, and appear in most cases to be only fragments of the material in GLAM, although the sole representation of some material is in BM.

The BRI collections have commonly been mounted in large, and now crumbling, folios but some are in packets and boxes. There is no pattern detectable concerning which specimens are in BRI and which are not. Some material determined by Stirton was later forwarded by Bailey to Müller-Argoviensis in Geneva, and it may be that some missing Stirton types will be found redetermined in Geneva Herbarium (G).

TYPIFICATION

Taxa are arranged in alphabetical sequence under the name published by Stirton. New combinations or published redeterminations are indicated in square brackets immediately below the original name. The type is then identified, and the collection in which th type may be found and its status indicated. Where the taxon appears to be misplaced currently the likely genus for the material is then indicated.

Arthonia albofarinosa Stirt. in Bailey 1899b p. 488
Type: 'Queensland, near Warwick. F. M. Bailey. no. 505, in the gap between upper Freestone Creek and Maryvale Valley. Rec. 17 Jan. 1899' GLAM (selected here as LECTOTYPE). An incompletely labelled, less heavily annotated specimen in BM is probably an isolectotype.

Arthonia conspersula Stirt. in Bailey 1899a p. 40
Type: No collector or location indicated.
No specimen found.

Arthonia subcondita Stirt. in Bailey 1899a p. 39
Type: No collector or location indicated.
No specimen found.

Ascidium profundum Stirt. 1880 p. 70
[*Thelotrema profundum* (Stirt.) Shirley]
Type: 'Queensland, Brisbane, F. M. Bailey no. 131' GLAM (LECTOTYPE), BM (ISOLECTOTYPE). The GLAM collection is heavily annotated by Stirton, that in BM labelled 'part of type'.

Cladonia arcuata Stirt. 1888 p. 308
[*Cladia sullivanii* (Müll. Arg.) Martin *fide* Teuvo Ahti 1966.]
Type: 'Australia, Victoria, Beechworth. Falck 1881'. GLAM (here selected as LECTOTYPE).

Collema gwytheri Stirt. in Bailey 1899b p. 484
[*Collema leptaleum* Tuck. var. *leptaleum* (Degelius 1974)]
Types: 'Queensland, F. M. Bailey out of no. 380. GLAM (here selected a LECTOTYPE). Bailey 1899b says collected Gwyther. A collection in BM (also a minute fragment) is probably identical, but is without collectors number and is not so heavily annotated by Stirton.

Collema hypoplasium Stirt. in Bailey 1899b p. 484
[*Lempholemma hypoplasium* (Stirt.) Zahlbr.]
Types: 'Gowrie Mts. nr. Brisbane, F. M. Bailey 1877 no. 30' GLAM (HOLOTYPE). A specimen in BM without a collection number may be a fragment of the type. This collection appears to be a *Physma* species.

Eumitria baileyi Stirt. 1882 p. 1
[*Usnea baileyi* (Stirt.) Zahlbr.]
Type: 'Queensland, F. M. Bailey n. 164' BM (here designated LECTOTYPE). This specimen is not Holotype as indicated by Swinscow and Krog (1974), as Stirton indicated two collections, simply as Brisbane (F. M. Bailey) and Fernando Po (G. Thomson).

Endocarpon baileyi Stirt. 1881 p. 74
[*Leptotrema baileyi* (Stirt.) Shirley; *Leptotrema wightii* (Tayl.) Müll.Arg.]
Type: 'Queensland, Brisbane, F. M. Bailey no. 249 Rec.' GLAM (HOLOTYPE), BRI (ISOTYPE). A collection in BM without a collection number is possibly a fragment of the type.

Eumitria formosa Stirt. 1883 p. 297
[*Usnea baileyi* (Stirt.) Zahlbr. (Swinscow & Krog 1974)]
Type: 'Australia, Peak Range; Slatter, ex Hv. Baron v. Müller' BM (selected here as LECTOTYPE).

Graphis circumfusca Stirt. 1880 p. 73
Types: 'Queensland, Brisbane, F. M. Bailey "white lines" no. 201'. GLAM (here selected as LECTOTYPE) 'Queensland, Brisbane, F. M. Bailey "white lines" no. 201". BM (ISOLECTOTYPE). The GLAM material is more heavily annotated by Stirton.

Graphis eludens Stirt. 1880 p. 72
[*Phaeographis eludens* (Stirt.) Shirley]
Type: Bailey 287.
No type collection located.

Graphis gyridia Stirt. 1880 p. 77
[*Graphina gyridia* (Stirt.) Zahlbr.]
Type: 'Australia. Waterloo. Gippsland. N. Paton'
BM (here selected a LECTOTYPE).

Graphis mucronata Stirt. 1876a p. 95
[*Phaeographis mucronata* (Stirt.) Shirley]
Type: 'Australia, Riverina. H. Paton'. BM (here selected as LECTOTYPE).

Graphis pertenella Stirt. 1880 p. 72
[*Graphina pertenella* (Stirt.) Shirley]
Type: Bailey 79, near Brisbane. BRI (HOLOTYPE).

Graphis repleta Stirt. 1880 p. 73
[*Graphina repleta* (Stirt.) Shirley]
Type: 'Corticola. Brisbane, coll. Bailey 226 ex parte'. BRI (HOLOTYPE).

Graphis subvelata Stirt. ex Bailey 1889b p. 488
[*Graphina subvelata* (Stirt. ex Bailey) Zahlbr.]
Type: without location or collector. BM (here selected as LECTOTYPE).

Lecanora alligata Stirt. ex Bailey 1899a p. 38
Type: 'Queensland, F. M. Bailey out of No. 27' BM (selected here as LECTOTYPE).

Lecanora mundula Stirt. 1881 p. 76
Type: 'Australia. Waterloo, Gippsland. H. Paton. GLAM (here selected as LECTOTYPE). BM (ISOLECTOTYPE). The GLAM collection is more heavily annotated by Stirton.' This is not a species of *Lecanora*, but is possibly *Bombyliospora*.

Lecanora phaeanthella Stirt. in Bailey 1899a, p. 38
Type: no collector or location designated.
No collection located.

Lecanora phaeoplaca Stirt. ex Bailey 1899b, p. 487
[*Haematomma phaeoplacum* (Stirt. ex Bailey) Zahlbr.]
Type: no location or collector designated. No collection located.

Lecanora punicea var. *infusea* Stirt. ex Bailey 1889a p. 38
[*Haematomma puniceum* var. *infuseum* (Stirt. ex Bailey) Zahlbr. 1928 5, 770]
Type: 'Queensland, Jimbour, F. M. Bailey (out of no. 10)' BM. Of the two BM specimens the heavily annotated specimen, not that from Kew is designated LECTOTYPE.

Lecanora pulverata Stirt. 1880 p. 70.
Type: 'Queensland, Brisbane, F. M. Bailey, no. 86 near Brisbane River'. GLAM (HOLOTYPE). A specimen in BM may be a fragment of the type, but has no collectors number.

Lecanora rutilescens Stirt. in Bailey 1899a p. 38
Type: No collector or location designated.
No collection located.

Lecanora subpurpurea Stirt. in Bailey 1899b p. 487
Type: No collector or location designated.
No collection located.

Lecidea aberrata Stirt. 1881 p. 71
Type: 'Taylor's Range, F. M. Bailey no. 190'. GLAM (here designated LECTOTYPE) BRI (ISOLECTOTYPE). This appears to be a *Lecanora*.

Lucidea demutans Stirt. 1880 p. 71
[*Buellia demutans* (Stirt.) Zahlbr.]
Type: 'Queensland. F. M. Bailey no. 82' GLAM (HOLOTYPE).

Lecidea foliata Stirt. 1880 p. 71
[*Phyllopsora foliata* (Stirt.) Zahlbr.]
Types: 'Brisbane, F. M. Bailey 156'. GLAM (selected here as LECTOTYPE), BRI (ISOLECTOTYPE).

Lecidea glomerella Stirt. in Bailey 1899b p. 487
[*Rinodina glomerella* (Stirt. in Bailey) Zahlbr.]
Type: No collector or location designated. No material located. The description suggests the collection was a *Buellia* species.

Lecidea grossulina Stirt. 1881 p. 77
[*Catillaria grossulina* (Stirt.) Zahlbr.; *Catillaria grossa* (Pers.) Körb. *fide* J. Mackenzie Lamb iv. 1953]
Type: Australia, Fern Tree Gully. H. Paton. Type 223(5). GLAM (here designated LECTOTYPE).

Lecidea inalbescens Stirt. 1880 p. 72
[*Opegrapha inalbescens* (Stirt.) Müll. Arg.]
Type: 'Brisbane, F. M. Bailey on Rosewood Scrub. no. 258' GLAM (here selected as LECTOTYPE), BRI (ISOLECTOTYPE). The specimens are neither *Lecidea* nor *Opergrapha*, but may be *Lecanactis*.

Lecidea nodulosa Stirt. in Bailey 1899b p. 488
[*Lecania nodulosa* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland, Warwick F. M. Bailey no number Rec. 17th Jan. 1899'. GLAM (here selected as LECTOTYPE). The collection is probably a *Rhizocarpon* species.

Lecidea placomorpha Stirt. in Bailey 1899b p. 487
[*Rinodina placomorpha* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland, F. M. Bailey, out of no. 365' GLAM (selected here as LECTOTYPE). The collection is apparently a species of *Buellia*.

Lecidea raffii Stirt. 1876 p. 168
[*Bacidia raffii* (Stirt.) Zahlbr.]
Type: 'A Raff, Brisbane. rec. 4 Jan. 76'. GLAM (here designated LECTOTYPE); BM (ISOLECTOTYPE).

Lecidea restituta Stirt. in Bailey 1899a p. 39
[*Buellia restituta* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland, Brisbane, F. M. Bailey no. 163'. GLAM (HOLOTYPE). The description does not designate a type specimen, but the GLAM specimen is annotated 'Pubn. July 1899' and is therefore considered to be the one the description was based on. The specimen in BM may be an isotype.

Lecidea sanguinolenta Stirt. in Bailey 1899b p. 488
[*Lecania sanguinolenta* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland near Brisbane, F. M. Bailey out of no. 163'. GLAM (here selected as LECTOTYPE). (Probably collected by Gwyther, near Warwick, Qld.) Apparently a species of *Buellia*.

Lecidea subcaerulea Stirt. in Bailey 1899a p. 41
Type: Location and collector not designated.
No material located. The description indicates that this is not a *Lecidea* but probably a *Lopadium* species.

Lecidea subconnexa Stirt. in Bailey 1899a p. 39
[*Buellia subconnexa* (Stirt. in Bailey) Zahlbr.]
Type: 'Mrs. Heywood Mc. Ewan 1896. 60 miles west of Brisbane'
No collection has been located.

Lecidea subhyalina Stirt. 1880 p. 77
[*Phyllopsora subhyalina* (Stirt.) Zahlbr.]
Type: 'Australia, Waterloo, Gippsland. H. Paton' BM (selected here as LECTOTYPE). A peculiar collection with globular transparent orange apothecia, but not *Phyllopsora*.

Lecidea subnubila Stirt.
Type: 'Fassifern, Bailey 261' BRI (HOLOTYPE). A collection in BM is without a collectors number, but is probably a fragment of the type.

Lecidea subrepleta Stirt. in Bailey 1899a, p. 39
[*Buellia subrepleta* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland, Jimbour, F. M. Bailey, June 1895, no. 11. Rec. June 1897' GLAM (here designated LECTOTYPE).

Lecidea vinicolor Stirt. in Bailey 1889b p. 487
[*Bacidia vinicolor* (Stirt. in Bailey) Zahlbr.]
Type: 'Queensland, F. M. Bailey' BM (here selected as LECTOTYPE).

Miltidea consanguinea Stirt. 1898 p. 385
[*Biatorella consanguinea* (Stirt.) Zahlbr.]
Type: Australia, Hugh Paton. No collection found. The description suggests that this may have been a species of *Candelariella*.

4

Opegrapha intrusa Stirt. 1880 p. 73
Type: Bailey 125 *ex parte*. Brisbane. No collections located.

Pannaria elatior Stirt. in Bailey 1889b p. 486
Types: Strathbrook, near Warwick (Gwyther), Killarney (Bailey). No collections located.

Pannaria terrestris Stirt. in Bailey 1899 p. 486
Type: 'Near Warwick. F. M. Bailey no. 444' BM (nominated here as LECTOTYPE).

Parmelia ablata Stirt. in Bailey 1899 p. 40
An invalid name, published without a description or diagnosis.

Parmelia amplexula Stirt. 1880 p. 69
[*Parmelia scabrosa* Tayl. (*fide* M. E. Hale 1965)]
Types: 'Queensland, nr. Brisbane F. M. Bailey 262' BM (HOLOTYPE), BRI (ISOTYPE).

Parmelia angustata var. *isidiella* Stirt. 1899 p. 81
[*Anzia angustata* var. *isidiella* (Stirt.) Zahlbr.]
Type: 'New South Wales, Tilba Tilba, Mrs. Reader' GLAM (here selected as LECTOTYPE).

Parmelia brisbanensis Stirt. 1881 p. 69
[*Parmelia sulphurata* Nees ex Flot. (Hale 1965)]
Types: 'Queensland, Brisbane, F. M. Bailey no. 228' GLAM (HOLOTYPE), BRI (ISOTYPE). A collection in BM without a number may also be an Isotype.

Parmelia confertula Stirt. 1889 p. 77
[*Parmelia rutidota* Hook f. ex Tayl. (Hale 1976)]
Type: 'F. M. Bailey, 20. Darling Downs' BM (LECTOTYPE).

Parmelia cyathina Stirt. 1877–78 p. 252
[*Parmelia subrugata* Kremp. (Hale 1965)]
Types: 'Queensland, nr. Brisbane F. M. Bailey no. 3' GLAM (here selected as LECTOTYPE). A specimen in BM is probably a fragment of the lectotype. The GLAM collection is more heavily annotated by Stirton then that in BM.

Parmelia erubescens Stirt. 1877–78 p. 201
[*Parmelia subcaperata* Kremp. (Hale 1965)]
Type: 'Queensland, nr. Brisbane, F. M. Bailey no. 11' BM (here selected as LECTOTYPE).

Parmelia euplecta Stirt. 1877/78 p. 299
[*Parmelia caperata* (L.) Ach. (Hale 1976)]
Type: 'Queensland, near Brisbane. F. M. Bailey No. 108' BM (here selected as LECTOTYPE).

Parmelia exoriens Stirt. 1899 p. 76
[*Parmelia texana* Tuck (Hale 1976)]
Types: 'Brisbane, F. M. Bailey' BM (LECTOTYPE); 'Brisbane, F. M. Bailey no. 215' GLAM (ISOLECTOTYPE); 'Kirton, Illawarra' BM, GLAM (SYNTYPES). Lectotype selected by Hale 1976.

Parmelia hypoxantha Stirt. in Bailey 1899 p. 76 (non *P. hypoxantha* Müll.Arg)
[*Parmelia heterochroa* (Hale & Kurokawa 1974)]
Type: 'Warwick, Queensland, Australia. Gwyther'. BM (here selected as LECTOTYPE).

Parmelia nitescens Stirt. 1877/78 p. 299
[*Cetrelia olivetorum* (Nyl.) Culb. et Culb. (Hale 1965)]
Type: 'Queensland, near Brisbane F. M. Bailey no. 10' BM (here selected as LECTOTYPE).

Parmelia obversa Stirt. 1899 p. 76
[*Parmelia ferax* Müll.Arg. (Hale 1976)]
Types: 'Australia, Riverina, N.S.W.: Hugh Paton' GLAM (LECTOTYPE), BM (ISOLECTOTYPE). Lectotype selected by Hale 1976.

Parmelia permutata Stirt. 1877/78 p. 252
Types: 'Queensland, Brisbane, F. M. Bailey no. 25' GLAM (here selected as LECTOTYPE). 'Brisbane River F. M. Bailey no. 25' BM (ISOLECTOTYPE). Hale (1965) indicated that the BM collection was Holotype and the GLAM specimen was Isotype. He annotated the specimens (GLAM 1959, BM 1963) the other way around. I have chosen to select the large GLAM specimen as Lectotype rather than the small BM specimen. Neither can be properly identified as Holotype.

Parmelia platycarpa Stirt. 1877/78 p. 252
Types: 'Queensland, near Brisbane, F. M. Bailey' GLAM (here selected as LECTOTYPE); 'Queensland near Brisbane' BM (ISOLECTOTYPE); Hale (1965) saw only the very poor BM

specimen, and treated it as Holotype of a *nominum inqurendum*. The GLAM material is quite copious, and therefore preferred as Lectotype.

Parmelia tiliacea var. *affixa* Stirt. in Bailey 1899b p. 485.
Type: Queensland.
No specimen has been located.

Parmelia redacta Stirt. 1899 p. 76
Types: New South Wales, Illawarra, Mr. Kirton 1882' GLAM (here selected as LECTOTYPE); BM (ISOLECTOTYPE). The GLAM collection is *Dirinaria applanata* (Fee) Awasthi. The BM collection includes some *Anaptychia* as well as *Dirinaria*.

Parmelia reparata Stirt. 1877/78 p. 201
Types: 'Queensland, Brisbane, F. M. Bailey 16a' GLAM (HOLOTYPE) 'Gowrie mts. Brisbane F. M. Bailey 16' BM (SYNTYPE) Hale 1965 nominated the poor BM collection as Lectotype. The copious GLAM collection, however, bears the annotation TYPE amongst Stirton annotations, and can threfore be taken as the Holotype.

Parmelia subbrunea Stirt. 1899 p. 80
Type: Grampian Mountains, Australia. Sullivan.
No material has been located.

Parmelia violascens Stirt. 1899 p. 77
Types: 'Australia, Grampians, Mrs. Sullivan no. 36' GLAM (here selected as LECTOTYPE); BM (ISOLECTOTYPE). Possibly *Parmelia scabrosa* Tayl. (Fide M. E. Hale 1963). The GLAM collection is more copious than that in BM.

Parmosticta purpurascens Stirt. 1899 p. 71
[*Sticta purpurascens* (Stirt.) Zahlbr.]
Type: 'Australia, Blue Mts. Herb. Baron von Mueller' BM (selected here as LECTOTYPE). This material is a species of *Pseudocyphellaria*.

Parmosticta rubrina Stirt. 1880 p. 69
[*Sticta rubrina* (Stirt.) Müll.Arg.]
Type: 'F. M. Bailey, Brisbane no. 11'. BM (selected here as LECTOTYPE); BRI (ISOLECTOTYPE). The BM material is fully annotated by Stirton. The collection is a species of *Pseudocyphellaria*.

Physcia excelsior Stirt. in Bailey 1899a p. 40
[*Teloschistes excelsior* (Stirton) Lamb]
Types: 'Australia, New South Wales, Riverina H. Paton 1875'. GLAM (HOLOTYPE), BM (ISOTYPE). A Stirton note on the GLAM collection indicates the published description was based on that collection. The collection is apparently *Teloschistes sieberianus* (Laur.) Hillman.

Physica laciniatula Stirt. 1899 p. 82
Type: 'Supra muscos, Illawarra, N.S.W., Kirton'. No specimen found.

Physcia sublurida Stirt. 1880 p. 69
Types: 'Queensland, F. M. Bailey on Rosewood scrub'. BM (2 collections), BRI (All syntypes, one to be selected as LECTOTYPE).

Placodium clavigerum Stirt. in Bailey 1899b p. 487
[*Caloplaca clavigera* (Stirt. in Bailey) Zahlbr.]
Type: No location or collector designated. No material located.

Plagiothelium australiense Stirt. 1880 p. 75
[*Parmentaria australiensis* (Stirt.) Müll.Arg.]
Types: 'Queensland, Brisbane, F. M. Bailey no. 58' GLAM (here designated LECTOTYPE), BM (ISOLECTOTYPE). The GLAM collection is copious and heavily annotated by Stirton.

Psoroma dispersum Stirt. 1880 p. 76
Type: 'Australia, Gippsland. Hugh Paton' BM (selected here as LECTOTYPE).

Pyxine obscurior Stirt. in Bailey 1880 p. 70
Type: Corticola, near Brisbane. Bailey 235. BM (HOLOTYPE). This is possibly a species of *Buellia*.

Pyxine rugulosa Stirt. 1898 p. 396
Types: 'Queensland, vicinity of Jimbour, F. M. Bailey', BM (HOLOTYPE).

Pyxine subcinerea Stirt. 1898 p. 397
Types: Queensland, F. M. Bailey, BM (HOLOTYPE).

Pyxine subvelata Stirt. 1898 p. 396
Types: 'Queensland, Jimbour F. M. Bailey no. 32, June 1897'. GLAM (selected here as LECTOTYPE). BM (ISOLECTOTYPE).

Ramalina exiguella Stirt. 1880 p. 68
Type: 'Bark, Brisbane, Bailey 91'. BRI (HOLOTYPE)

Ramalina perpusilla Stirt. 1880 p. 68
Type: 'Bark, near Brisbane River, Bailey 113'. BRI (HOLOTYPE).

Sticta parvula Stirt. 1899 p. 73
Types: Queensland, C. de Burgh, and Lachlan River (ex Herb. F. von Müller). No type material has been located.

Stictina diversa Stirt. 1899 p. 75
[*Sticta diversa* (Stirt.) Zahlbr.]
Type: 'Queensland, F. M. Bailey 140' BM (here selected as LECTOTYPE).

Stictina luridoviolacea Stirt. 1899 p. 73
[*Sticta luridoviolacea* (Stirt.) Zahlbr.]
Type: 'Australia, Snowy Creek, Ovens River (Victoria) Mrs. McCann 1881' BM (here selected as LECTOTYPE).

The collection is a species of *Pseudocyphellaria.*

Stictina rutilans Stirt. 1880 p. 68
[*Sticta rutilans* (Stirt.) Zahlbr.]
Type: 'Queensland, F. M. Bailey, Brisbane' BM (selected here as LECTOTYPE).

Stictina subcrocea Stirt. 1899 p. 74
[*Sticta subcrocea* (Stirt.) Zahlbr.]
Type: 'Queensland, Brisbane, F. M. Bailey no. 134' BM (selected here as LECTOTYPE). The collection is possibly a species of *Pseudocyphellaria.*

Stictina suberecta Stirt. 1899 p. 73
[*Sticta suberecta* (Stirt.) Zahlbr.]
Type: 'Brisbane, Queensland F. M. Bailey no. 152' BM (selected here as LECTOTYPE).

Strigula elatior Stirt. 1880 p. 75
[*Strigula elegans* (Fee) Müll.Arg. (Santesson 1952)]
Type: Queensland, Brisbane, F. M. Bailey no. 96. On leaves of *Phyllanthus ferdinandi.* BM (HOLOTYPE).

Trichocladia baileyi Stirt. 1882 pl.
[*Heterodea muelleri* (Hampe) Nyl. (Filson 1978)]
Type: 'Prope Brisbane Bailey 288' BRI (HOLOTYPE).

Trypethelium exiguellum Stirt. ex Bailey 1899a, p. 40
Type: 'Queensland, Thursday Island, F. M. Bailey June 1897'. BM (here selected as LECTOTYPE).

Usnea consimilis Stirt. 1882 p. 295
[*Usnea scabrida* Tayl. (Motyka 1936–38)]
Types: 'Australia, Revd. M. L. Anderson recd. 15 Sept. 1870' BM (here selected as LECTOTYPE) GLAM (ISOLECTOTYPE). The GLAM collection, while heavily annotated is very poor and a mixture of different species.

Usnea elegans Stirt. 1880 p. 68
[*Usnea scabrida* Tayl. (Motyka 1936–38)]
Types: 'Queensland, Gowrie Mts. near Brisbane Mr. Bailey no. 13' GLAM (here selected as LECTOTYPE), BM (ISOLECTOTYPE), BRI (ISOLECTOTYPE). The GLAM collection is adequate and heavily annotated by Stirton.

Usnea himanthodes Stirt. 1883b p. 75
Type: 'Australia, N.S.W., Illawarra; Kirton, rec. 11 Sept. 1882' GLAM (here selected as LECTOTYPE), BM (ISOLECTOTYPE). The GLAM material is copious and heavily annotated.

Usnea luridorufa subsp. *pallida* Stirt. 1883a p. 295
Type: 'Australia, upper Hunter River, Miss Carter, New South Wales ex Hb. Baron F. von Müller, no. 8' GLAM (HOLOTYPE), BM (ISOTYPE). The GLAM collection is heavily annotated and labelled 'Type' by Stirton Apparently identical with *Usnea ramulosissima* Stevens & Rogers.

Usnea molliuscula Stirt. 1883b p. 77
Types: 'Australia (Victoria) Mrs. McCann. Subalpine country in the Upper Ovens R. Rec. 23rd May 1882 no. 1'. GLAM (selected here as LECTOTYPE) BM (ISOLECTOTYPE). The GLAM collection annotated by Stirton.

Usnea chaetophora subsp. *propinqua* Stirt. 1883b p. 76
[*Usnea propinqua* (Stirt.) Zahlbr.]
Types: 'Australia, Victoria, Waterloo, Gippsland. H. Paton' GLAM (here selected as LECTOTYPE), BM (ISOLECTOTYPE). The GLAM collection is heavily annotated by Stirton.

Usnea rubescens Stirt. 1883b p. 76
[*Usnea rubicunda* Stirt. (James 1979)]
Type: 'Australia, New South Wales, Illawarra Mr. Kirton. Rec. 14 Sept. 1882, on rocks' BM (LECTOTYPE selected James 1979), (GLAM ISOLECTOTYPE.)

Usnea subsordida var. *tenebrosa* Stirt. 1898a p. 389
Type: Vicinity of Brisbane. F. M. Bailey. No collection has been located.

Usnea undulata Stirt. 1883b p.75 non *U. undulata* Stirt. 1881 p. 104
[*Usnea torquescens* Stirt. 1898a p. 391]
Type: 'Australia, New South Wales, Illawarra on Rocks. Bulli. Rec. 14th Sept. 1882'. BM (selected here as LECTOTYPE).

Verrucaria analtiza Stirt. 1876A p. 95
[*Microthelia analtiza* (Stirt.) Zahlbr.]
Type: 'New South Wales, Riverina, Hugh Paton' GLAM.

Verrucaria circumrubens var. *rubrotecta* Stirt. 1880 p. 74
[*Pyrenula circumrubens* var. *rubrotecta* (Stirt.) Shirley]

Verrucaria coarctata Stirt. ex Bailey 1899a p. 40
[*Polyblastiopsis coarctata* (Stirt.) Zahlbr.]
Type: 'Jimbour, Queensland F. M. Bailey 1895' BM (selected here as LECTOTYPE). Bailey's introduction suggests Gwyther collected this specimen.

Verrucaria fibrata Stirt. ex Bailey 1899b p. 488
[*Pyrenula fibrata* (Stirt. ex Bailey) Zahlbr.]
Type: 'Queensland, Warwick, F. M. Bailey Rec. Jan. 1899' BM (selected here as LECTOTYPE). It is likely that this Warwick material was actually collected by Gwyther.

Verrucaria flaventior Stirt. 1881 p. 74
[*Pyrenula mastophora* (Nyl.) Müll.Arg. (Weber & Wetmore 1972)]
Type: No collector or location indicated. No collection has been located.

Verrucaria obovata Stirt. 1880 p. 74
[*Microthelia obovata* (Stirt.) Müll.Arg.]
Type: 'Brisbane. F. M. Bailey n.125' BM. No collection has been located.

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THE NOMENCLATURE OF SOME AUSTRALIAN LICHENS DESCRIBED AS LECANORA AND PLACODIUM BY MÜLLER-ARGOVIENSIS

by

R. W. Rogers*

ABSTRACT

J. Müller (Müll.Arg.) described a large number of lichens from Australia. When examining specimens in his herbarium it became apparent that some of the material he described as *Lecanora* and *Placodium* was in need of revision. *Placodium flavostramineum* Müll.Arg. is reduced to synonymy with *Dirinaria applanata (Fée) Awasthi. Lecanora connivens* Müll.Arg. and *L. subimmersa* Müll.Arg. (non Vainio) are reduced to synonymy with *L. atra* (Huds.) Ach. while the varieties *L. atra* var. *serialis* Müll. Arg. and *L. atra* var. *virens* Müll.Arg. are considered unworthy of formal taxonomic recognition. The new combinations *Candelariella xanthostigmoides* (Mull.Arg.) R. W. Rogers, *Lecidea glaucoflavens* (Müll.Arg.) R. W. Rogers, *L. hyalinescens* (Müll.Arg.) R. W. Rogers, *Ochrolechia macrosperma* (Müll. Arg.) R. W. Rogers, *Cladonia glaucolivida* (Müll.Arg.) R. W. Rogers, and *Xylographa perminuta* (Müll. Arg.) R. W. Rogers are made. *Lecanora albellaria* Müll.Arg. and *L. glebularis* (Müll.Arg.) Zahlbr. are presented as correct names for two common Australian taxa.

INTRODUCTION

In March 1978 most of the type specimens of the Australian lichens described by J. Müller (Müller-Argoviensis) were examined in Geneva. When examining the many species of *Lecanora* and *Placodium* that Müller-Argoviensis described it became apparent that some specimens were misplaced in those genera, that others were synonyms of well known lichens, and that others represented common Australian taxa for which no satisfactory name was currently in use. These taxa were typified and relevant details concerning the specimens noted. A copy of the notes is lodged in the National Herbarium of Victoria (MEL).

The specimens discussed in this paper were borrowed from Geneva and examined microscopically. All but one were also examined by thin layer chromatography.

TAXA REDUCED TO SYNONYMY

Placodium flavostraminium Müll.Arg. (1895A:29).
Lecanora flavostraminea (Müll.Arg.) Zahlbr. (1928:621)

Typification: *Wilson 331*, on quartz from Victoria (G, holotype). The specimen is a small, closely adnate thallus with marginal lobes.

Chemistry: atranorin and divaricatic acid.

There is no doubt that this is synonymous with *Dirinaria applanata* (Fée) Awasthi, in Awasthi & Agarwal (1970:135).

Lecanora atra var. **serialis** Müll.Arg. (1895B:632).

Typification: *Knight 268*, Thursday Island [Queensland] (G, holotype). The specimen is of scattered areoles mostly in the patterns of the rock surface.

Chemistry: atranorin, alectoronic acid, α-collatolic acid, and phenolics.

Culberson (1969, 1970) and Culberson *et al.* (1977) have documented the chemical variation of *Lecanora atra* (Huds.) Ach. (1810:344) and do not mention the presence of alectoronic acid. Alectoronic acid is similar to α-collatolic acid, and commonly co-occurs with it in other taxa. Such minor variation in chemistry is insufficient to justify formal taxonomic recognition. In addition, the holotype does

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* Botany Department, University of Queensland, St. Lucia, Queensland 4067.

Muelleria 5(1): 31-34 (1982).

not differ morphologically from *Lecanora atra* var. *atra*. There is no doubt that *L. atra* var. *serialis* cannot be maintained as a distinct variety, but must be placed in synonymy with *Lecanora atra* var. *atra*.

Lecanora atra var. **virens** Müll.Arg. (1882:484)

Typification: *Kirton*, Illawarra, N.S.W. on bark (G, lectotype here chosen. This is the only specimen in Geneva annotated by Müll.Arg.). The grey-green colouration of the thallus is insufficient reason to accord varietal status.

Chemistry: atranorin, alectoronic acid and phenolics.

This taxon cannot be maintained as a distinct variety, for reasons discussed under *L. atra* var. *serialis*. It is synonymous with *Lecanora atra* var. *atra*.

Lecanora connivens Müll.Arg. (1891:389)

Typification: *Bailey 435*, corticolous, Queensland (G, holotype).

Chemistry: atranorin, alectoronic acid, and phenolics.

The apothecia are unusually concave in early stages, but later flatten to produce a slightly convex disk and slightly irregular margin, characters insufficient to justify taxonomic recognition. There is no doubt that this taxon is synonymous with *Lecanora atra* var. *atra*.

Lecanora subimmersa Müll.Arg. (1893A:124), non *Lecanora subimmersa* Vainio 1890.

As the name *L. subimmersa* Müll.Arg. is a later homonym and therefore invalid it was replaced by *L. brisbanensis* Zahlbr. (1928:400).

Typification: *Bailey 93*, on bark, Brisbane (G, holotype).

Chemistry: atranorin.

The specimen has some of the apothecia partly immersed in the thallus, probably due in part to the highly irregular surface on which the thallus is growing. It does not differ in any significant way from *Lecanora atra*. Both *L. subimmersa* Müll.Arg., *nom. inval.*, and *L. brisbanensis* Zahlbr. must be placed in synonymy under *L. atra* var. *atra*.

NEW COMBINATIONS

Candelariella xanthostigmoides (Mull.Arg.) R. W. Rogers, comb. nov.
Lecanora xanthostigmoides Müll.Arg. (1882:484)
Candelaria xanthostigmoides (Müll.Arg.) Müll.Arg. (1893B:33)

Typification: *Woolls*, Parramatta N.S.W. (G, lectotype here chosen. This specimen is the more heavily annotated one of the two mentioned by Müll.Arg.); *Sullivan*, Grampians, Victoria (G, syntype).

Description of Lectotype: *Thallus* a deep yolk-gold crust of scattered granules up to 0.3 mm diameter. *Apothecia* sessile, up to 0.25 mm diameter, with an initially prominent thalline margin which becomes thinner and less prominent, coloured like the thallus; disk more or less plane, deep yolk-gold; asci 8-spored; spores simple, hyaline, 12-15 x 3-4 μm.

Lecidea glaucoflavens (Müll.Arg.) R. W. Rogers, comb. nov.
Lecanora glaucoflavens Müll.Arg. (1893B:39)

Typification: *Wilson 457*, Warrnambool, Victoria (G, lectotype here chosen. This is the more copious of the two collections mentioned by Müll.Arg.); *Wilson 711*, Warrnambool, Victoria (G, syntype).

Description of Lectotype: *Thallus* crustose, thin, yellow-green, granular, margin effuse. *Apothecia* sessile, to 1.5 mm diameter, with a distinct pale proper margin when young, less prominent with age; disk flesh-coloured, usually epruinose, plane to slightly convex; paraphyses simple; asci 8-spored; spores simple, hyaline, 18-22 x 9-11 μm.

Chemistry of Lectotype: isoarthothelin, thyringione.

Lecidea hyalinescens (Müll.Arg.) R. W. Rogers, comb. nov.
Lecanora hyalinescens Müll.Arg. (1882:484)

Typification: *White*, Twofold Bay, on bark [N.S.W.] (G, holotype).
Thallus dirty-white to grey, thin, ecorticate. *Apothecia* sessile to somewhat immersed, up to 1 mm diameter; margin white and prominent when young, becoming hyaline and disappearing with age, devoid of algae; disk initially concave, later somewhat convex, pale pinkish-brown to brown; asci 8-spored; spores simple, hyaline, 13-15 x 8-10 μm.

Chemistry: no lichen products were demonstrated by T.L.C.

Ochrolechia macrosperma (Müll.Arg.) R. W. Rogers, comb. nov.
Lecanora macrosperma Müll.Arg. (1893B:40)

Typification: *Wilson 366*, on bark, Lakes Entrance [Victoria] (G, holotype). *Thallus* crustose, white or grey, thick, densely isidiate. *Apothecia* adnate to immersed, c. 1 mm diameter, thalline margin thick and isidiate; disk deeply sunken within the margin, brown, epruinose; paraphyses reticulately branched; asci 8-spored; spores 38-50 x 18-20 μm, simple, hyaline.

Chemistry: perlatolic acid.

Cladonia glaucolivida (Müll.Arg.) R. W. Rogers, comb. nov.
Placodium glaucolividum Müll.Arg. (1891:388)
Lecanora glaucolivida (Müll.Arg.) Zahlbr. (1928:624)

Typification: *Bailey 706*, on soil, Queensland (G, holotype). *Thallus* of squamules up to 1.5 mm across, grey to yellow-grey, usually irregular, sometimes rosette-like, convex or with an ascending tip. *Apothecia* up to 2 mm diameter but usually much smaller, sessile or substipitate, with a well developed margin devoid of algae sometimes disappearing with age; disk brown or pale pinkish-brown, plane becoming somewhat convex, algal layer well developed below the hypothecium; asci 8-spored; spores simple, hyaline, 10-12 x 5-7 μm.

Chemistry: merochlorophaeic acid, 4-0-methylcryptochlorophaeic acid, traces of boninic acid and 2-0-methyl sekikaic acid.

The type specimen is small and poorly developed. However a recent collection (South Nobby, Qld [28°28'S, 153°30'E] on soil on a dry ridge close to the ocean, *Rogers 2394*) shows a fuller development. The short, hollow, corticate podetia could easily be mistaken for a thalloid exciple which would lead to placing the material in the genus *Squamarina* or in *Lecanora.*

Xylographa perminuta (Müll.Arg.) R. W. Rogers, comb. nov.
Lecanora perminuta Müll.Arg. (1893B:39)

Typification: *Wilson 1694*, dead wood, Mt. Macedon [Victoria] (G, holotype). *Thallus* not detectable. *Apothecia* black or very dark brown, minute (0.1-0.2 mm diameter), irregular, with a poorly developed thalline exciple, more or less adnate to the substrate; paraphyses simple; asci 8-spored; spores simple, hyaline, 6-12 x 4-5 μm.

Chemistry: no lichen products were demonstrated by T.L.C.

SPECIES OF SPECIAL INTEREST

Lecanora albellaria Müll.Arg. (1895B:632)

Typification: *Knight 423*, on bark, Queensland (G, holotype). *Thallus* white, thin, chinky to granular. *Apothecia* sessile; thalline margin well developed, thick, prominent, entire or slightly irregular; disk sunken, flat to concave, pale pinkish-brown, sometimes becoming hyaline; asci 8-spored; spores 5-7 x 10-13 µm, simple, hyaline.

Chemistry: atranorin, 2-0-methylperlatolic acid.

Similar material is very common on mangroves on the eastern coast of Australia, from Cairns to Sydney.

Lecanora glebularis (Müll.Arg.) Zahlbr. (1928:624).
Placodium glebulare Müll.Arg. (1888:204)

Typification: *C. French*, Lake Albacutya, Victoria, on soil (G, holotype). *Thallus* white, areolate, the areolae strongly convex. *Apothecia* 0.5-1.0 mm diameter, solitary and sessile on the areoles; margin prominent, permanent, coloured like the thallus; disk plane or somewhat convex, black, epruinose; asci 8-spored; spores 6-8 x 7-10 µm, simple, hyaline.

Chemistry: atranorin, 2-0-methylperlatolic acid.

Similar material is widespread on soils in semi-arid Victoria, New South Wales and South Australia. All material treated as *Lecanora atra* by Rogers and Lange (1972) is *L. glebularis*. *L. atra* differs chemically (atranorin, alectoronic acid, α-collatolic acid) and also has much larger apothecia which are not born at the apex of almost globular areoles.

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The Macrolichen Flora from the Mangroves of Moreton Bay

G. N. Stevens and R. W. Rogers

Department of Botany, University of Queensland, Brisbane

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SYNOPSIS

The mangrove communities of Moreton Bay have a macrolichen flora (fruticose and foliose lichens) of at least 59 species representing 20 genera: *Bulbothrix, Coccocarpia, Collema, Dirinaria, Heterodermia, Hypotrachyna, Leptogium, Pannaria, Parmelia, Parmelina, Parmotrema, Physcia, Physciopsis, Physma, Pseudoparmelia, Pyxine, Ramalina, Relicina, Teloschistes, Usnea.* All species are corticolous. Seven species of mangrove grow around Moreton Bay and the position which each species occupies within the plant community forms a rather indistinct zonation pattern, which could be a factor contributing to the prevalence of lichens on some mangroves and their scarcity on others. Most of the mangrove lichens are also found in the Brisbane area and surrounding mountains, however some appear to be exclusively maritime. A brief description of each species is given and a key to the taxa is included.

INTRODUCTION

The systematic study of Queensland's lichen flora was commenced about 1880 when F. M. Bailey (Queensland Government Botanist) and J. Shirley (an Inspector of Schools) sent their collections for identification to James Stirton of Glasgow and Jean Müller of Switzerland, both of whom were eminent European lichenologists. The lichen descriptions by Stirton and Müller appeared in various botanical journals of the time. 'The Lichen Flora of Queensland' (Shirley 1890) gives descriptions which lack many modern diagnostic characters.

Weber and Wetmore (1972) listed references to Queensland lichens in a catalogue of Australian lichens. Rogers (1977) recorded the presence of fruticose species from mangroves in the Brisbane area. However this is the first study of lichen flora in the mangrove community of Moreton Bay that has been reported upon.

GEOGRAPHICAL LOCATION

Moreton Bay extends from latitude 27°S to 28°S being bounded to the east by Moreton Island and North and South Stradbroke Islands, and to the north by Bribie Island. The coastline is composed of Quaternary deposits of shale, silt, clay and coral resting on a basement of Triassic-Jurassic sandstones and shales, with some Tertiary basalts and Palaeozoic metamorphics.

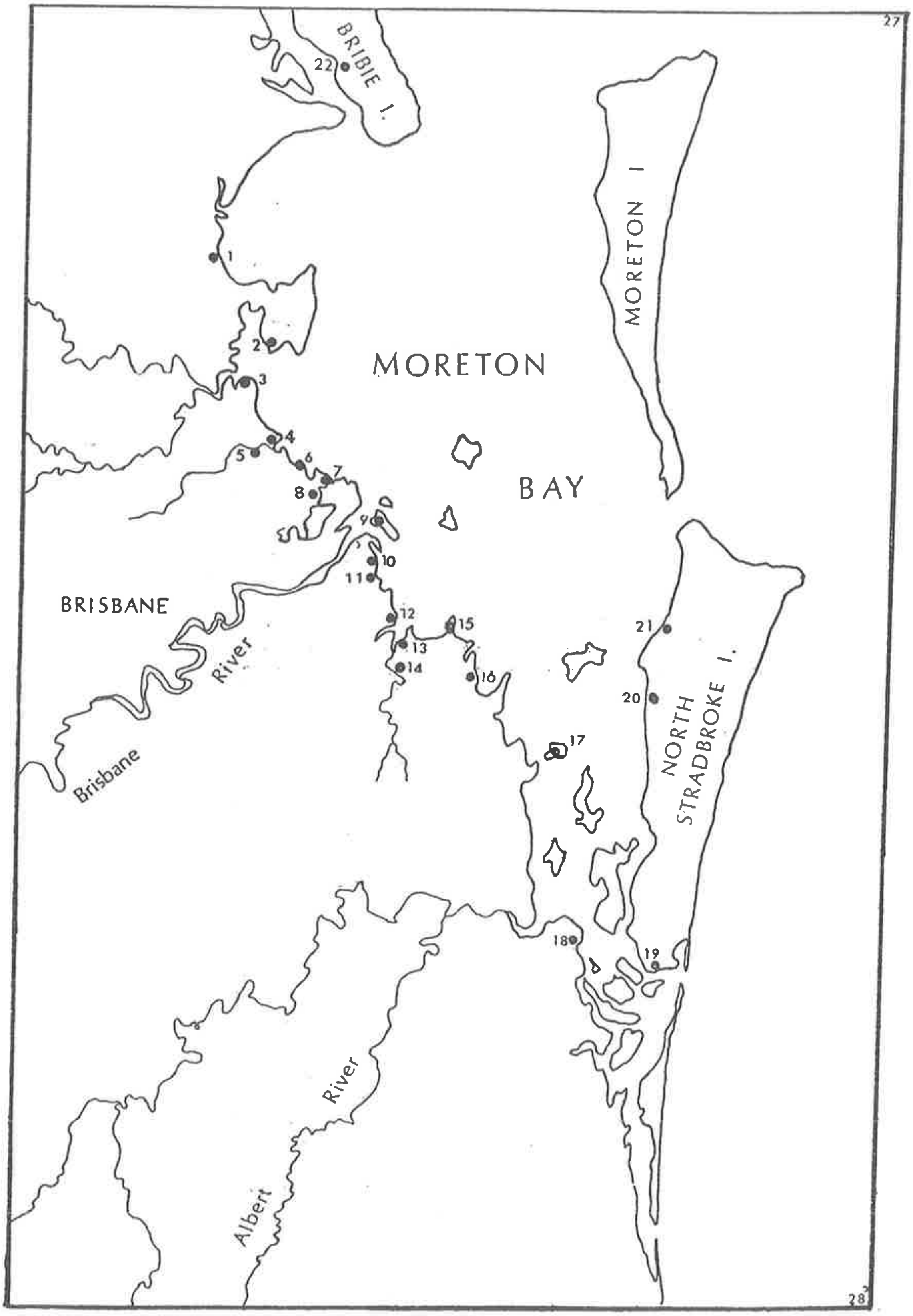
Several rivers empty into the bay, the largest being the Brisbane. Other streams are the North and South Pine Rivers, Cabbage Tree Creek, Serpentine Creek and the Albert, Logan and Coomera Rivers (Fig. 1).

THE MANGROVES

The deposit of silt from these streams has given rise to shallow water at their mouths, and stands of mangroves have developed in protected sections of the coast and on the shores of the bay islands. Mangroves also extend upstream for some distance. The mangrove communities of Moreton Bay comprise seven species: *Avicennia marina, Ceriops tagal, Rhizophora stylosa, Bruguiera gymnorrhiza, Aegiceras corniculatum, Excoecaria agrallocha* and *Lumnitzera racemosa*.

Avicennia marina is predominant and inhabits the whole seaward fringe of the mangrove communities. It is a pioneer species which becomes established when enough siltation has occurred to enable the growth of its seedlings. The presence of these plants results in more deposition of material as the pneumatophores trap floating debris and slow down water currents. *A. marina* occurs mainly on firm sandy muds but also exists on deep black muds. It can grow to a height of 10 m and develops a very thick trunk. The lichen flora on these trees varies from sparse at the seaward edge, to quite prolific in the mid and landward zones. In the middle zone the canopy cover can cause deep shade and foliose lichens only are found in such habitats.

Rhizophora stylosa is usually found growing behind the *Avicennia marina* front, although further north, it too is a pioneer species. The reason for its position in the Moreton Bay mangroves may be that it is


BRIBIE I.
MORETON I
MORETON
BAY
BRISBANE
Brisbane
River
Albert
River
NORTH
STRADBROKE I.
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at its southern biogeographic limit (Chapman 1973). It mainly inhabits deep soft mud, where it reaches a height of only 5 m. The sheltered position it occupies together with a roughness of its bark makes this species a suitable host for a prolific growth of lichens.

Bruguiera gymnorrhiza is present where the initial community is well established. It requires a well aerated soil and a more protected environment than *Avicennia marina* or *Rhizophora stylosa*. The tree reaches a height of 4–5 m and has a dense canopy. Its position and bark texture enable many species of lichens to become established, but the thickness of the canopy cover apparently prevents lichen growth on the twigs, and lichens are found only on the less shaded branches and trunk.

Ceriops tagal var. *australis*, the yellow leaved mangrove, grows on the landward side of the mangrove community. It is light-loving and requires a well drained soil, often occurring in pure stands behind the *Avicennia marina* groves. It is a small tree, only reaching a height of 3 m in Moreton Bay. Its leaves tend to stand vertically allowing a high proportion of light to reach the stems so that a large variety of lichens inhabits both the stems and the trunks.

Aegiceras corniculatum forms more of a bushy shrub than a tree and grows mainly along the tidal creeks and rivers. However it is also found in association with the *Avicennia* seaward fringe in quieter waters. Lichens are usually sparse on this mangrove due to its smooth bark and slender branches.

Both *Excoecaria agallocha* (the milky mangrove) and *Lumnitzera racemosa* (the white flowered, black mangrove) are rarely found, but can occur on the landward side of the mangrove community at the upper limit of high tide. *Excoecaria agallocha* reaches a height of 7–8 m while *Lumnitzera racemosa* merely attains 3–4 m.

FACTORS CONTROLLING LICHEN DISTRIBUTION

The presence or absence of lichens at any locality can be directly related to the influence of climatological and substrate factors. Such factors as light, moisture, humidity, wind, exposure, salt tolerance, bark texture and chemistry will prove favourable or restricting to the establishment and growth of lichens.

In the mangrove wetland environment of Moreton Bay there is adequate water and humidity for growth, so the distribution of lichen species can partly be related to sunlight intensity. The sun-loving lichens are found on the open canopied *Ceriops tagal* trees and at the edges of the mangrove community. Shade-requiring lichens frequent the middle zone of mangroves where canopy cover ensures mottled shade. Too deep shade, such as the underneath of a sloping branch or trunk prevents any lichen growth at all.

Habitat preference is often related to bark texture; rough bark could trap lichen diaspores more readily than smooth bark. Rough bark offers more protection in establishment and possibly provides more nutrients and water for the foliose lichens.

At the seaward fringe of the community, salt sea spray, wind, and sand abrasion may be contributing factors which restrict the presence of lichens on the smooth trunks of *Avicennia marina*, but where *Rhizophora stylosa* inhabits the seaward fringe, many lichen species can be found on the rough-barked trunk despite scouring by wind-driven salt spray and sand.

THE ESSENTIALLY MARITIME LICHENS

The majority of the 59 lichen species in the mangrove communities are also found in the Brisbane area. Where only one collection of a species has been made from mangroves its range of habitat is inconclusive. However some of the lichens appear to occur essentially in maritime habitats.

All five species in the genus *Ramalina* (*R. exiguella*, *R. peruviana*, *R.* aff. *leiodea*, *R. perpusilla* and *R. reagens*) only occur in a maritime environment. *Parmotrema robustum* and *Parmotrema parahypotropum*

Fig. 1: Map of Moreton Bay showing lichen collection sites.

1, Deception Bay
2, North end of Hornibrook Highway
3, South end of Hornibrook Highway
4, Shorncliffe, Wharf Street
5, Boondall, Cabbage Tree Creek
6, Nudgee Beach
7, Cribb Island
8, Serpentine Creek
9, Fisherman Island
10, Lytton, Wynnum North Road
11, Manly, The Esplanade
12, Lota, Chelsea Road
13, Thornside, The Esplanade
14, Tingalpa Creek bridge
15, Wellington Point
16, Ormiston, Sleeth Street
17, Coochiemudlo Island
18, Little Rocky Point
19, South end of N. Stradbroke Island
20, Dunwich, 1 km south of
21, Myora Springs
22, Bribie Island, White Patch

are only found along the coastline at this latitude. *Pseudoparmelia* aff. *crozalsiana* appears to be mainly maritime in its distribution as only one other specimen has been collected away from the coast (in the Brisbane suburb of The Gap). *Pyxine berteriana* has been found only along a 10 km-wide coastal fringe.

The foliose lichens which have a blue green alga as phycobiont, *viz. Collema, Coccocarpia, Leptogium, Pannaria* and *Physma,* apparently require moister conditions than those containing a green alga as phycobiont. Those species found in the wetland mangrove environment do not occur in the Brisbane suburbs except in moist rain forest areas. *Teloschistes flavicans* also seems confined to mangrove communities at sea level, but can be found at higher altitudes on the Dividing Range (Filson 1969).

METHODS OF COLLECTION AND IDENTIFICATION

Selected areas along the coastline and islands (Fig. 1) were visited during 1975–77 and the mangrove communities inspected for lichen growth. A sharp knife was used to remove the lichen together with its bark substrate and the specimens were carried in paper bags labelled as to locality, host, environment and date.

In this paper G. N. Stevens collections are cited by only a collection number and locality number (Fig. 1) in brackets. Collections made by R. W. Rogers and C. Scarlett are indicated by RR.CS., and H. T. Clifford by HC., with a collection number and a location number in brackets. In the descriptions that follow, the abbreviation A.n.v. is used to denote apothecia not seen in the Moreton Bay area.

Identification of species was made by reference to the literature.

Chemical spot testing was routinely carried out on all specimens, using the reagents K = 10% aqueous solution of potassium hydroxide (KOH), C = fresh aqueous solution of calcium hypochlorite, $Ca(OCl)_2$, KC = KOH followed by $Ca(OCl)_2$, and P = fresh solution of paraphenylenediamine in ethanol. Confirmatory microchemical tests were performed by standard methods (Hale 1967, 1969 and Moore 1968). Some of the specimens (indicated by TLC) have been chemically analysed by Dr J. Elix using thin layer chromatography to determine those lichen acids which cannot be identified by microchemical crystallizations. All chemical constituents reported were determined or verified during the present study.

ACKNOWLEDGEMENTS

We wish to thank Dr J. A. Elix, Department of Chemistry, A.N.U., for his help and determinations of lichen acids in the *Ramalina* species and some others as indicated; Dr M. E. Hale, Smithsonian Institute, Washington D.C., who identified several of the Parmeliaceae, Dr G. Degelius, University of Göteborg, Sweden, for confirming identification of the *Collema* species and Mr P. M. Jørgensen, University of Bergen, Norway for identification of the *Pannaria* species. Responsibility for the names used, must, however, remain with the authors. This study was greatly facilitated by a grant from the Australian Biological Resources Study.

DESCRIPTIONS OF THE MACROLICHENS OF MORETON BAY

Bulbothrix goebelii (Zenker) Hale 1976b: 14
Parmelia goebelii Zenker 1827: 134
Thallus white to greenish-grey, foliose, adnate, smooth, sometimes shiny; lobes sublinear-elongate, 0.5–1 mm wide; bulbate cilia, sometimes apically branched; moderately isidiate, small cylindrical isidia; lower surface black at centre, pale margin; rhizines black, densely branched. Spore size 8–10 × 4–6 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C + rose, KC + red, P—. Atranorin and gyrophoric acid.
Specimens examined: 537, 1831: (21).

Bulbothrix tabacina (Mont. & Bosch) Hale 1974b: 481
Parmelia tabacina Mont. & Bosch 1856: 498
Thallus grey-green foliose, somewhat maculate, closely adnate, cracked with age; lobes sublinear to subirregular; cilia bulbate, short; without soredia, isidia cylindrical, simple, small; lower surface black with a tan margin, moderately rhizinate. Spore size 9–15 × 5–8 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K + yellow turning red, C—, KC—, P + orange. Salazinic acid and atranorin.
Specimens examined: 1724: (1), 2644: (3), 562: (21).

Coccocarpia cronia (Tuck.) Vain. 1915: 24
Parmelia cronia Tuck. 1848: 228
Thallus blue-grey, pale grey, brownish-grey, foliose, appressed; lobes narrow, fanshaped at ends; isidia

cylindrical, moderately dense at centre; lower surface corticate, pale; rhizines short, dark or pale, forming a dense mat. Apothecia uncommon, colour black, brown, red, or pale. Spore size 8–9 × 4–5 μm. A.n.v.
Specimen examined: 1620: (17)

Coccocarpia erythroxili (Spreng.) Swinsc. & Krog 1976: 256
Lecidea erythroxili Spreng. 1820: 47
Thallus lead-grey, foliose, loosely adnate; lobes rotund, somewhat crenate with zoned ring markings, imbricate, the smaller lobes overlapping larger lobes below; without isidia; lower surface pale to yellow-brown, white tomentum turning bluish-black at centre of thallus. Apothecia convex, pale to orange, brown to black. Spore size 9–13 × 2–5 μm.
Specimens examined: 2638: (3), 1590: (8), 1610, 1612: (17).

Coccocarpia pellita (Ach.) Müll. Arg. 1882: 320
Parmelia pellita Ach. 1810: 468
Thallus lead-grey, foliose, closely appressed; lobes narrow wedge-shaped, centre of thallus areolate and lobular; without isidia; lower surface dark, a black hypothallus of tomentum demarks the edge of lobes. Apothecial disc black, margin lacking. Spore size 13 × 3 μm.
Specimens examined: 2645: (3), 1606, 1627, 1709: (17).

Collema laeve Hook.f & Tayl. var. *laeve* 1844: 656.
Thallus dark olive-green, foliose; lobes loosely adnate, moderately thick, surface rough, matt; without isidia. Apothecia laminal, often crowded, at first immersed and visible as small white dots (looking like pycnidia), later becoming sessile, disc plane or concave, strongly white pruinose, margin entire, moderately thick; spores hyaline, 5 septate, size 40–50 × 4–4.5 μm.
Specimen examined: 1601: (17).

Collema glaucophthalmum var. *implicatum* (Nyl.) Degel. 1974: 164
Collema glaucophthalmum Nyl. 1858: 377
Thallus dark olive-green, foliose, adnate with somewhat ascending margins, margin entire, broadly lobate, thin membraneous, ridged; lower surface paler, matt. Apothecia numerous, crowded, sessile with constricted base, epruinose, 0.4–0.9 mm diam., disc plane to convex, dark red, margin thin, smooth; spores broadly acicular, straight or curved, 5–9 septate, hyaline, size 40–60 × 4.5–6 μm.
Specimens examined: 1725: (1), 1603: (17), 1479: (18), 526: (20).

Collema rugosum Krempelh. 1870: 128
Thallus dark green, foliose, adnate, broadly lobate, thin, membraneous, coarsely ridged, isidia small, cylindrical, numerous on crests of ridges and on thallus between ridges. Spore size 40–75 × 4–6.5 μm. A.n.v.
Specimens examined: 1602: (17), 505: (21)

Dirinaria applanata (Fée) Awasthi 1970: 135
Parmelia applanata Fée 1824: 126
Thallus pale green, glaucous-grey or grey-white, foliose, tightly appressed, lobes irregularly divided, contiguous with flabellate apices, confluent longitudinally plicate-rugose, pruinose; soralia laminal, globose-capitate, discrete, soredia usually fine, farinose; lower surface black, rhizines minute. Spore size 12–34 × 6–10 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C—, P—. Divaricatic acid and atranorin.
This species has been found at most sites, though usually not in large quantities, with the exception of Fisherman Island where it occurs plentifully on the trunks of *Avicennia marina*. It appears to be a pollution tolerant lichen as it is abundant in this area where oil refinery and chemical plant air pollution occur. A few specimens of *D. applanata* have been collected which have patches of yellow-orange in the lower medulla (which are K + red/purple) and the apical regions of the lobes are maculate, this is regarded as an environmental variation.

Specimens examined: 1710: (1), RR.CS.4763: (2), 4405: (3), 4409: (4), 4404: (5), 4434: (6), 4430: (7), 1176: (8), 1774: (9), RR.CS.5060: (10), RR.CS.5121: (11), 1752: (13), RR.CS.5416: (15), 1647: (17), 1444: (18), 571: (21), 1655: (22).

Dirinaria aspera (H. Magn.) Awasthi 1964: 371
Physcia aspera H. Magn. 1945: 63
Thallus suborbicular, glaucous-grey, foliose, closely appressed, lobes slightly pruinose, confluent, radiating, apices somewhat discrete, soralia are initially minute protruberances on the thallus, becoming dome shaped, then burst open, producing granular soredia in crateriform soralia, lower surface black, rhizines rudimentary, sparse. Spore size 12–19 × 5–7 μm. A.n.v.

Reactions: Cortex K + yellow, medulla K—, C—, P—. Divaricatic acid and atranorin.

This species may be confused with *Dirinaria applanata*, from which it differs in the more rugulose, verrucose thallus and the crateriform soralia.

Specimens examined: RR.CS.4892: (2), 4781: (3), 4881: (7), 1738: (8), RR.CS.5061: (10), RR.CS.5014: (12), 1744: (14), RR.CS.5317: (15).

Dirinaria confluens (Fr.) Awasthi 1975: 28

Parmelia confluens Fr. 1825: 284

Thallus pale grey or white, foliose, adnate, centre of thallus rugose, and reticulately cracked, lobes subdichotomously divided, contiguous confluent with rounded flabellate apices, pruinose, without soredia or isidia, lower surface black with sparsely distributed minute rhizines, medulla white, or pale yellow in the upper part. Apothecia numerous in centre of thallus, disc black with or without white pruina, margin concolorous with thallus, thick, somewhat crenate; spore size 14–24 × 8–10 μm.

Reactions: Cortex K + yellow, medulla K—, C—, P—. Divaricatic acid and atranorin.

Specimens examined: 1723: (1), 1745: (13), 1640: (17).

Dirinaria consimilis (Stirt.) Awasthi 1970: 597

Physcia consimilis Stirt. 1879: 310

Thallus pale greenish-grey or greyish-white, foliose, closely appressed, lobes imbricate to confluent, faintly pruinose at apices, somewhat longitudinally plicate-rugose eventually subverrucose, soralia laminal, capitate, granular soredia, medulla white, lower medulla yellow, lower surface black (pale brown at margin), rhizines black, sparse. Apothecial disc brown to black, lightly pruinose or epruinose, margin thick; spore size 14–23 × 6–8 μm.

Reactions: Cortex K + yellow, medulla K— or K + pink, C—, P—. Sekikaic acid and atranorin.

Specimens examined: 1730: (1), 2642: (3), 1099: (8).

Dirinaria melanoclina (Knight) Awasthi 1975: 77

Physcia melanoclina Knight 1882: 49

Thallus whiteish-grey, foliose, appressed, lobes contiguous, subpinnately divided, plane to slightly convex, apices rounded, thallus centre becoming verrucose, soralia (if present) capitate, lower surface brown to black, rhizines black, sparse. Apothecial disc red pruinose, sometimes brownish-black, margin concolorous with thallus, sub-pedicilate; spore size 16–20 × 6–9 μm.

Reactions: Cortex K + yellow, medulla K—, C—, P—.

Specimens examined: 1119: (8), 1739: (13), 1477: (18).

Dirinaria picta (Sw.) Clem. et Shear. 1931: 323

Lichen pictus Sw. 1788: 146

Thallus greyish-white, foliose, adnate, lobes contiguous, apices discrete, narrow, not at all flabellate confluent, soralia laminal, capitate, sparse to closely distributed but remaining discrete not coalescing, globose, soredia fine to moderately granular, lower surface black, rhizines minute, sparse. Spore size 14–17 × 5–7 μm. A.n.v.

Reactions: Cortex K + yellow, medulla K—, C—, P—. Divaricatic acid and atranorin. This species closely resembles *Dirinaria applanata*, however the lobes are generally pinnatifid and discrete for the greater part of their length.

Specimen examined: 1500: (18).

Heterodermia tremulans (Müll. Arg.) Culb. 1966a: 485

Physcia hypoleuca var. *tremulans* Müll. Arg. 1880: 277

Thallus grey-white, foliose, adnate; lobes sublinear, somewhat imbricate, dichotomously branching; soralia marginal, revolute; without isidia; lower surface white; rhizines sparse, pale to dark. Apothecia 3–8 mm diam; margin servediate; spores 24–28 × 10–12 μm. A.n.v.

Reactions: Cortex K + yellow, medulla K + yellow, C—, KC—, P—.

Specimens examined: 2639: (3), 1050: (8), 1757: (13).

Heterodermia obscurata (Nyl.) Trevis. 1869: 114

Physcia obscurata Nyl. 1863: 310

Thallus grey or grey-white or green-grey, foliose, sometimes partly blackened at centre; lobes dichotomously branched, elongate, smooth, narrow, margin entire; servediate, labriform soralia at tips of lateral branches; without isidia; without cilia; lower surface decorticate, arachnoid, deep orange; marginal rhizines, black squarrosely branched 1–2 mm long. Spore size 29–35 × 15–19 μm. A.n.v.

Reactions: Cortex + yellow, medulla K + yellow slightly, C—, KC—, P—.

Specimen examined: 1819: (21)

Hypotrachyna immaculata (Kurok.) Hale 1975: 41
Parmelia immaculata Kurok. 1964: 178
Thallus greyish-white, foliose, loosely attached, lobes linear to sublinear, surface shiny, sometimes white maculate, slightly wrinkled and cracked with age. Soralia subterminal, laminal, capitate, soredia coarsely granular, without isidia, without cilia, lower surface black, rhizines black, dense, dichotomously branched, fragile. Spore size 11 × 6 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K + yellow turning red-brown, C—, KC—, P—. Atranorin and the lividic acid complex (colensoic acid, 4–O–methylphysodic acid, lividic acid, norcolensoic acid, physodic acid and hydroxyphysodic acid), identified by TLC. Lichexanthone present as thallus is UV + white.
Specimens examined: 1732: (1), 1607, 1646, 1682: (18), 1824: (21).

Leptogium phyllocarpum var. *isidiosum* Nyl. 1860: 130
Thallus lead-grey, foliose, undulate, loosely adnate, gelatinous when wet, lobes rotund, entire and somewhat ascending, isidia short, cylindrical sometimes becoming squamulose, sparse to dense on lobes and lobe margins, also occurring on the lower surface, lower surface paler than upper and wrinkled. Apothecia not known.
Specimen examined: 1612: (17).

Pannaria elatior Stirt. ex Bailey 1899: 486.
Thallus light brownish-fawn to grey, adnate, linear or somewhat imbricate, margins crenate, ascending bearing grey isidia-like soredia which become dense at centre of thallus, totally covering the surface and giving a smoky-blue appearance; lower surface pale brown with deeper brown tomentum. Apothecia not always present, disc orange, margin greyish-white, thick, crenate, spores hyaline, simple, thin walled, size 17 × 8.5 μm.
Reactions: Medulla K—, P + orange.
Specimens examined 1613, 1615: (17), 503: (21).

Pannaria lurida (Mont.) Nyl. 1857: 109.
Collema luridum Mont. 1842: 256.
Thallus light brown or pale grey, adnate, lobes linear, at times imbricate, pruinose or epruinose, margins pale grey, crenate slightly ascending, thickened, at times sorediate, lower surface brown with pale to bluish-black tomentum. Apothecia frequent, disc orange-brown, flat to convex, margin greyish-white, crenate, thick, spores hyaline, simple, thin walled, size 14–17 × 8.5 μm.
Reactions: Medulla K—, P + orange.
Specimens examined: 1616: (17), 501: (21).

Parmelia erumpens Kurok. 1969: 225.
Parmelia tenuirima Hook.f. & Tayl. *corallina* Müll. Arg. 1883: 46
Thallus greenish-grey, foliose, markedly maculate and reticulately cracked to margin, lobes linear, 2–3 mm broad, with fine black margin, sometimes pruinose, soredia exude from cracks in thallus in separate patches or clustered as at centre of thallus, without isidia, without cilia, lower surface black with a dark brown naked marginal zone, rhizines black, short, moderately dense. Apothecia rare, disc light brown, margin concolorous with thallus, the edges rolled inwards, spore size 7–10 × 3–5 μm, hyaline, simple.
Reactions: Cortex K + yellow, medulla K + yellow turning red, K—, KC—, P + deep yellow. Salazinic acid and atranorin.
Specimens examined: 1608, 1628: (17), 1587: (18), 1822: (21).

Parmelina aurulenta (Tuck.) Hale 1974b: 482
Parmelia aurulenta Tuck. 1858: 424
Thallus greenish-grey, foliose, loosely appressed, lobes 2–5 mm broad, subrotund, surface plane to rugulose, cilia simple, sparse, medulla pale yellow, soralia pustular, coalescing into large capitate clumps, soredia coarse, without isidia, lower surface black with a slightly paler margin, rhizines black, simple, moderately dense to margin. Spore size 12 × 7 μm. A.n.v.
Reactions: Cortex K + y, medulla K—, C—, KC + yellow-orange, P—. Atranorin. This species has a pan temperate and montane pantropical distribution (Hale 1976c, p. 19) and has not previously been reported for Australia.
Specimen examined 1632: (17).

Parmelina damaziana (Zahlbr.) Hale 1976c: 23
Parmelia damaziana Zahlbr. 1905: 541
Thallus greenish-grey, foliose, adnate, lobes sublinear to subirregular, surface slightly maculate, shiny,

cilia long, some squarrousely branched, without soredia, without isidia, medulla white, lower surface black, rhizines black, simple, sparse to moderate. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C—, KC + pink, P—. Atranorin, 4, 5, di-O-methylhiascic acid, and gyrophoric acid, identified by TLC.
Specimen examined: 1910: (21).

Parmelina spumosa (Asah.) Hale 1974b: 483
Parmelia spumosa Asah. 1951: 259
Thallus pale greenish-grey, foliose, adnate, lobes sublinear, upper surface smooth, shiny and in places slightly maculate, cilia short and sparse, densely pustulate-isidiate, the pustules fragile, bursting open but not becoming sorediate, medulla faintly yellow, lower surface, black with slightly lighter margin, rhizines black, simple, sparse. Apothecia rare, spore size 12–14 × 7–8 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C + rose, KC + red, P—. Gyrophoric acid, atranorin and a pigment, identified by TLC.
Specimens examined: 1734: (1), 1826: (21).

Parmelina aff. *tiliacea* (Hoff.) Hale 1974b: 483
Thallus whiteish-grey, foliose, maculate, shiny, cracked, lobes 1.5–3.5 mm broad, edged with a thin black line, cilia sparse, black, simple, isidia short, cylindrical rarely branched, dense, usually blackening at the tips, without soredia, medulla white, lower surface black with a pale margin, rhizines black, short, simple. Apothecia rare: spore size 8–11 × 5–6 μm. A.n.v.
Reactions: Cortex K + yellow slightly, medulla K—, C + pink red, KC + brick red, P—. Atranorin and lecanoric acid.
This species resembles *Pseudoparmelia conlabrosa* Hale but the possession of cilia on the narrow lobes precludes it from this genus.
Specimens examined: 574, 1829: (21).

Parmotrema austrosinense (Zahlbr.) Hale 1974: 335
Parmelia austrosinensis Zahlbr. 1930: 192
Thallus greenish-grey, foliose, loosely attached, lobes broad, margins crenate, soredia marginal on sinuate lobes, without cilia, without isidia, upper surface dull, smooth, but wrinkled or cracked towards centre, lower surface white and naked in a broad zone along the margin, black at the centre, rhizines black, sparse. Spore size 13–20 × 8–10 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C + red, KC + red, P—. Lecanoric acid and atranorin.
Specimen examined: 1737: (13).

Parmotrema crinita (Ach.) Choisy 1952: 175
Parmelia crinita Ach. 1814: 196
Thallus greenish-grey, foliose, loosely adnate, lobes rotund, 2–4 mm broad, variable, crenate, cilia 0.5–1 mm long, somewhat ascending, isidia, often dense, ciliate, without soredia, lower surface black with tan naked marginal zone, rhizines black, dense. Apothecia rare; spore size 20–25 × 12–16 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K + y, C—, KC—, P + orange. Stictic acid and atranorin.
Specimens examined: 1714: (1), 2643: (3), 1051: (8), RR.CS.5071: (10), 1746: (13), 1677: (17), 1520: (18), 517: (21), 1658: (22).

Parmotrema parahypotropum (Culb.) Hale 1974a: 338
Parmelia parahypotropa Culb. 1973: 29
Thallus greyish-white to white, foliose, loosely adnate, lobes 2–5 mm broad, strongly ascending, deeply dissected, the lacinae narrow with terminal soralia, revolute, cilia long, sparse or absent on lacinae bearing soredia, without isidia, lower surface black, ascending lobes white below, rhizines on black lower surface only. Apothecia not recorded.
Reactions: Cortex K + yellow, medulla K + yellow turning red, C—, KC—, P + yellow. Norstictic acid and atranorin.
The most striking character of this species is the long, narrow, ascending lacinae 2–3 mm in length with white lower surface and terminal soralia.
Specimens examined: 2648: (3), 1609, 1635: (17).

Parmotrema rampoddense (Nyl.) Hale 1974a: 338
Parmelia rampoddensis Nyl. 1900: 6
Thallus greenish-grey to pale grey, foliose, loosely adnate, lobes rotund, margins entire, soralia terminal, involute, cilia long and ascending, without isidia, lower surface black, dark brown at margin, rhizines black, sparse. Apothecia rare; spore size 10–12 × 6–7 μm. A.n.v.

Reactions: Cortex K + yellow, bluish-white fluorescent in UV, medulla K—, C—, KC + red, P—. Atranorin and alectoronic acid.
Specimens examined: 2636: (3), 1096: (8), HC.72: (19), 1700: (22).

Parmotrema reticulata (Tayl.) Choisy 1952: 175
Parmelia reticulata Tayl. in Mack. 1836: 148
Thallus greenish-grey, foliose, loosely adnate, maculate, reticulately cracked, lobes rotund, 2–3 mm broad, cilia simple, of uneven lengths, sparse to dense, without isidia, soralia marginal, labriform on ascending lacinae of lobes, lower surface black, margin tan, except for the ascending lacinae which are sometimes white, rhizines black, simple or slightly branched, sparse to moderately dense. Apothecia pedicilate, disc brown, concave, in some perforate, margin entire, sorediate; spores hyaline, size 10–11 × 7 μm.
Reactions: Cortex K + yellow, medulla K + yellow turning red, C—, P + yellow. Salazinic acid and atranorin.
Specimens examined: 1713: (1), 1747: (13), 1624: (17), 1484: (18), 531: (21).

Parmotrema robustum (Degel.) Hale 1974a: 338.
Parmelia robusta Degel. 1941: 33.
Thallus greenish-grey, foliose, loosely adnate, upper surface dull, rugose in centre of thallus, lobes rotund 5–10 mm broad, crenate, edged by a thin black line, soredia marginal on short irregular ascending lacinae, or partly submarginal, without isidia, without cilia, lower surface black with tan naked marginal zone, rhizines black, sparse. Apothecia rare; spore size 17–22 × 8–10 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K— or very slight yellow, C—, KC + pink P + orange-red. Atranorin and protocetraric acid.
Specimens examined: 1715: (1), 2649: (3), 1080: (8), 1748: (13), 1675: (17), 1465: (18), 546: (21), 1659: (22).

Parmotrema saccatilobum (Tayl.) Hale 1974a: 339
Parmelia saccatiloba Tayl. 1847: 174
Thallus pale greenish-grey, loosely adnate, foliose, lobes broad 5–10 mm, rotund becoming broadly convoluted, margin smooth, surface dull, reticulately cracked with age, without cilia, isidia cylindrical, simple or slightly branched, small, 0.1–0.15 mm high, moderate to dense, lower surface black, pale broad naked zone at margin, rhizines sparse. Spore size 22–26 × 12–16 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C—, KC + pale rose, P + orange. Atranorin and protocetraric acid.
Specimen examined: 1641: (17).

Parmotrema subtinctorium (Zahlbr.) Hale 1974a: 339
Parmelia subtinctoria Zahlbr. *in* Handel-Mazzetti 1930: 193
Thallus greenish-grey, foliose, loosely adnate, lobes rotund, 5–10 mm wide, margins crenate, surface shiny, sometimes maculate, cracked with age, cilia sparse, isidia short, cylindrical, moderately dense, without soredia, lower surface uniformly pale tawny-white, veining on the lower cortex, rhizines black, simple, sparse. Spore size 8–11 × 5–8 μm. A.n.v.
Reactions: Cortex K + slightly yellow, medulla K + yellow turning red-brown, C—, KC—, P + orange. Salazinic acid and atranorin.
Specimen examined: 1633: (17).

Parmotrema tinctorum (Nyl.) Hale 1974a: 339
Parmelia tinctorum Nyl. 1872: 547
Thallus greenish-grey, foliose, very loosely adnate, lobes rotund, 10 mm broad, margin entire, without cilia, isidia cylindrical, granular or papillate and most numerous in centre of thallus, without soredia, lower surface black, brown naked zone at margin, rhizines black, sparse. Apothecia rare, spore size 13–15 × 7–10 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K—, C + red, KC + red, P—. Lecanoric acid and atranorin.
Specimens examined: 1712: (1), 1082: (8), 1749: (13), 1641: (17), 1448: (18).

Physcia tribacoides Nyl. 1869: 322
Thallus light grey, foliose, adnate, lobes linear, soralia laminal, large, capitate, without isidia, without cilia, lower surface pale, rhizines pale to black, short, simple, sparse. Apothecia rare; spores 17–22 × 7–9 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K + yellow, P—.
Specimens examined: 1731: (1), 2641: (3), 1750: (13), RR.CS.5407: (15), 1645: (17).

Physciopsis adglutinata (Flk.) Choisy 1950: 20
Lecanora adglutinata Flk. 1819: 7
Thallus greenish-brown, green or grey-green, usually darker along the lobe margins, foliose, small, mostly orbicular in outline, up to 3 cm diam., usually 2 cm, lobes thin, very closely appressed to substrate, lobes narrow 0.1 mm, but can be 0.5 mm broad, sometimes distinctly separated or broad and imbricate, soralia laminal, small, dot-like, usually abundant towards centre, lower surface usually tightly appressed to substrate, dark brown, rhizines short. Apothecia small, sessile, 0.5 mm diam., disc brown, epruinose, margin thick, spore size 13–20 × 6–10 μm.
Reactions: Cortex K–, medulla K–, C–, KC–, P–.
Specimens examined: 1720: (1), RR.CS.4775: (2), 4435: (3), 4479: (4), 4547: (5), 4438: (6), 4477: (7), 1772: (9), RR.CS.4976: (10), 1743: (13), 530: (20), 1661: (22).

Physma byrsinum (Ach.) Müll. Arg. 1885: 531
Parmelia byrsea Ach. 1803: 222
Thallus greyish-brown, foliose, sometimes mottled brown and white, sometimes silvery-grey, rugose, lobes thick, pruinose or epruinose, lower surface black, tomentose. Apothecia frequent, 0.3–0.9 mm diam., disc red-brown, margin concolorous with thallus, thick, crenate; spores simple, hyaline, thick walled, size 14 × 7 μm.
Specimens examined: 1592: (8), 1605, 1637: (17), 1521: (18), 1705: (22).

Pseudoparmelia caperata (L.) Hale 1974c: 189
Lichen caperatus L. 1753: 1147
Thallus yellow-green, foliose, slightly maculate, adnate; lobes sub-irregular, apically rotund, surface somewhat rugulose and cracked on older lobes; soralia marginal and laminal, pustular, soredia granular, without isidia, without cilia, lower surface black, dark brown zone at margin, rhizines sparse. Spore size 14–20 × 7–10 μm. A.n.v.
Reactions: Cortex K– or K + pale yellow, medulla K + pale yellow, C–, KC–, P + orange-red. Protocetraric acid, usnic acid and atranorin.
Specimens examined: 1630, 1678: (17).

Pseudoparmelia aff. *crozalsiana* (B. de Lesd.) Hale 1974c: 189
Thallus green-grey, foliose, somewhat maculate, reticulate, ridged and wrinkled in centre; lobes 2–3 mm wide, rotund, entire, without cilia, without isidia, soralia along margin ridges of thallus, globose, often coalescing, soredia coarse, lower surface black, tan marginal zone, rhizines black, small, almost to margin. Pycnidia often numerous. Apothecia not recorded.
Reactions: Cortex K + yellow, medulla K + yellow-orange, C–, KC–, P + orange. Atranorin, stictic, norstictic and constictic acids and associated unknowns identified by TLC. The true *P. crozalsiana* does not contain norstictic acid and has larger lobe width.
Specimens examined: 2646: (3), 1736, 1062: (8), 1487: (18), 1656: (22).

Pseudoparmelia texana (Tuck.) Hale 1974c: 191
Parmelia texana Tuck. 1858: 424
Thallus pale green, or ashy-grey, foliose, adnate, reticulately cracked with age, lobes subirregular, apically rotund, indented, edged with a thin black line, soralia laminal, warty at first, becoming small capitate clusters of soredia, without isidia, without cilia, lower surface black, narrow brown naked zone at margin, rhizines black, sparse to moderate. Apothecia rare; spore size 9–11 × 6–7 μm. A.n.v.
Reactions: Cortex K + yellow, medulla K–, C–, KC–, P–. Divaricatic acid and atranorin.
This species can be broadly interpreted as *P. texana* although it differs in some aspects.
Specimen examined: 1735: (1).

Pyxine berteriana (Fée) Imsh. 1957: 254
Circinaria berteriana Fée 1824: 128
Thallus green or yellow-green, foliose, very maculate, lobes linear, branching, epruinose, without soredia, without isidia, medulla yellow, lower surface black, rhizines black. Apothecia usually numerous, largest near centre of thallus, disc and margin black, flat; spore size 15–22 × 6–9 μm.
Reactions: Cortex K–, UV + yellow, medulla K–, C–, KC–, P–.
Specimens examined: 1717: (1), 1751: (13), 1474: (17), 527: (20).

Pyxine cocoes (Sw.) Nyl. 1857: 108
Lichen cocoes Sw. 1788: 146
Thallus pale whitish-green, foliose, adnate, lobes narrow to moderately broad, variable, pruinose tips, soralia mainly marginal, also laminal, punctiform, orbicular to linear, without isidia, lower surface dark

green or black, rhizines moderately dense, pale or dark, medulla white. Apothecial disc and margin black; spore size 12–20 × 5–8 μm.
Reactions: Cortex UV + yellow, medulla K—, C—, P—.
Specimens examined: 1718: (1), RR.CS.4778: (2), 4486: (3), 4426: (4), 4424: (5), 4427: (6), 4428: (7), 1093: (8), 1777: (9), 4479: (10), 5015: (12), 5403: (15), 1482: (17), 529: (20), 524: (21).

Pyxine aff. *physciaeformis* (Malme) Imsh. 1957: 257
Thallus pale grey, ashy-white, foliose, lobes loosely or firmly appressed, somewhat imbricate and confluent, glistening pruina, isidia cylindrical, without soredia, lower surface pale brownish-green, rhizines black, medulla yellow in upper layer and white below. Spore size 15–20 × 6–8 μm. A.n.v.
Reactions: Cortex UV + yellow, medulla K—, C—, P—.
This name may not be applicable as only one poor specimen has been collected but as no further identification can be made we have referred it tentatively to this species.
Specimen examined: RR.2040: (20).

Pyxine retirugella Nyl. 1859: 240
Thallus green, greenish-grey, foliose, maculate and reticulate, adnate, lobes sub-linear, indented at margin, thin, pruinose, soredia in corticate cups on lamina, without isidia, lower surface black, pale at margin, rhizines pale to dark, sparse, medulla white. Apothecia black; spore size 14–17 × 5–7 μm.
Reactions: Cortex K—, UV + slightly, medulla K + y, C—, P + orange. Norstictic acid.
Specimens examined: 1719: (1), 1596: (17), 1586: (18).

Pyxine subcinerea Stirt. 1898: 397
Thallus pale green or greenish-grey, foliose, adnate, lobes linear, edges dissected, often with fine white margin, slightly imbricate, very heavily pruinose at tips, soralia marginal and spreading onto lamina, orbicular or ellipsoidal, semicircular, without isidia, lower surface dark green, rhizines pale to dark, medulla pale yellow. Apothecia black; spore size 12–14 × 5–7 μm.
Reactions: Cortex K—, UV + yellow, medulla K—, C—, P—.
Specimens examined: 1716: (1), 2640: (3), 1083: (8), 1773: (9), RR.CS.5649: (15), 1666: (17), 1440: (18), 528: (20), 524: (21), 1662: (22).

Ramalina exiguella Stirt. 1881a: 67
Thallus pale green to pale straw, fruticose, small, erect, rigid, tufty, up to 30 mm high, branches sub-terete thin and stringy, sparingly divided, the apices attenuated, the tips often black pointed. Apothecia small, laminal, pedicilate, causing a knee bend in branch, disc slightly concave or flat, sometimes convex, pruinose, margin shiny, smooth, entire, cream to lemon coloured; spore size 10–13 × 6–7 μm.
Reactions: Medulla K—, C—, P—. Usnic acid.

Ramalina aff. *leiodea* Nyl. 1870: 141
Thallus greenish-grey, fruticose, erect to pendent, branching from base, caespitose, the branches rigid, flattened or canaliculate, with small depressions and striae. Apothecia pedicellate, subterminal (spurred) or marginal, sparse to numerous, concave to flat or becoming convex with crenate margin, often becoming dissected, margin concolourous with thallus, disc pale yellowish-green, spore size 10–14 × 3–5 μm.
Reactions: Medulla K + pink, P—. Cryptochlorophaeic and usnic acids. This lichen varies markedly in length of thallus and broadness of branches (from 0.5 mm to 4 mm broad), the narrower the breadth the more canaliculate it becomes, the broadest branches may not be canaliculate, but are markedly striate, and bear laminal apothecia as well as subterminal. This lichen is very common in the mangroves and is found mostly on *Avicennia marina*.
Specimens examined: 1721: (1), 4466: (3), 4471: (7), 1046:(8), 1775: (9), RR.CS.5055: (10), RR.CS.135: (11), 1753: (13), 1877: (15), RR.CS.5451: (16), 1667: (17), 1494: (18), 502: (21), 1663: (22).

Ramalina perpusilla Stirt. 1881a: 68
Thallus pale yellow-green, fruticose, small, caespitose, inflated and perforated, usually about 10 mm high, branches dichotomously branched. Apothecia terminal or subterminal, disc 0.5–2 mm diameter, flat, pruinose, concolorous with thallus, margin hardly detectable, entire; spore size 10–14 × 3–4 μm.
Reactions: Medulla K—, P—. Divaricatic acid.
Specimens examined: 2650: (3), 1755: (13), 1670: (17), 1412: (18), HC.3073: (19), 1699: (22).

Ramalina peruviana Ach. 1810
Thallus pale grey-green, fruticose, sub-pendant, sub-terete or flattened, dendritic branching, thin stems, soredia granular, marginal, erupting at intervals along whole length of stem and at the apices. Apothecia not recorded.
Reactions: Medulla K + pink, C—, P —. Usnic, sekikaic and homosekikaic acids. The pink reaction is an

hydrolysis reaction which is not related to the three chemical constituents (Elix, pers. comm.).
Specimens examined: 2647: (3), 1097: (8), 1873: (13), 1480: (18), HC.3074: (19).

Ramalina reagens (B. de Lesd.) Culb. 1966b: 847
Ramalina farinacea var. *reagens* B. de Lesd. 1920: 217
Thallus green or greenish-yellow, fruticose, pendant, flattened, leathery, branches narrow, 1 mm wide, dichotomously branched with apices attenuated, soralia marginal and laminal, ellipsoidal sometimes coalescing. Apothecia rarely reported; spore size 14–17 × 4–5 μm, hyaline.
Reactions: Medulla K + yellow turning ferruginous red, P + orange. Salazinic and usnic acid.
This lichen varies in size enormously, often as small as 3 cm in length, one specimen found at site (18) was 28 cm long. Apothecia were present on a sorediate specimen from Little Rocky Point, the apothecia were marginal, pedicellate, sparse, disc greenish-yellow to flesh-coloured, flat or convex, margin thin, entire.
Specimens examined: 1722: (1), 4608: (3), 4609: (6), 1048: (8), 1776: (9), 5053: (10), RR.CS.5456: (16), 1654: (17), 1483: (18), HC.3075: (19), 1660: (22).

Relicina sydneyensis (Gyeln.) Hale 1974b: 485
Parmelia sydneyensis Gyeln. 1938: 292
Thallus yellow-green, foliose, adnate, centre becoming cracked with age, lobes shiny, finely sub-linear, elongate, cilia bulbate, usually long, isidia cylindrical, simple, dense, without soredia, lower surface brown with simple black rhizines. Apothecia infrequent, disc tan, margin concolorous with thallus, crenate, ecoronate, the base retrosely rhizinate; spore size 7–8 × 4–5 μm.
Reactions: Cortex K—, medulla K + yellow turning red, C—, KC—, P + orange.
Norstictic acid, atranorin and usnic acid.
Specimens examined: 1651: (17), 543: (21), 1704: (22).

Teloschistes flavicans (Sw.) Norm. 1853: 229
Lichen flavicans Sw. 1788: 147
Thallus yellow-orange to bright orange, fruticose, sub-terete, or slightly flattened, 0.5–1 mm diam. dichotomously branched, branches produce fine fibrils up to 0.6 mm in length with black tips, sorediate along branches, soralia elliptical, without isidia. Spore size 13–18 × 8–12 μm. A.n.v.
Reactions: Cortex K + crimson, medulla K—, P—.
This lichen is a sun-loving species occurring where direct sunlight is assured. *Ceriops tagal* trees are the most common habitat although some specimens have been collected from the trunks of *Avicennia marina*. In this habitat it is usually yellow-green because of insufficient light to produce full orange pigmentation.
Specimens examined: 2637: (3), 1056, 1957: (8), RR.CS.5074: (10), 1505: (18), HC.3079: (19).

Usnea baileyi (Stirt.) Zahlbr. 1927: 182
Eumitria baileyi Stirt. 1881b: 100
Thallus pale green-grey, fruticose, rigid, subpendulose, erect or prostrate, branches and branchlets or fibrils dense, giving a feathery effect, without soredia, isidia sometimes present, axis thick, centre of axis hollow, medulla thin, rust-red colour. Apothecia rare.
Reactions: Medulla K— or slightly K + yellow, which is difficult to detect as the red medulla fades when K is added. Usnic and norstictic acids.
Specimens examined: 1706: (17), 515, 1836: (21).

Usnea leprosa Mot. 1936–38: 106
Thallus green or grey-green, fruticose, up to 5 cm long, subpendulose, branches terete, many inflated, fusiform, attenuated, pseudocyphellae raised or plane, orbicular, punctiform or elongate, numerous on secondary branches, sparse to dense on branchlets, fibrils few, isidia abundant on main stems, and on pseudocyphellae, medulla lax, twice as wide as axis, axis solid, white to pale cream pink, notably thin. A.n.v.
Reactions: Medulla K + yellow slightly, P + orange. Stictic, constictic and usnic acids + 2 unknown fatty acids, identified by TLC.
There is no salazinic acid present in the specimens examined in this study. This acid is the normal constituent of *U. leprosa*. However as some chemical variance is recorded for this species (Swinscow and Krog 1975) and one group described in the report contains stictic acid, we have referred our material to this species.
Specimens examined: 1063, 1177, 5191: (8), 1642: (17).

Usnea propinqua (Stirt.) Stirton 1898: 319
Usnea chaetophora Stirt. sub. sp. *propinqua* Stirt. 1883: 76
Thallus green or greenish-yellow, fruticose, pendant, terete branches, articulate at joints, sub-

dichotomously branching, up to 15 cm or more in length, sparse to dense isidia on pseudocyphellae (irregular cracks in thallus), medulla white, dense, axis solid, pale yellow, same width as medulla, but variable sometimes. No apothecia recorded.
Reactions: Medulla K + yellow turning orange-red, P + yellow-orange. Norstictic acid and usnic acid.
Specimens examined: 1644: (17), HC.3071, 3077: (19), 1845: (21).

Usnea ramulossissima nom. nov.
Usnea dasypogoides var. *microcarpoides* Müll. Arg. 1883: 20
Usnea microcarpoides (Müll. Arg.) Mot. 1936: 525 non *U. microcarpoides* (Vain.) Vain. 1928: 67.
Thallus pale green, fruticose, rigid, subpendulous, dense branching, fibrils numerous on all stems, without isidia, without pseudocyphellae, axis solid, pale yellow, as broad as medulla, medulla white, thin. Apothecia 0.6 mm diam., ciliate, flat, terminal; spore size 8–9 × 6 μm.
Reactions: Medulla K + yellow turning red, P + yellow. Norstictic acid.
A new name is required for this species since the combination *U. microcarpoides* (Müll. Arg.) Mot. is a later homonym of *U. microcarpoides* (Vain.) Vain.
Specimen examined: 2529: (19).

Usnea rubescens Stirt. 1883: 76
Thallus pale green with rust-red tones, fruticose, rigid, pendant or prostrate, lateral branching, fibrils from main branches, isidia small, simple, arising from pseudocyphellae, axis solid, medium thickness with medulla half as thick as axis. Apothecia not recorded.
Reactions: Medulla K + yellow turning red, P + orange. Norstictic and Salazinic acid.
Specimens examined: 514, 1838: (21).

Usnea rubicunda Stirt. 1881b: 102
Thallus pale green or glaucous-straw coloured, variegated with red, fruticose, erect to prostrate, cortex irregularly broken with cracks showing a thick white medulla, branches terete, branchlets attenuated, numerous fibrils, isidia dense on pseudocyphellae of small branches, or absent, axis solid of variable thickness, usually greater than medulla. Apothecia very rare. A.n.v.
Reaction: Medulla K + yellow, P + pink-orange. Stictic acid and usnic acid.
Specimen examined: 1595: (17).

Usnea undulata Stirt. 1881b: 104
Thallus pale greyish-green, fruticose, straggling, moderately lax, branches terete, attenuating, many branchlets with dense fibrils, sometimes pseudocyphellae on tapering ends of branches and branchlets, soredia absent, medulla white, moderately dense, axis solid, half width of medulla. No apothecia recorded.
Reactions: Medulla K + yellow turning orange-red, P + yellow. Norstictic acid.
Specimen examined: 1473: (18).

KEY TO THE MACROLICHEN FLORA SPECIES

1.	Thallus fruticose, i.e. without dorsiventral differentiation, round or ribbon like	Section I.
	Thallus foliose, i.e. with dorsiventral differentiation, leaflike, flat with obvious lobes	2
2.	Thallus containing green algae	Section II.
	Thallus containing blue-green algae	Section III.

SECTION I. FRUTICOSE LICHENS

1.	Thallus branches with a central axis	2
	Thallus branches without a central axis	8
2.	Axis hollow	*Usnea baileyi*
	Axis solid	3
3.	Thallus tinged with red	4
	Thallus green, yellow-green or yellow-orange	5
4.	Medullary reaction K + yellow	*Usnea rubicunda*
	Medullary reaction K + yellow turning red	*Usnea rubescens*
5.	Medullary reaction K + yellow turning red	6
	Medullary reaction K + yellow or K−	7
6.	Fibrils dense on branches, simple	*Usnea ramulosissima*
	Fibrils dense and branched	*Usnea undulata*
	Fibrils absent or few	*Usnea propinqua*

7. Medulla lax and twice as wide as axis .... *Usnea leprosa*
Medulla not as above 8

8. Thallus colour yellowish-orange or orange .... *Teloschistes flavicans*
Thallus colour green, or yellow-green 9

9. Thallus inflated and perforate .... *Ramalina perpusilla*
Thallus not inflated and perforate 10

10. Thallus sorediate 11
Thallus not sorediate 13

11. Soredia bursting from stems and apices .... *Ramalina peruviana*
Soredia not bursting from apices 12

12. Thallus rarely with apothecia but always with marginal and laminal soredia .... *Ramalina reagans*
Thallus regularly bearing apothecia 13

13. Thallus branches subterete, narrow, ending in pointed tips, often blackened .... *Ramalina exiguella*
Thallus branches canaliculate or broad and slightly canaliculate .... *Ramalina* aff. *leiodea*

SECTION II FOLIOSE LICHENS WITH GREEN ALGAE

1. Cilia present 2
Cilia absent 13

2. Thallus with ciliate isidia .... *Parmotrema crinita*
Thallus without ciliate isidia 3

3. Soredia present 4
Soredia absent 5

4. Thallus markedly maculate .... *Parmotrema reticulata*
Thallus not maculate, or only slightly .... *Parmotrema rampoddense*

5. Cilia simple 6
Cilia bulbate 11

6. Medulla pale yellow .... *Parmelina aurulenta*
Medulla white 7

7. Isidia present 8
Isidia absent 10

8. Isidia pustulate .... *Parmelina spumosa*
Isidia cylindrical 9

9. Lobes narrow and very small .... *Parmelina* aff. *tiliaceae*
Lobes broad and large .... *Parmotrema subtinctoria*

10. Medullary reactions K—, C—, KC + pink, P— .... *Parmelina damaziana*
Medullary reactions K + yellow turning red, P + orange .... *Parmotrema parahypotropum*

11. Thallus yellow green .... *Relicina sydneyensis*
Thallus greenish-grey, green or whiteish-grey 12

12. Medullary reaction K + yellow turning red .... *Bulbothrix tabacina*
Medullary reaction K— .... *Bulbothrix goebelii*

13. Isidia present 14
Isidia absent 17

14. Medulla yellow in upper part, white below .... *Pyxine physciaeformis*
Medulla not as above 15

15. Medullary reactions K—, C—, KC + rose, P + orange .... *Parmotrema saccatilobum*
Medullary reactions not as above 16

16. Lobes narrow and very small .... *Parmelina* aff. *tiliaceae*
Lobes broad and large .... *Parmotrema tinctorum*
Lobes not as above 17

17. Soralia absent 18
Soralia present 19

18.	Apothecia present, black with black margin	*Pyxine berteriana*
	Apothecia present, black with white margin	*Dirinaria confluens*
19.	Rhizines black, densely dichotomously branched	*Hypotrachyna immaculata*
	Rhizines pale or dark, simple or squarrously branched	21
20.	Thallus maculate	*Pyxine retirugella*
	Thallus yellow-green	*Pseudoparmelia caperata*
	Thallus greenish-grey or greyish-white	*Heterodermia obscurata*
21.	Soralia marginal on broad sinuate lobes	*Parmotrema austrosinense*
	Soralia marginal	*Heterodermia tremulans*
	Soralia on thallus ridges, coalescing	*Pseudoparmelia* aff. *crozalsiana*
	Soralia not as above	22
22.	Cortex K + yellow	23
	Cortex K—	27
23.	Thallus maculate and reticulate	*Parmelia erumpens*
	Thallus not maculate	24
24.	Medullary reaction P + orange	*Parmotrema robustum*
	Medullary reaction P—	25
25.	Sekikaic acid present	*Dirinaria consimilis*
	Sekikaic acid absent	26
26.	Apothecia present, disc red-pruinose	*Dirinaria melanoclina*
	Apothecia absent	*Pseudoparmelia texana*
27.	Lower surface pale	*Physcia tribacoides*
	Lower surface black at centre	28
28.	Thallus lobes contiguous, apices discrete	*Dirinaria picta*
	Thallus lobes confluent to apices	29
29.	Soralia laminal, initially as minute verrucae becoming small crateriform	*Dirinaria aspera*
	Soralia laminal, globose-capitate, sometimes coalescing	*Dirinaria applanata*
	Soralia not as above	30
30.	Medulla pale yellow	*Pyxine subcinerea*
	Medulla white	31
31.	Cortex UV + yellow	*Pyxine cocoes*
	Cortex UV—	*Physciopsis adglutinata*

Section III Foliose Lichens With Blue-Green Algae

1.	Thallus gelatinous when wet	2
	Thallus not gelatinous when wet	5
2.	Thallus lead-grey	*Leptogium phyllocarpum* var. *isidiosum*
	Thallus dark green or black	3
3.	Thallus isidiate	*Collema rugosum*
	Thallus not isidiate	4
4.	Apothecia with white pruinose disc	*Collema laeve* var. *laeve*
	Apothecia with red to black disc	*Collema glaucophthalmum* var. *implicatum*
5.	Thallus dark brown or mottled grey, very thick	*Physma byrsinum*
	Thallus pale brown to light grey, thin	6
	Thallus lead-grey	7
6.	Thallus with isidia-like soredia	*Pannaria elatior*
	Thallus without isidia-like soredia	*Pannaria lurida*
7.	Thallus isidiate	*Coccocarpia cronia*
	Thallus without isidia	8
8.	Thallus lobes with zoned rings	*Coccocarpia erythroxili*
	Thallus lobes wedge-shaped	*Coccocarpia pellita*

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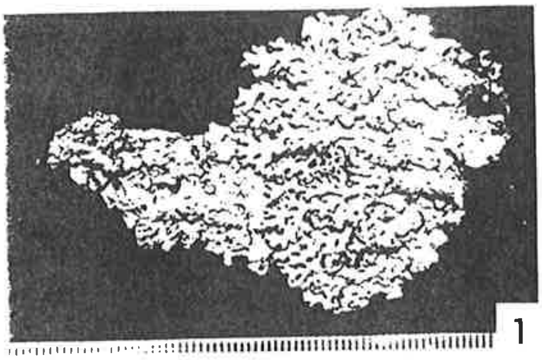
PLATE 1

Some of the lichens occurring on mangroves in Moreton Bay. Scale divisions in mm. Photographs by G. N. and N. C. Stevens.

Fig. 1: *Relicina sydneyensis* on *Rhizophora stylosa* bark
Fig. 2: *Ramalina* aff. *leiodea* showing morphological variation
Fig. 3: *Dirinaria applanata* on *Avicennia marina* bark
Fig. 4: *Ramalina reagans*
Fig. 5: *Usnea propinqua*
Fig. 6: *Parmotrema crinita* on *Avicennia marina* bark
Fig. 7: *Heterodermia obscurata* on *Ceriops tagal* bark
Fig. 8: *Pyxine berteriana* on *Avicennia marina* bark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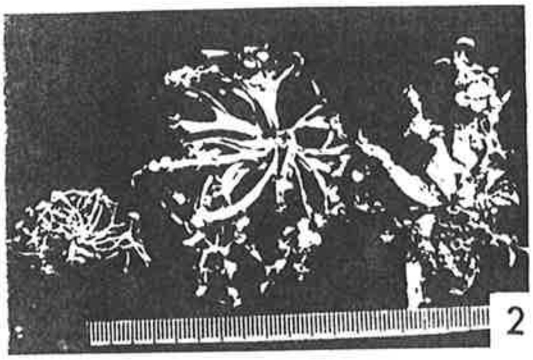
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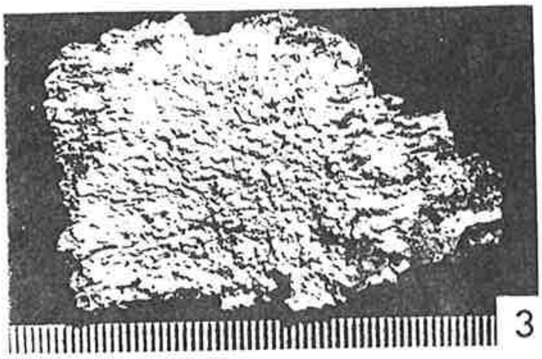
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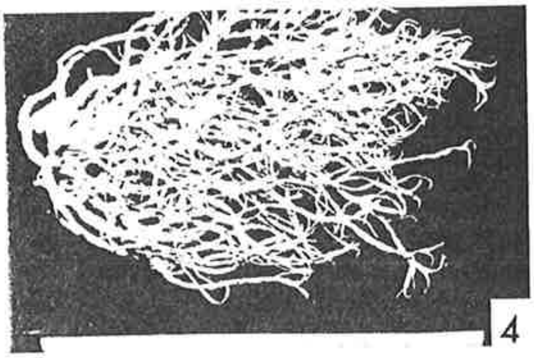
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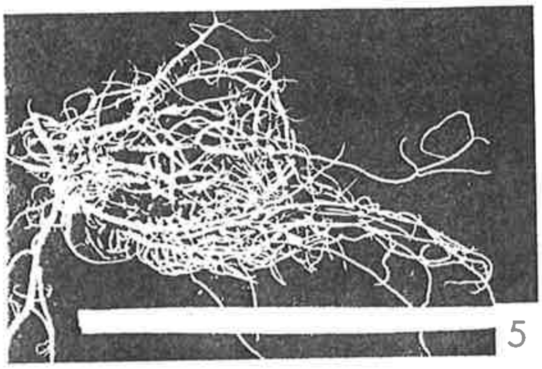
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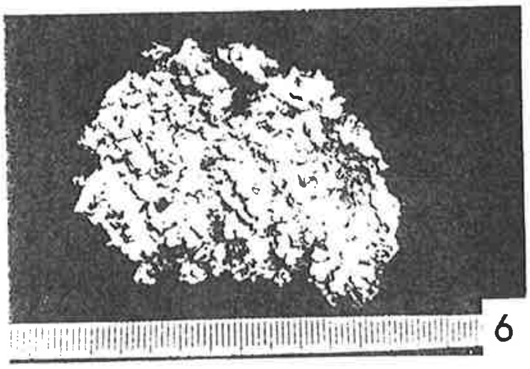
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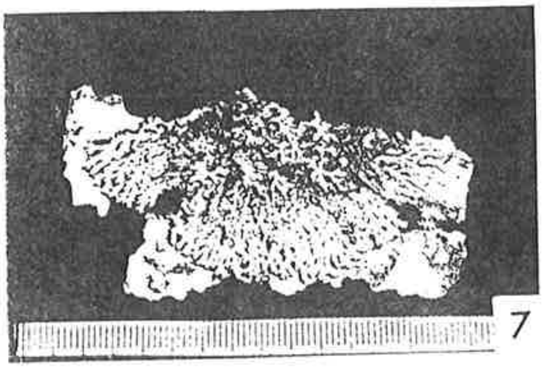
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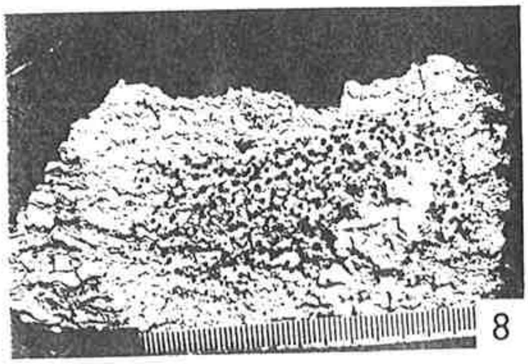
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APPENDIX 3

(A) ANNOTATED LIST OF LICHENS FROM MT COOLUM

by

R.W. ROGERS

Buellia spp.	Several unidentified species forming white crusts on rock faces.
Caloplaca spp.	Two unidentified crustose species one yellow, one gold-orange on dry, vertical rock faces.
Cladia aggregata (Sw.) Nyl.	A common tufty fruticose species, on seasonally wet south facing rock faces and on soil.
Cladonia capitata (Michx.) Sprengel	A fruticose species with developed leafy bases growing with mosses in rock crevices.
Cladonia squamosula Müll. Arg.	An erect fruticose species on the base of *Lophostemon confertus* in a moist area.
Dirinaria aegialita (Ach.) Moore	A small foliose species on rock surfaces.
Heterodea mulleri (Hampe) Nyl.	A foliose species loosely attached to soil or fine gravel surfaces, often rather distorted when dry.

Heterodermia obscurata (Nyl.) Trevis.	A common closely appressed foliose species on seasonally wet rock faces.
Hypotrachyna immaculata (Kurok.) Hale	A species of seasonally wet rock faces.
Lecidea sp.	Crustose species on rock faces.
Leprocaulon arbusculum (Nyl.) Nyl.	A small, friable somewhat fruticose species on bark of *Planchonella laurifolia*.
Leptogium phyllocarpum var. *isidiosum* Nyl.	A moderate sized foliose thallus growing on damp, shaded rocks.
Opegrapha sp.	A white crust on wood.
Pannaria stylophora Vainio	A moderate sized foliose species growing on damp, shaded rocks.
Parmotrema grayanum (Hue) Hale	A large foliose species on seasonally wet rock faces.
Parmotrema leucosemothetum (Hue) Hale	A large foliose species of shaded dry rocks and on bark.
Parmotrema perlatum (Huds) Choisy	A large foliose species of seasonally wet south facing rock faces.
Parmotrema reticulatum (Tayl.) Choisy	A large foliose species of seasonally wet south facing rock faces.
Parmotrema saccatilobum (Tayl.) Hale	A large foliose species on bark of *Stenocarpus sinuatus*.
Parmotrema tinctorum (Nyl.) Hale	A large foliose species of shaded rock surfaces (also common on bark in other places).
Peltula aff. *bolanderi* (Ach.) Wetmore	Very small squamules (c. 1 mm) rare, on vertical, dry overhung rock faces.
Pertusaria spp.	Several common sterile crustose species, one very common yellow species colouring large areas of exposed rocks.
Physcia sp.	An indeterminate species on bark of this small foliose genus.
Pseudoparmelia neoquintaria Hale	A moderate size foliose species widespread on rock faces.
Pseudoparmelia spodochroa (Kurok. & Filson) Hale	A moderate sized foliose species of seasonally wet south facing rock faces.

Pyxine consocians Vainio	A small foliose species on bark in moist places.
Pyxine cungens Vainio	A common, small foliose species of dry but usually shaded rocks.
Relicina sydneyensis (Gyelnik) Hale	A small foliose species of seasonally wet south facing rocks.
Thelotrema spp.	Several species in this poorly known group of mostly tropical crustose lichens, usually on bark.
Thysanothecium hyalinum (Tayl.) Nyl.	A small, erect fruticose species restricted to charred wood in moist places.
Usnea undulata Stirton	A tufty fruticose lichen on twigs.
Xanthoparmelia flavescentireagens (Gyeln.) Hale	A moderate sized foliose species of seasonally wet south facing rocks.
Xanthoparmelia globulifera (Kurok. & Filson) Hale	A small sized foliose species of seasonally wet south facing rocks.
Xanthoparmelia scabrosa (Tayl.) Hale	A small sized foliose species of exposed, north facing rocks.

APPENDIX 3

(B) KEY TO THE FOLIOSE AND FRUTICOSE LICHENS OF MT COOLUM, QLD

BY

R.W. ROGERS

1a	Thallus fruticose or shrubby, standing up or hanging from the substrate	2
1b	Thallus foliose or leafy, more or less appressed to the substrate	6
2a (1a)	Thallus as beard-like tufts on twigs	*Usnea undulata*
2b	Thallus not as tufts on twigs	3
3a (2b)	On bark, thallus recumbent of indistinct structure	*Leprocaulon arbusculum*
3b	On soil or rock, thallus clearly shrubby and erect	4
4a (3b)	Thallus dark green to brown, much branched	*Cladia aggregata*
4b	Thallus pale grey to grey-green little , branched	5
5a (4b)	Thallus longitudinally striate or fissured (10 x lens)	*Cladonia capitata*
5b	Thallus not longitudinally striate or fissured	*Cladonia squamosula*
6a (1b)	Lobes mostly more than 10 mm wide	7
6b	Lobes mostly less than 5 mm wide	12
7a (6a)	Margins of thallus with long black cilia (10 x lens)	8
7b	Margins of thallus without long black cilia (10 x lens)	10
8a (7a)	Upper surface of thallus with a pattern of fine white reticulate markings (10 x lens) (medulla K+ yellow turning red)	9
8b	Upper surface without a pattern of reticulate markings (10 x lens) (medulla K+ yellow)	*Parmotrema perlatum*

9a(8a) With a broad bare zone below lobe tips .... *Parmotrema leucosemothetum*

9b With sparse rhizines up to the lobe tips .... *Parmotrema reticulatum*

10a(7b) Thallus bearing small coral-like structures (isidia) on lobe surface or margins 11

10b Thallus bearing floury patches (soralia) on lobe margins .... *Parmotrema grayanum*

11a(10a) Medulla C+ pink .... *Parmotrema tinctorum*

11b Medulla C- .... *Parmotrema saccatilobum*

12a(6b) Thallus gelatinous and black to dark olive when wet .. *Leptogium phyllocarpum* var. *isidiosum*

12b Thallus not gelatinous and black to dark olive when wet 13

13a(12b) Thallus yellow green to straw yellow or green 14

13b Thallus grey to brown 17

14a(13a) Thallus without globular or coralloid structures (isidia) on the lobes 25

14b Thallus with globular or coralloid structures (isidia) on the lobes 15

15a(14b) Margins of lobes with black cilia swollen at the base .... *Relicina sydneyensis*

15b Margins of lobes without cilia 16

16a(15b) Lower surface pale brown, medulla KC- .... *Xanthoparmelia globulifera*

16b Lower surface dark brown, medulla KC+ pale pink .... *Xanthoparmelia scabrosa*

17a(13b) Lower surface distinctly yellow to orange .... *Heterodermia obscurata*

17b Lower surface black, brown or inaccessible 18

18a(17b) Thallus with neither isidia (coralloid structures) nor soredia (floury patches) on the lobes 24

18b Thallus with either isidia or soredia on the lobes 19

19a(18b) Thallus sorediate (with floury patches) 20

19b Thallus isidiate (with coralloid structues) 23

20a(19a) Thallus easily separated from the substrate, lobes > 2 mm broad .. *Hypotrachyna immaculata*

20b Thallus closely appressed to the substrate, lobes < 2 mm broad 21

21a(20b) Lobes tending to coalesce laterally .... *Dirinaria aegialita*

21b Lobes not coalescing laterally 22

22a(21b) Lobes dappled white and grey (10 x lens), soralia not erupting from pustules (10 x lens) .... *Physcia* sp.

22b Lobes not dappled, soralia in small wart-like pustules .... *Pyxine consocians*

23a(19b) Isidia forming a dense mass in the centre of the thallus .... *Pannaria stylophora*

23b Isidia sparse .... *Pseudoparmelia neoquintaria*

24a(18a) Lobes flat, cortex K- .... *Pyxine pungens*

24b Lobes convex, cortex K+ yellow .... *Pseudoparmelia spodochroa*

25a(14a) Loosely adnate on soil or gravel .... *Heterodea mulleri*

25b Closely adnate on rock .... *Xanthoparmelia flavescentireagens*

K+	colour change when a droplet of 10% potassium hydroxide solution is added.
K-	no colour change when a droplet of 10% potassium hydroxide is added.
KC+	colour change when 10% KOH is followed by a drop of household bleach or fresh solution of bleaching powder.

41. **Rogers, R.W.** (1986). Lichens and List of Lichens from the Brisbane Forest Park. pp 181-5 in '*Recreation Management*' (Forest Park, Brisbane).

Recreation managemen workshop

Held at Queensland Institute of Technology, Friday, 18th October, 1985 to Sunday, 20th October, 1985.

Hosted by The Brisbane Forest Park Administration Authority and The Biology and Environmental Science Department, Queensland Institute of Technology.

Workshop convenors Bill Carter, Director, Brisbane Forest Park. John Wilson, Lecturer, Queensland Institute of Technology.

LICHENS

R.W. Rogers
Botany Department,
University of Queensland.

Although the lichen flora of the Brisbane Forest Park has not been subject to intensive or systematic study a flora of 72 genera with 159 species identified within the 58 genera for which species determinations have been attempted has been documented. Almost all identifications are based on collections housed in the Herbarium of the Botany Department of the University of Queensland. Significant collections have been made from a number of locations - rocks and tree trunks in a creek bed with a rainforest-fringe flora mixed with elements of the open forest near Highvale; on a rocky road cutting at the intersection of the roads from Mt. Nebo and Samsonvale to Mt. Glorious; in rainforest on tree trunks, dead wood, leaves and fallen twigs in the vicinity of Mt. Tennison-Woods; on Rocky outcrops between Jollies Lookout and Enoggera Reservoir; and on rocky outcrops in the foothills near Ferny Vale. Many incidental collections have also been made.

It is difficult to discuss the distribution pattern of lichens in the Park in any but the very broadest terms, partly because data is very limited and partly because while lichens are relatively specific to environments, suitable microenvironments may be found in a range of habitat types and on a range of substrates. Some species of *Parmotrema,* for example, can occur on rocks or tree trunks in an open forest, but will also be found on twigs in the upper canopy of a closed forest. It is, however, generally true that a lichen will normally be found on rocks or on wood and bark, or on soil, or on leaves. The lichens found on leaves of undershrubs in the rainforest are not only restricted to leaves, but in many cases belong to families restricted to that substrate, although they are likely to occur on the leaves of a number of shrub species. Two substrate specificities deserving special mention are *Navordnikia hawaiensis* (Tuck.) Tibell, which is restricted to the flaky bark on trunks of *Lophostemon confertus* and *Thysanothecium scutellatum* which is associated with charcoal.

Despite these limitations it is still possible and helpful to discuss the lichen flora of the Park in terms of habitat type, treating the park as broadly composed of two vegetation formations - closed forest (Rain Forest) and open forest (essentially eucalypt forest).

At ground level in the rainforests lichens are not normally common. One exception is *Dimerella lutea* which forms an inconspicuous thin green film over rocks and tree trunks, sometimes being dotted with bright yellow apothecia. Also apparent in some cases is the development of a range (17 species on Mt. Glorious) of foliicolous lichens on the leaves of the undershrubs. A considerable lichen flora is to be found in the rainforest canopy, evidenced by the windfall found from time to time. The margins of rainforest communities and such features as creek beds which admit additional light often have a very rich lichen flora. In these areas genera containing large foliose species such as *Sticta*, *Pseudocyphellaria,* and *Lobaria* may be found on rocks and tree trunks. The genera *Coccocarpia, Pannaria* and *Leptogium,* all characterised by blue-green photobionts instead of the common green photobiont are also common on the rainforest fringe and in the transition zone to open forest. A feature of bare earth on the roadsides in the rainforest communities is the small pink apothecia of *Baeomyces intermedia*.

The open forest has a well developed lichen flora at ground level if fire has been excluded for considerable periods. The genus *Parmotrema* is often present as very large (up to 25cm diameter) gre thalli spreading over ironbark trunks and over rocks. In misty areas the eucalypts are likely to support large populations of beard-like *Usnea* species, *U.misaminensis* sometimes forming trails up to 1m long. Rocks in these communities often have a flora including *Xanthoparmelia, Heterodermia* and *Pyxine,* as well as numerous crustose species. Soils may support *Cladia, Cladonia* and *Heterodea*.

It must be stressed that the following list is incomplete, and in very few cases are determinations the result of critical study.

.../cont'd.

LIST OF LICHENS FROM BRISBANE FOREST PARK AND VICINITY

Codes: Growth Habits A - shrubby or fruticose, B - foliose or leafy, C - crustose. Habitats O - open forests (normally dominated by species of *Eucalyptus*), R - closed forests or rainforests. Substrates colonised c - corticolous (on bark) or lignicolous (on wood), f - foliicolous (on rainforest leaves), s - saxicolous (on rocks), t - terricolous (on soil).

Anthracothecium sp. CRc
Bacidia sp. CRc
Baeomyces intermedia Tayl. CRt
Bottaria sp. CRc
Brigantiaea microcarpa CRc
Bulbothrix apophysata (Hale & Kurok.) Hale BOc
Byssoloma leucoblepharum (Nyl.) Vain. em. R.Sant. CRf
Calicium queenslandiae (F.Wils.) Tibell COc
Caloplaca sp. COs
Cladia aggregata (Sw.) Ach. AOt
Cladonia diffissa F.Wils. AOt
Cladonia floerkiana (Fr.) Floerke AOt
Cladonia squamosula Mull.Arg. AOt
Clathroporina sp. CRc
Coccocarpia domingensis Vain. BOs
Coccocarpia guimarana (Vain.) Swinscow BOc
Coccocarpia palmicola (Spreng.) Arvidds. & D. Galloway BORc
Coccocarpia smaragdina Pers. em. L Arvidds. BOc
Coenogonium sp. CRc
Dimerella lutea (Dicks.) Trevis. CRcs
Diploschistes sticticus (Koerb.) Mull.Arg. COs
Dirinaria applanata (Fee) Awasthi BORc
Dirinaria confluens (Fr.) Awasthi BORc
Glyphis cicatricosa Ach. CRc
Graphina plurispora (Redinger) Wirth & Hale CRc
Graphis semiaperta Mull.Arg. CRc
Gyalectidium filicinum CRf
Haematomma collatum (Stirton) Dodge COc
Haematomma similis Bagl. COc
Heterodea muelleri (Hampe) Nyl. BOt
Heterodermia comosa (Eschw.) Follmann & Redon BOc
Heterodermia obscurata (Nyl.) Trevis. BOc
Heterodermia leucomela (L) Poelt BORc
Heterodermia speciosa (Wulf.) Trevis. BOcs
Hyperphyscia adglutinata (Floerke) Mayrhofer & Poelt BOc
Hypotrachyna formosana (Zahlbr.) Mull.Arg. BOc
Hypothrachyna immaculata (Kurok.) Hale BOc
Lecanactis inalbescens Stirton CRc
Lecanora atra (Huds.) Ach. complex COc
Lecanora aff. *chlarotera* COc
Lecidea sp. COs
Lepraria sp. CORc
Leptogium denticulatum Nyl. BOs

.../cont'd.

Leptogium phyllocarpum var. isidiosum Nyl BORc
Leptogium marginellum (Sw.) S.Gray BOc
Leptotrema laeviscule (Nyl.) Zahlbr. CRc
Letrouitia bifera (Nyl.) Hafellner CRc
Letrouitia muralis Hafellner CRc
Lobaria isidiophora Yoshimura BRc
Lobaria querzicans Michx. BOc
Lopadium fuscum Mull.Arg. CRf
Mazosia melanophthalma (Mull.Arg.) R.Sant. CRf
Mazosia phyllosema (Nyl.) Zahlbr. CRf
Megalospora melanodermia (Mull.Arg.) Zahlbr. CRc
Myriotrema animalaiense (Patw. Kulk) Hale CRc
Myriotrema masonhalei (Patw. & C. Kulk) Hale CRc
Nadvornikia hawaiensis (Tuck.) Tibell COc
Neofuscelia verrucella (Essl.) Essl. COs
Opegrapha vegae R.Sant. CRf
Pannaria mariana (Fr.) Mull.Arg. BOc
Pannaria stylophora Vain. BOc
Parmelia signifera Tayl. BOs
Parmeliella sp BOc
Parmelina spumosa (Asahina) Hale BOc
Parmelina subfatiscens (Kurok.) Hale BOc
Parmotrema austrosinensis (Zahlbr.) Hale BORc
Parmotrema crinitum (Ach.) Hale BORc
Parmotrema cristiferum (Tayl.) Hale BORc
Parmotrema grayanum (Hue) Hale BOs
Parmotrema leucosemothetum (Hue) Hale BOs
Parmotrema parahypotropum (Culb.) Hale BORc
Parmotrema perlatum (Huds.) Hale BORc
Parmotrema permutatum (Stirton) Hale BORc
Parmotrema praesorediosum (Nyl.) Hale BOs
Parmotrema rampoddensis (Nyl.) Hale BOs
Parmotrema reticulatum (Tayl.) Choisy BORc
Parmotrema tinctorum (Nyl.) Hale BORc
Pertusaria spp CORcs
Phaeophyscia endococcinodes (Poelt) Essl. BRs
Phaeophyscia pusilloides (Zahlbr.) Essl. BRc
Phyllopsora spp. BRc
Physcia adscendens (E.Fr.) Oliv. em. Bitt. BOc
Physcia fragilescens Zahlbr. BOc
Porina epiphylla Fee CRf
Porina impressa R.Sant. CRf
Porina leptosperma Mull.Arg. CRf
Porina rufula (Krempelh.) Mull.Arg. CRf
Polyblastiopsis sp. CRc
Protoblastenia sp. COs
Pseudocyphellaria aurata (Ach.) Vain. BOc
Punctelia subrudecta (Nyl.) Krog BOc
Pyrenula sp. COc
Pyxine minuta Vain. BOs
Pyxine pungens Vain. BORc
Pyxine retirugella Nyl. BORc
Pyxine sorediata (Ach.) Mont. in Sagra BOs
Pyxine subcinerea Stirton BOc
Pseudoparmelia conlabrosa (Kurok.) Hale BOc
Pseudoparmelia euplecta (Stirton) Hale BOcs
Pseudoparmelia rutidota (Hook & Tayl.) Hale BOc

.../cont'd.

Pseudoparmelia numinbahensis (Elix) Elix BOs
Pseudoparmelia scotophylla Hale BOs
Pseudoparmelia texanum (Tuck) Hale BOc
Ramalina celastri (Spreng.) Krog & Swinscow AORc
Ramalina perpusilla Stirton AORc
Ramalina peruviana Ach. ARc
Relicina limbata (Laurer) Hale BRc
Relicina sydneyensis (Gyelnik) Hale BOs
Rinodina compensata (Nyl.) Zahlbr. COs
Sporopodium xantholeucum (Mull.Arg.) Zahlbr. CRf
Sticta aff *weigelii* Isert BRs
Sticta suberecta Stirton BRs
Strigula elegans (Fee) Mull.Arg. CRf
Strigula maculata (Cooke & Massee) R.Sant. CRf
Strigula nitidula (Mont.) J.Sant. CRf
Strigula schizospora R.Sant. CRf
Strigula subtilissima (Fee) Mull.Arg. CRf
Teloschistes xanthoroides J. Murray ARc
Theletrema kumaki (Patw. & C.Kulk) Hale CRc
Thelotrema sp. CRc
Thysanothecium scutellatum (Fr.) D.Galloway AOc
Trichothelium alboatrum Vain. CRf
Trypethelium tropicum Mull.Arg. CRc
Usnea arida Mot. AOc
Usnea baileyi Stirton AOc
Usnea leprosa Mot. AOc
Usnea misaminensis (Vain.) Mot. AORc
Usnea propinqua (Stirton) Stirton
Usnea ramulosissima Stevens & Rogers AOc
Usnea rubicunda Stirton AOc
Usnea scabrida Tayl. AOc
Usnea torquescens Stirton AOc
Usnea undulata Stirton AOc
Xanthoparmelia amplexula (Stirton) Elix BOs
Xanthoparmelia scabrosa (Tayl.) Hale BOs

42. **Hafellener, J., Filson, R.B. & Rogers, R.W.** (1989). Some genera and species of lichenized fungi new to Australia. *Nova Hedwigia* **48**, 229-35.

Nova Hedwigia 48 1—2 229—235 Stuttgart, Februar 1989

Some genera and species of lichenized fungi new to Australia

by

J. Hafellner

Institute of Botany, Karl-Franzens-University, Holteigasse 6, A-8010 Graz, Austria

R.B. Filson

National Herbarium Victoria, South Yarra, Victoria, Australia

and

R.W. Rogers

Botany Department, University of Queensland, St. Lucia, Queensland, Australia

Hafellner, J., R.B. Filson & R.W. Rogers (1989): Some genera and species of lichenized fungi new to Australia. - Nova Hedwigia 48: 229-235.

Summary: The lichen genera *Absconditella*, *Arthrorhaphis*, *Catinaria* s.str., *Gyalidea*, *Scoliciosporum*, *Vezdaea* and *Zamenhofia* together with the species *Austroblastenia pupa*, *Buellia aeruginascens*, *Calopadia subcaerulescens*, *Lecanora leprosa*, *Saccomorpha icmalea*, *Thelenella brasiliensis*, *Thelenella modesta* and *Trapeliopsis flexuosa* are reported for the first time for Australia. The genus *Catolechia* (*C. wahlenbergii*) has been incorrectly cited for the Australian flora.

Introduction

In 1986 the first author had the opportunity to visit Australia to study the lichenised fungi in both the field and herbaria. In revising this material he found representatives of species which have not been previously reported for this continent. These records seem worthy of publication particularly in light of work proceeding on the Lichen Flora of Australia project.

Results

1. **Absconditella modesta** (Hegetsch.) Vezda

Vezda (1965: 243) stated that *A. modesta* can be found on small pebbles in shaded humid habitats but later (Poelt & Vezda 1977: 2) he admitted that this species can live on wood in decomposition too. *A. modesta* has previously not been found on the southern hemisphere.

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Locality: Queensland, North Stradbroke Island, NE of Brown Lake, 27°29'S/153°26'E; mixed forest, on a fallen trunk, 10 Aug. 1986, leg. Hafellner 19208 (GZU, Hafellner, Kalb, MEL, UPS).

2. **Arthrorhaphis alpina** (Schaerer) R. Sant.

All of the specimens held in the National Herbarium of Victoria (MEL) and labeled *Catolechia wahlenbergii* proved to be *Arthrorhaphis alpina.* In Australasia the species is also known from New Zealand (Galloway 1985) [as *Arthrorhaphis citrinella*] and New Guinea (Streimann 1986) [as *Arthrorhaphis citrinella* var. *alpina*]. As the record of *Catolechia wahlenbergii* (Ach.) Flotow was based on the specimens in MEL, the species/genus consequently has to be deleted from the checklist of Australian lichens (Filson 1986).

Localities: Tasmania: Mt. Field National Park, Mt. Mawson, 19 Feb. 1968, leg. Filson 10578 (MEL). Cradle Mountain National Park, summit of Mt. Acropolis, Lake St. Clair, 7 Jan. 1965, leg. Filson 6940 (MEL).

3. **Austroblastenia pupa** Sipman

Until now *Austroblastenia pauciseptata* (Shirley) Sipman, known from Tasmania was the only species in the genus reported for Australia. This is the first time that *A. pupa* has been recorded outside of New Zealand. The specimen from Federation Peak also shows the poorly developed ascospores commented on by Sipman (1983).

Locality: Tasmania, Federation Peak area in the SW of the island, Forest Shute-Skree Shute area, 29 Dec. 1964, leg. Filson 6692 (MEL).

4. **Buellia aeruginascens** Nyl.

The Australian specimens match exactly the specimen of *B. aeruginascens*, Kalb, Lich. Neotropici 121 conserved in GZU.

Localities: Queensland: Tandora about 25 km ENE of Maryborough, sea level, 25° 27'S/152°52'E; mangroves, 23 Aug. 1986, leg. Hafellner 19316 & Rogers (Hafellner). Noosa River NE of Tewantin, about 70 km SE of Gympie, sea level, 26°23'S/153°02'E, mangroves, on *Excoecaria,* 27 July 1986, leg. Hafellner 19638 & Stevens (GZU). Same locality, on *Rhizophora,* leg. Hafellner 19199 & Stevens (GZU, Hafellner). Mt. Mee State Forest, about 1 km NW of the forest station, ca. 500 m, 27°04'S/152°45'E, rainforest, 13 Aug. 1986, leg. Hafellner 19461 & Stevens (Hafellner).

5. **Calopadia subcaerulescens** (Zahlbr.) Vezda

This collection has been distributed by Vezda in his exsiccate (Lich. Sel. exs. 2186) and is the first record of the species for Australia.

Locality: Queensland, Bunya Mountains, about 56 km NE of Dalby, NE of the J.S. Fisher Lookout, about 1050 m, 26°53'S/151°37'E, edge of a subtropical rainforest, 3 Sept. 1986, leg. Hafellner & Rogers (in the herbaria which receive Vezda, Lich. Sel. exs.).

6. **Catinaria atropurpurea** (Schaerer) Vezda & Poelt

All other species attributed to *Catinaria* in Australia (Filson 1986) are better referred to other genera (e.g. *Megalaria*). Although the lectotype species of the genus was not selected until 1984 (Hafellner 1984), the present species was correctly placed in *Catinaria* by Poelt & Vezda (1981).

Locality: Queensland: North Stradbroke Island, NE of Brown Lake, 27°29'S/153°26'E, mixed forest, on *Acacia*, 10 Aug. 1986, leg. Hafellner 19237 (GZU, MEL, Hafellner). Victoria: Marlo, on bark of tree behind dunes, at sea level, 20 Jan. 1978, leg. Stevens 4092a (BRIU).

7. **Gyalidea epiphylla** Vezda

The species has been distributed by Vezda (Lich. Sel. exs. 2185) and is the first record of a *Gyalidea* species from Australia. *G. epiphylla* was described by Vezda (1966) using material collected in tropical Africa. It has been found since in other African countries (Kenya, Ghana, Tanzania) as well as Vietnam and Papua New Guinea (Vezda, in litt.).

Locality: New South Wales, McPherson Range, Grady's Creek E of Cougal, at the edge of the Border Ranges National Park, 800 m, 28°21'30''S/153°00'30''E, edge of a rainforest, 29 Aug. 1986, leg. Hafellner, Merrotsy & Rogers (in the herbaria which receive Vezda, Lich. Sel. exs.).

8. **Lecanora leprosa** Fee

According to Brodo (1984) *Lecanora leprosa* is a pantropical species and it is well known e.g. from the Hawaiian archipelago (Magnusson 1955). Although it is very common in southern Queensland it has not previously been reported for Australia. It may be that *Lecanora albella* Pers. (Shirley 1889: 130) refers to the same species.

Localities: Queensland: Tandora about 25 km ENE of Maryborough, sea level, 25°27'S/152°52'E, mangroves, 23 Aug. 1986, leg. Hafellner 17936 & Rogers (Hafellner). NE of Gunalda, abut 59 km S of Maryborough, E of Hwy 1, about 180 m, 25°58'S/152°36'E, on trees in a grazing ground, 22 Aug. 1986, leg. Hafellner 17935 & Rogers (GZU). Ibid., leg. Hafellner 18585 & Rogers (Hafellner). Noosa Heads, S of the river mouth of the Noosa River, sea level, 26°22'S/153°05'E, on *Avicennia marina,* 14 Sept. 1986, leg. Hafellner 17937 & Stevens (GZU, Hafellner). Noosa River NE of Tewantin, about 70 km SE of Gympie, sea level, 26°23'S/153°02'E, mangroves, 27 July 2986, leg. Hafellner 17946 & Stevens (GZU). Weyba

Creek SW of Noosa Heads, about 70 km SE of Gympie, sea level, 26°24'30''S/153°05'E, mangroves, on *Avicennia marina*, 27 July 1986, leg. Hafellner 17927 & Stevens (Hafellner). Sunshine Coast, Maroochydore, small island in the Maroochydore River, sea level, 26°39'S/153°06'E, on *Avicennia marina,* 12 Sept. 1986, leg. Hafellner 17931 & Stevens (GZU, MEL). In a state forest about 25 km E of Jandowae, N of Dalby, about 450 m, 26°47'S/151°20'E, open forest with bottle trees, 2 Sept. 1986, leg. Hafellner 18721 & Rogers (Hafellner). Bunya Mountains, on the road from the ridge to Maidenwell, 1.8 km NE of the intersection, about 920 m, 26°53'S/151°40'E, eucalypt forest, 3 Sept. 1986, leg. Hafellner 19673 & Rogers (GZU). S of the New England Hwy 20 km SW of Yarraman, about 600 m, 26°55'S/151°50'E, on sclerophyll tree trunks on the edge of an *Araucaria cunninghamii* plantation, 4 Sept. 1986, leg. Hafellner 17933 & Rogers (GZU). Glasshouse Mountains, S of Tibrogargan Creek, about 40 m, 26°57'S/152°56'E, mixed forest, 19 Aug. 1986, leg. Hafellner 19453 (Hafellner). Glasshouse Mountains, N-facing hills SSW of Tibrogargan Mtn., 100-150 m, 26°57'S/162°56'E, eucalypt forest, 19 Aug. 1986, leg. Hafellner 19430 (GZU). Sellin's Road 1 km E of Mt. Mee State Forest station, about 500 m, 27°05'S/152°45'E, on exposed scrubs, 13 Aug. 1986, leg. Hafellner 17939 & Stevens (GZU). On the road from Pechey to Perseverance Dam, SE of Crows Nest, about 520 m, 27°17'S/152°04'E, on shrubs on the edge of a forest, 4 Sept. 1986, leg. Hafellner 18768 & Rogers (Hafellner). Perseverance Dam SE of Crows Nest, about 480 m, 27°17'S/152°07'30''E, eucalypt forest with granite boulders, 4 Sept. 1986, leg. Hafellner 17932 & Rogers (GZU). Fig Tree Point S of Wynnum, about 30 km E of Brisbane, sea level, 27°28'S/153°12'E, mangroves, 2 Aug. 1986, leg. Hafellner 17940 & Rogers (Hafellner). Wellington Point about 30 km SE of Brisbane, sea level, 27°28'S/153°15'E, mangroves, on *Avicennia marina,* 12 Sept. 1986, leg. Hafellner 17929 & Rogers (GZU). Indooroopilly W of Brisbane, Robertson Park, about 30 m, 27°30'S/152°59'30''E, on cultivated trees, 16 Aug. 1986, leg. Hafellner 19266 (Hafellner). St. Lucia W of Brisbane, Carmody Road, about 50 m, 27°30'S/153°00'E, open eucalypt forest, 3 Aug. 1986, leg. Hafellner 17938 (GZU). Indooroopilly W of Brisbane, Long Pocket, at the bank of Brisbane River, about 30 m, 27°31'S/153°00'E, on trees at the river bank, 16 Aug. 1986, leg. Hafellner 17934 (GZU). North Stradbroke Island, W of the Mining Co. Road on the east coast, about 20 m, 27°31'S/153°30'E, *Acacia* plantation, 9 Aug. 1986, leg. Hafellner 19759 (GZU). New South Wales: McPherson Range, Gradys Creek E of Cougal, at the edge of the Border Ranges National Park, 800 m, 28°21'30''S/153°00'30''E, at the edge of a rainforest, 29 Aug. 1986, leg. Hafellner 19348, Merrotsy & Rogers (GZU).

9.**Saccomorpha icmalea** (Ach.) Clauz. & Roux

This species has not been reported previously from Australia although some records of *Saccomorpha uliginosa* may prove to be *S. icmalea.* The nomenclature of *Saccomorpha* has been dealt with by Nimis & Poelt (1987) and Coppins et al. (1987) with completely different conclusions.

Locality: Queensland: Perseverance Dam SE of Crows Nest, about 480 m, 27°17'S/152°07'30''E, eucalypt forest with granite boulders, on fallen trunk, 4 Sept. 1986, leg. Hafellner 18672 & Rogers (GZU). Bellbird Grove Forest Park E of Mt. Nebo Road, NW of Brisbane, about 400 m, 27°25'S/152°53'E, open eucalypt forest with small rock outcrops, on dead fallen trunk, 1 Aug. 1986, leg. Hafellner 18440 & Rogers (Hafellner). North Stradbroke Island, NE of Brown Lake, 27°29'S/153°26'E, mixed forest, on fallen trunk, 10 Aug. 1986, leg. Hafellner 19207 (GZU, MEL, Hafellner). New South Wales, Kaputar National Park, The Gins, 30°06'30''S/150°04'E, 1100 m, on dead stump in open forest, 13 July 1986, leg. Merrotsy 269b (BRIU).

10. **Scoliciosporum compactum** Koerber

This taxon was not generally recognised at species level, but the characteristic bright greenish-blue epihymenium of *S. compactum* is not known to occur in the closely related *S. umbrinum*. This is a new record for both the species and genus in Australia.

Locality: New South Wales, Kaputar National Park, The Gins, 30°06'30''S/150°04'E, 1100 m, on rock, 13 July 1986, leg. Merrotsy 245a (BRIU).

11. **Scoliciosporum umbrinum** (Ach.) Arnold

Together with the previous taxon two species of *Scoliciosporum* are now recorded for Australia.

Localities: New South Wales: Patonga, mangroves, on *Avicennia marina,* 19 Jan. 1978, leg. Stevens (BRIU). Sawtell area, Boambee Creek, 30°22'S, mangroves, on *Avicennia marina,* 24 Aug. 1977, leg. Stevens 4575 (BRIU).

12. **Thelenella brasiliensis** (Muell.-Arg.) Vainio

According to Mayrhofer (1987) the species is widely distributed on suitable rocks in the tropics and subtropics but until now was unknown from Australia. Together with the recently described *Thelenella harrisii* Mayrh. this is the second species of the genus found in Australia.

Locality: Queensland, Perseverance Dam SE of Crows Nest, about 480 m, 27°17'S/152°07'30''E, on granite boulders in a eucalypt forest, 4 Sept. 1986, leg. Hafellner 15371 & Rogers (GZU, Hafellner, Kalb, MEL).

13. **Thelenella modesta** (Nyl.) Nyl.

Mayrhofer (1987) has not mentioned *Thelenella modesta* for Australasia. So three species of *Thelenella* are known now from Australia.

Locality: Queensland, Albert River Valley S of Beaudesert, S of Kerry, about 200 m, 28°10'S/153°02'30''E, on *Callitris* in a pasture, 1 Sept. 1986, leg. Hafellner 18472 & Rogers (Hafellner).

14. **Trapeliopsis flexuosa** (Fr.) Coppins & P. James

Trapeliopsis flexuosa is not rare in southern Queensland where, as in the Holarktis, it can be found on fallen trunks in rather dry mixed forest.

Localities: Queensland: Glasshouse Mountains, S of Tibrogargan Creek, about 40 m, 26°57'S/152°56'E, mixed forest, on wood, 19 Aug. 1986, leg. Hafellner 19442 (Hafellner). Perseverance Dam SE of Crows Nest, about 480 m, 27°17'S/152°07'30''E, eucalypt forest with granite boulders, on fallen trunk, 4 Sept. 1986, leg. Hafellner 18667 & Rogers (GZU, MEL). Bellbird Grove Forest Park E of Mt. Nebo Road, NW of Brisbane, about 400 m, 27°25'S/152°53'E, open eucalypt forest, on dead fallen trunk, 1 Aug. 1986, leg. Hafellner 18441 & Rogers (Hafellner) North Stradbroke Island, NE of Brown Lake, 27°29'S/153°26'E, mixed forest, on fallen trunk, 10 Aug. 1986, leg. Hafellner 19209 (GZU, M, MEL, UPS, Hafellner).

15. **Vezdaea aestivalis** (Ohlert) Tscherm.-Woess & Poelt

This species was located amongst undetermined *Catillaria* specimens in MEL. It is the first record of a *Vezdaea* species in Australasia or even outside of the Holarctis (Tschermak-Woess & Poelt 1976, Poelt & Döbbeler 1975).

Locality: Victoria, Warrnambool, on moss, Nov. 1886, leg. Wilson (MEL 7184).

16. **Zamenhofia coralloidea** (P. James) Clauz. & Roux

The genus *Zamenhofia* was described by Clauzade & Roux (1985) for a group of *Porina*-like lichens, all having isidiate thalli and halonate ascospores. We were able to find *Z. coralloidea* in a *Eucalyptus regnans* forest with many tree ferns in the understory. This is the first record of the genus for the southern hemisphere.

Localities: Victoria: Great Dividing Range, Fernshaw at Watts River, NE of Healesville, about 350 m, 37°43'S/145°37'E, on rough bark of an undetermined tree, 17 July 1986, leg. Hafellner 18408 & Filson (Hafellner). Ibid., leg. Hafellner 19377 & Filson (MEL, Hafellner).

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21 Lichens

R. W. Rogers and G. N. Stevens

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21 Lichens

1. Introduction

Studies on the lichen flora of Australia are still in their infancy. Taxonomic treatment is fragmentary, and many land areas are virtually unexplored. However, sufficient information is now available from a range of taxa and locations to construct an outline of the ecological biogeography of Australian lichens. Throughout the discussion extensive use is made of the authors unpublished distribution records of Australian lichens.

The lichen flora of Australia comprises about 2,000 species (Wetmore 1963, Weber & Wetmore 1972) distributed over some 170 genera. The flora appears remarkably low in endemics. No genus can be said to be entirely restricted to Australia, with the possible exception of *Neophyllis* if that genus is recognized as an entity instead of as a synonym of *Gymnoderma. Heterodea* is reported from Australia and New Caledonia (Filson 1978), *Chrondropsis* from Australia and New Zealand (Rogers 1971), *Thysanothecium* from Australia, Indonesia and from Japan (Asahina 1957). Of the 148 species involved in the preparation of Table 1, only 25 (17%) are Australian endemics; of the 38 species reported from arid South Australia (Rogers 1974) only 13% were Australian endemics; of the 57 corticolous macrolichens we have found in the Brisbane area only 11% were Australian endemics.

2. Distribution of lichens within Australia

The ability of the Australian landscape to support a lichen flora is very variable. The cool wet forests of Tasmania and Victoria support a very rich flora (Bratt, pers. comm. 1970) as do the rainforests and mangroves of Queensland and New South Wales. More surprising is the more or less continuous carpet of lichens on undisturbed arid zone soils right across southern Australia (Rogers 1972a,b, Rogers & Lange 1972). The eucalypt forests are by-and-large poor in lichens, becoming poorer as rainfall decreases. In particular, the monsoonal eucalypt woodlands and forests of northern Australia are very poor in lichens. Specht (1958) found only two species in Arnhem land, and failed to find any in the eucalypt forests on Cape York Peninsula in the vicinity of Weipa (Specht et al. 1977). Searches in the tropical arid zone around Mt. Isa, Queensland, initially failed to find any lichens but Ewart (pers. comm. 1978) found three crustose species on rocks. Studies on soil surface lichens (Rogers 1972b) showed a tendency for areas with a marked summer rainfall incidence to support a poorer lichen flora, and studies in the physiology of the species *Chondropsis semiviridis* indicated sensitivity to heat when the thallus was wet. In the north of Australia, in areas with low rainfall, shade cast by the trees is

Table 1. Species of nine recently revised lichen genera and of foliicolous lichens occurring in Australia showing the number of those species which are endemic to Australia and the number in common with North America (including central America), South America, Africa, India (including Nepal), Eastern Asia (Japan, Korea, China, Taiwan), Southeast Asia (Malaysia, Indonesia, Phillipines), and Europe. The last column indicates the number of species reported from Australia which are confined to the former Gondwanaland areas. Figures in heavy type indicate the region with the greatest number of species in common with Australia.

Category	Australian species	Australian endemics	North America	South America	Africa	India	Eastern Asia	Southeast Asia	Europe	Gondwana endemic	
Parmotrema	22	1	14	13	**16**	7	10	9	6	2	Hale 1965
Pseudoparmelia	20	7	4	**8**	6	5	3	3	3	5	Hale 1976a
Bulbothrix	4	1	4	**4**	3	2	3	3	0	0	Hale 1976b
Relicina	8	1	1	1	0	0	3	**7**	0	0	Hale 1975b
Parmelina	4	0	**3**	2	**3**	2	2	2	0	0	Hale 1976c
Dirinaria	7	0	3	4	**6**	**6**	0	**6**	0	1	Awasthi 1975
Collema	17	3	6	6	**9**	6	5	8	3	1	Degelius 1974
Heterodermia	13	0	7	9	**11**	**11**	**11**	7	2	2	Kurokawa 1962,
Usnea	22	11	2	2	**9**	4	2	5	1	5	1973.
Foliicolous	34	1	17	26	29	14	1	**31**	2	2	Motyka 1936–8
TOTALS	148	25	60	75	92	57	40	81	18	18	Stantesson 1952

sparse. During the summer when most of the rain falls the humidity and temperature remain high, and solar radiation can be intense. It seems likely that under such conditions a lichen thallus would remain wet until it reached fatal temperatures, thus precluding lichens from much of the continent.

Knowledge of the distribution patterns of lichens within Australia is confined to the southern half of the continent where revisions of *Teloschistes* and *Heterodea* (Filson 1969, 1978) and ecological studies on soil surface lichens (Rogers 1971, 1972a, 1972b) have resulted in the production of species distribution maps and discussions concerning factors controlling distributions. Along the eastern coast studies have been carried out on the latitudinal range of the foliose and fruticose lichen species growing on mangroves (Stevens 1978).

The distribution of the foliose lichens in the genera *Teloschistes* and *Heterodea* appears to be essentially controlled by climate (Fig. 1) *T. fasciculatus* is confined to alpine areas, *T. velifer* is found in eucalypt forests in cooler and moister areas of Victoria and South Australia, and *T. chrysopthalmus* is widespread across the temperate southern part of the continent but not commonly in the semi-arid and arid areas. The distribution of *T. flavicans*, however, presents something of a problem. *T. flavicans* is a fruticose lichen, colored brilliant gold, and reaching up to 10 cm in length, a species not easily overlooked. It has been found on bark of mangroves along the Queensland coast, on trees at a number of locations near the coast about

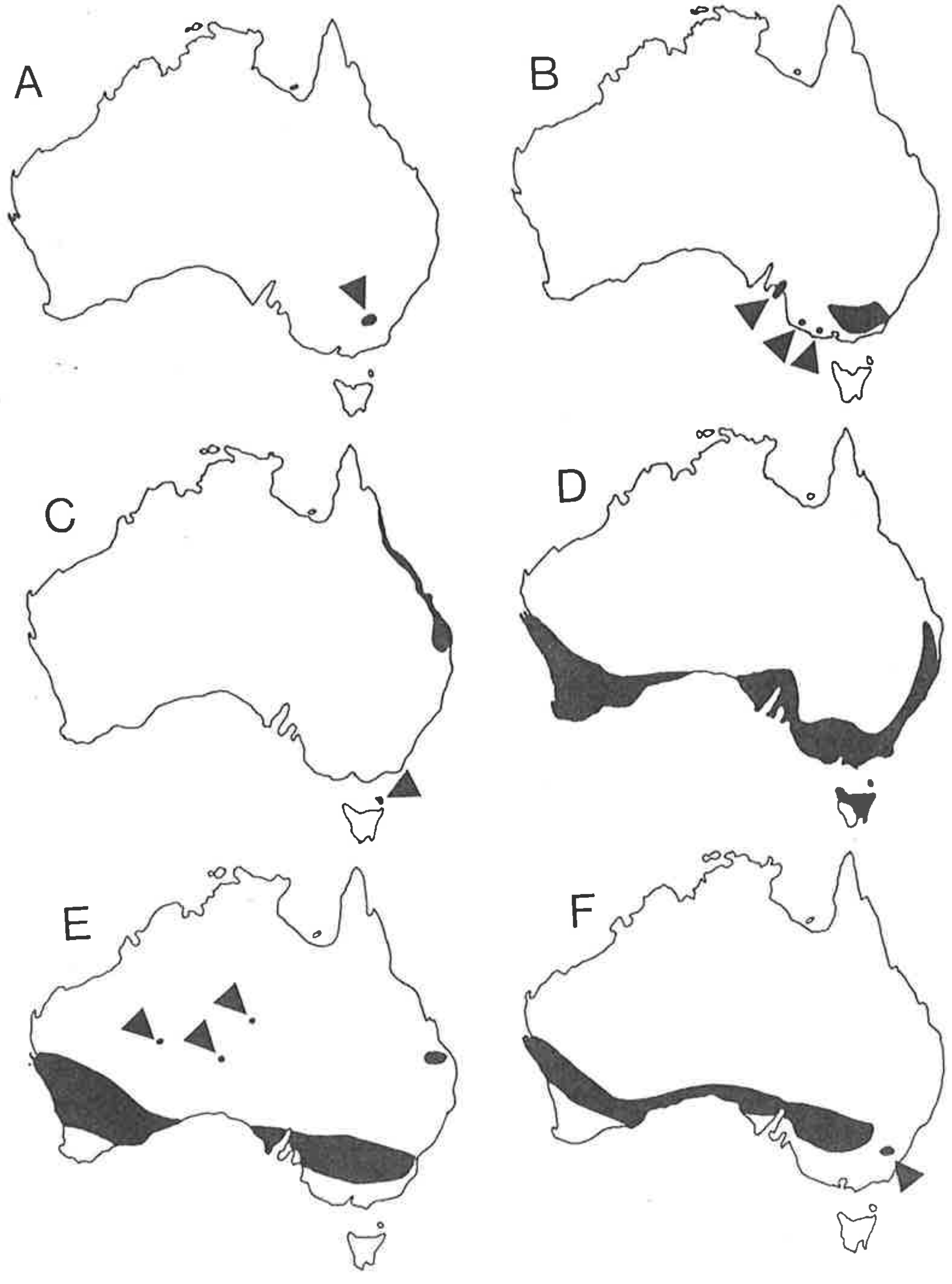

Fig. 1. Some distribution patterns of lichens in Australia. A – *Teloschistes fasciculatus* (Filson 1969), B – *Teloschistes velifer* (Filson 1969), C – *Teloschistes flavicans* (Filson 1969), D – *Teloschistes chrysopthalmus* (Filson 1969), E – *Heterodea beaugleholei* (Filson 1978) and F – *Chondropsis semiviridis* (Rogers 1971), all distributions except *T. fasciculatus* being augmented by data from the authors' records.

latitude 28°S and at a single location on rock on Flinders Island in Bass Strait (latitude 40°S) (Filson pers. comm. 1975). As yet no hypothesis has been advanced to account for this peculiarity in distribution.

Heterodea beaugleholei, a foliose lichen growing on soil, penetrates into the arid fringe, and shows a disjunction from the southern coastal strip over the arid lands to the wetter Musgrave Ranges in central Australia, and also to the high altitude and hence cooler and relatively dry areas in southern Queensland. *Chondropsis semiviridis* (a foliose lichen which lies free on the soil) show a peculiar disjunction from semi-arid southern Australia, where it is confined to areas with a marked winter incidence of rainfall ranging from 150 mm to 350 mm per annum, to the subalpine grasslands in the Cooma area of New South Wales, and also to exposed sub-alpine sites in New Zealand. Rogers (1971) has discussed the climatic factor which control the distribution of *Chondropsis* at length. The foliose and crustose lichens which carpet the soil in much of arid and semi-arid southern Australia are apparently distributed in relation to annual rainfall, rainfall seasonality, and summer temperatures, although some species show a wider tolerance to factors such as soil sodium concentration, soil calcium concentration and soil pH than others (Rogers 1972b). There is a striking parallel between the distribution of *Diploschistes ocellatus*, a soil encrusting lichen in semi-arid and arid southern Australia and that of the shrub *Maireana sedifolia* (Chenopodiaceae), suggesting that lichens and the higher plants are controlled in their distribution by essentially the same factors (Rogers, 1977).

The foliose and frutiose lichen flora on the mangroves of the east coast of Australia show considerable variation in species richness. In the tropical region (17°S–23°S) a total of 53 species are found, in the subtropical region (23°S–30°S) there are 76 species, and in the temperate region (30°S–38°S) only 40 species. Although there is a rich flora of crustose lichens growing on the bark of some mangrove species throughout the length of coast studied (17°S to 38°S latitude), their taxonomy is such that they could not be treated biogeographically. There is a continuous change in species of lichens on mangroves from Cairns to Melbourne, the change being well illustrated by a study of the ranges of species in the eight genera of the family Parmeliaceae which occur along the coast (Fig. 2).

It is apparent from Fig. 2 that the genera can be arranged in a sequence from tropical to temperate in the order *Relicina*, *Bulbothrix Parmotrema*, *Parmelina*, *Parmelia*, *Pseudoparmelia* and *Menegazzia*, the proper placement for the one very widely distributed species of *Hypotrachyna* being uncertain. Within each genus a similar trend is evident among the species. The very marked peak for the total number of species in the Parmeliaceae at latitude 27°S (Fig. 3) may be due in part to the very heavy collecting which has occurred in this area (Stevens & Rogers 1979), but it is part of a generally richer floristic area extending from latitude 24°S to 28°S. If the number of genera in the Parmeliaceae is plotted against the latitude the richness of the flora in the region 24°–28°S is even more apparent (Fig. 3).

The rate of species replacement in the lichen flora of the mangroves as a whole is illustrated in Fig. 4.

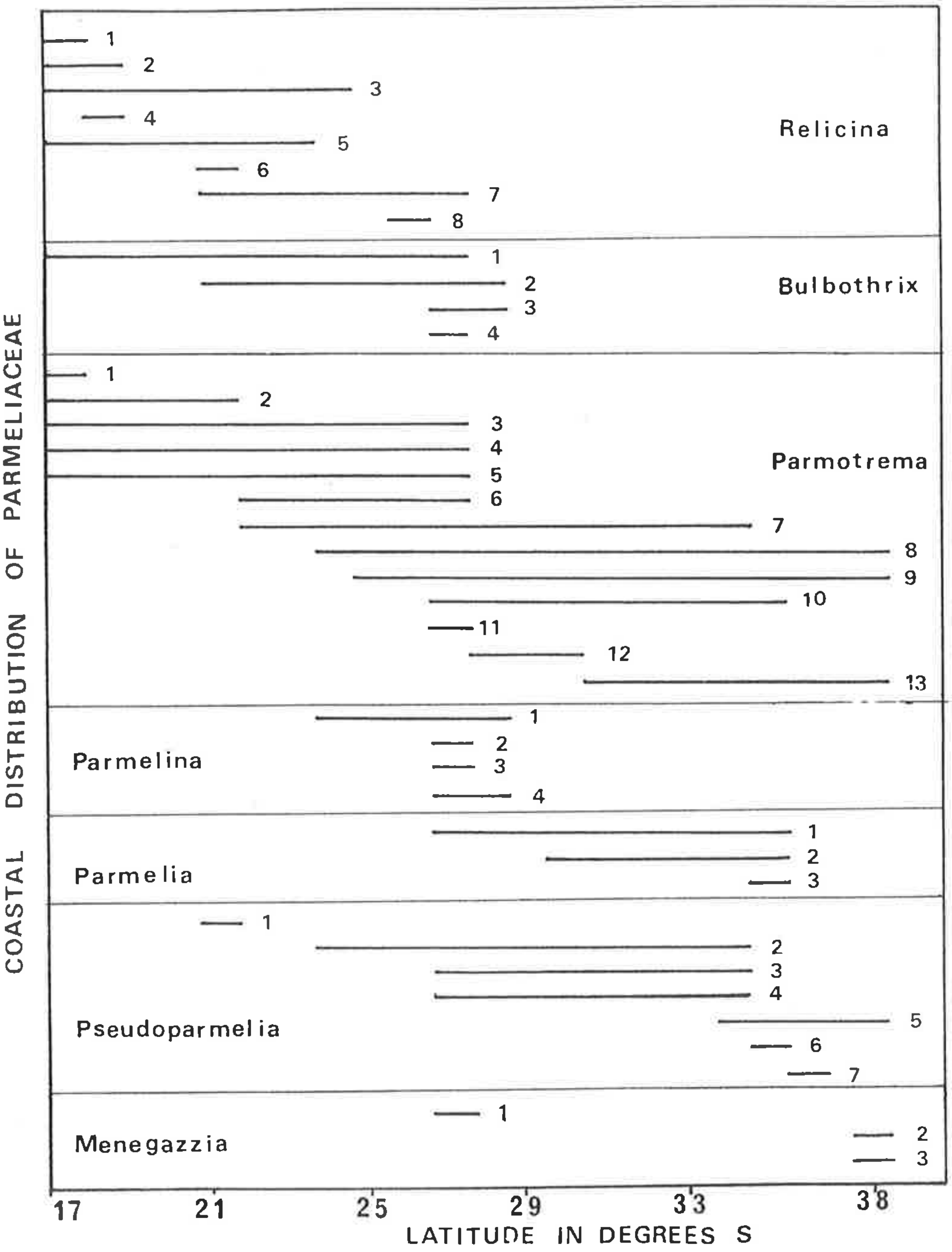

Fig. 2. Distribution ranges of the species of seven of the eight genera in the family Parmeliaceae which occur on Mangroves in Eastern Australia. The species within the genera are: RELICINA 1. *R. circumnodata* 2. *R. abstrusa* 3. *R. sublanea* 4. *R. subabstrusa* 5. *R. amphithrix* 6. *R. samoensis* 7. *R. sydneyensis* 8. *R. limbata*; BULBOTHRIX 1. *B. goebelii* 2. *B. tabacina* 3. *B. apophysata* 4. *B. pigmentacea*; PARMOTREMA 1. *P. cristiferum* 2. *P. disparile* 3. *P. saccatilobum* 4. *P. parahypotropum* 5. *P. robustum* 6. *P. rampoddense* 7. *P. tinctorum* 8. *P. crinita* 9. *P. reticulata* 10. *P. austrosinense* 11. *P. subtinctorium* 12. *P. permutatum* 13. *P. perlata*: PARMELINA 1. *P. tiliacea* 2. *P. aurulenta* 3. *P. damaziana* 4. *P. spumosa* PARMELIA 1. *P. erupens* 2. *P. subrudecta* 3. *P. borreri*; PSUEDOPARMELIA 1. *P. rahengensis* 2. un-named species 3. *P. texana* 4. *P. caperata* 5. *P. rutidota* 6. *P. carneopruinata* 7. *P. sorediata*; MENEGAZZIA 1. *M. pertransita* 2. *M. globulifera* 3. *M. circumsorediata*

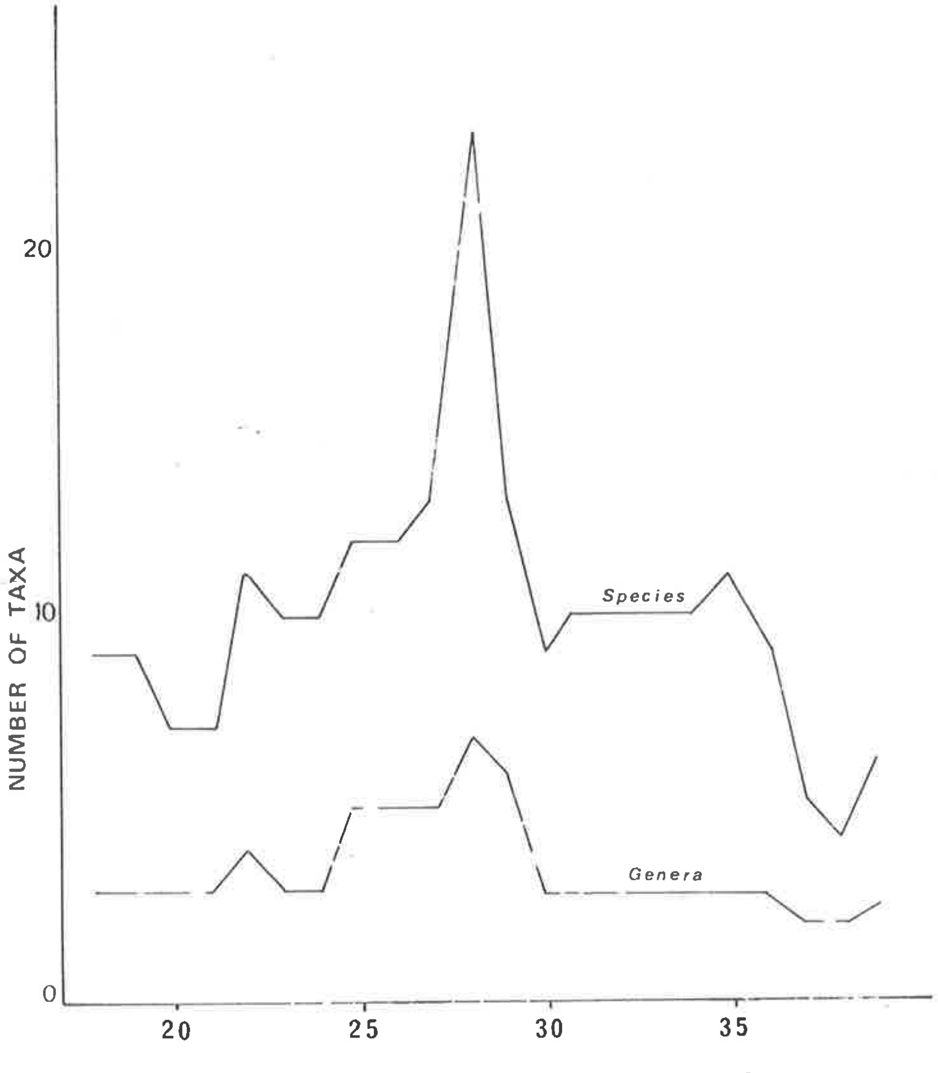

Fig. 3. Variation in the number of genera and species of Parmeliaceae on the mangroves of the eastern Australian coast from 17° to 38° south latitude.

The activities of man have not been without their effect on the lichen populations. In arid rangeland areas in Southern Australia it has been shown that grazing animals modify the lichen flora quite markedly (Rogers 1972b). Around the city of Brisbane it has been shown that some species populations have been greatly enhanced in inner city and industrial areas, and that other species have been totally destroyed within the same area (Rogers 1977). An area some 15 km in diameter in the centre of Brisbane is now devoid of species in the fruticose genus *Usnea*. The effect of cities on lichen populations has been quite clearly demonstrated in many places (Ferry, Baddeley & Hawksworth 1973), the changes, usually in terms of species destruction, being attributed to the effects of air pollutants, notably sulphur dioxide and hydrogen fluoride. It is likely, therefore that cities such as Melbourne and Sydney have had a massive impact on the lichens in their

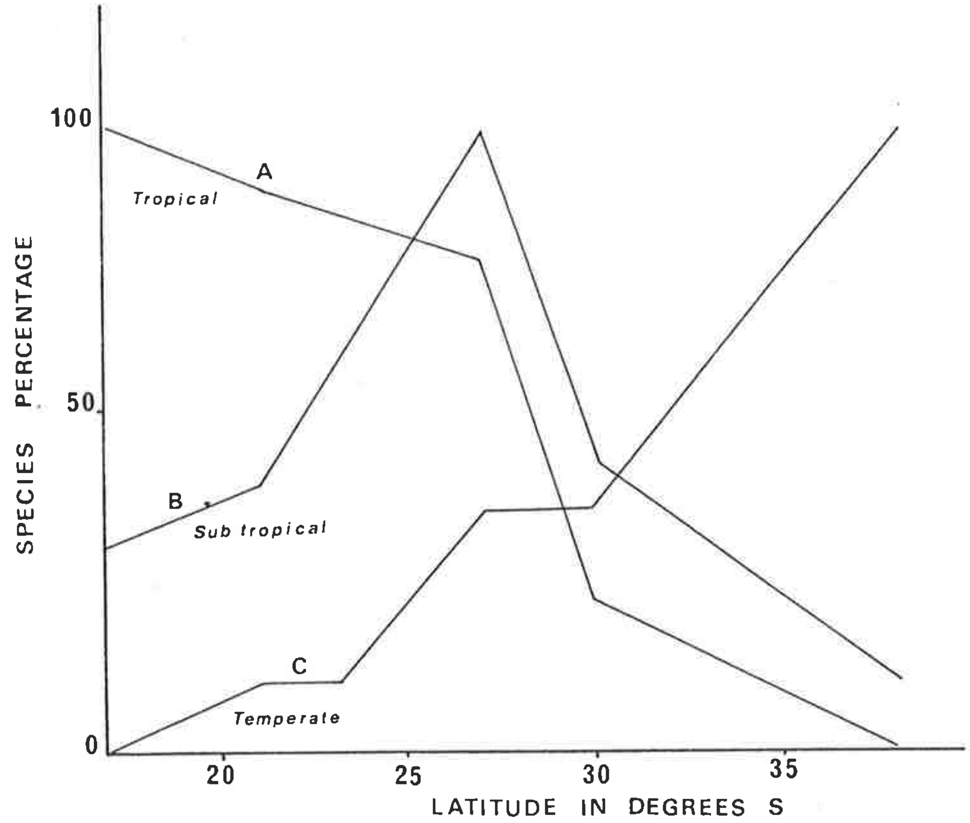

Fig. 4. The percentage of lichens growing on mangroves in (a) the tropics (17°S) (b) the subtropics (27°S) and (c) the temperate zone (38°S) which are found on mangroves at varying latitudes along the eastern Australian coastline.

vicinity, as would also industrial centers such as Newcastle and Wollongong. Point sources of pollutants such as aluminium smelters, brick works and cement works, all of which emit fluorides are also likely to have influenced the lichen populations in their surroundings.

3. Biogeographic affinities of the Australian lichen flora

The biogeography of the lichens of the Southern Hemisphere has traditionally been considered in terms on a number of essentially subantarctic genera, notably *Placopsis*, *Menegazzia* and *Pseudocyphellaria* (Du Reitz 1929, Santesson 1943, Lindsay 1977). All three of these genera are found in Australia. The most antarctic of the genera, Placopsis (a crustose genus) is represented in Australia by seven species, five being found in Tasmania, and five on the mainland (Wetmore 1963, Weber & Wetmore 1972). A total of 17 species occur in the Australasian region, twenty in South America, six in the South Atlantic islands, but only two in the whole of the Northern Hemisphere. *Menegazzia* (a foliose genus) is also mostly confined to the Southern Hemisphere, with centres of development in South America (11 species, Santesson 1943), New Zealand (15 species, Martin 1966) and Australia (9 species, Wetmore 1963, Weber, 1972). Only one species of

Menegazzia is reported from the United States and Canada (Hale & Culberson 1970) and one from Great Britain (Duncan & James 1970). *Pseudocyphellaria* (a genus of very large foliose species) penetrates more into tropical and subtropical areas than the two preceding genera, but is still largely a genus of cool temperate areas. A total of 45 species is reported from Australia (29 from Tasmania, Wetmore 1963, 41 from the mainland, Weber & Wetmore 1972). Fifty species are reported from New Zealand, 25 of which are common to Tasmania (Martin 1965). Fifty species are also reported from Chile (Follmann 1966) of which 19 were common to Australia. Only fifteen were reported by Doidge (1950) from South Africa, of which seven occurred in Australia, and a total of six species are known from the United States and Canada (Hale & Culberson 1970).

All of these genera appear to be essentially Southern Hemisphere, presumably representing genera which had their origin in the Gondwana land mass, and which have since spread into the Northern Hemisphere in a minor way, but have generally failed to adapt to tropical conditions.

India, the component of Gondwanaland rafted across the Equator, has no *Placopsis*, (although the Himalayan region is certainly suited to it climatically), no *Menegazzia* (although the climate is again suitable in parts of the subcontient) and only eight species of *Pseudocyphellaria* (Awasthi 1965). These subantartic genera seem to suggest closer ties for Australia with South America than the older Gondwana areas.

When the distribution of a selection of temperate to subtropical and tropical genera is considered (Table 1) a rather different picture emerges. Of the genera listed in Table 1, *Collema*, *Heterodermia*, *Parmotrema*, *Pseudoparmelia* (all foliose) and *Usnea* (fruticose) are essentially genera of temperate to subtropical areas; *Dirinaria* and *Relicina* (foliose) of subtropical and tropical areas; and *Bulbothrix* of dry tropical scrubs (Hale 1976) although to date most *Bulbothrix* species located in Australia have been in mangroves. Foliicolous lichens (minute crustose species growing on leaves) are commonly associated with tropical rainforests (Santesson 1943). Because all of the categories in Table 1 have been the subject of a recent world revision, it is possible to draw biogeographic conclusions on the basis of recorded species distributions. It is striking that for six of the ten categories in Table 1, Africa has the greatest number of species in common with Australia, or else shares that position with one or more other regions. With the exception of *Dirinaria*, they are the genera of the temperate and subtropical regions. The three categories most common in the Southeast Asian region (*Relicina*, *Dirinaria* and the foliicolous lichens) are essentially tropical in distribution. The two best represented in South America are genera of dry tropical and subtropical scrubs.

The relationship with Africa suggested here warrants special attention. There are few species disjunctions between Australia and one other continent but almost all those within Table 1 are with Africa. In the genus *Usnea* Motyka (1936) indicated that *U. pulvinata*, *U. maculata*, *U. trichodioides*, *U. molliuscula* were disjunct Australia-Africa. The same disjunction occurs with *Heterodermia appendiculata* (Kurokawa 1973), *Parmelia subfatiscens*

(Hale 1976c), *Parmotrema cooperi* (Filson, pers. comm.), *Dirinaria melanoclina* (Awasthi 1975), *Parmelia* (*Xanthoparmelia*) *convoluta* and *Lecidea crystallifera* (Rogers 1977). Rogers (1977) also found that the lichen floras of the arid regions of Australia and southern Africa were more like each other in the genera present than like other arid lands. Of the 16 *Ramalina* species found on mangroves in Australia at least half are conspecific with those found in East Africa (Krog & Swinscow 1976). Apart from the special disjunctions and peculiar ecological cases cited, the number of species common to Australia and Africa (62% of those in Table 1) is impressive. That the cool temperate lichen genera *Placopsis*, *Menegazzia* and *Pseudocyphellaria* are poorly developed in Africa is no surprise, for the climatic conditions necessary for those genera are not to be found in southern Africa.

Although the lichen flora of North America is better known than that of Africa, India, Southeast Asia or South America, it is with the former Gondwana land masses that the Australian warm temperate to tropical lichen flora has the largest number of species in common. The relationship is such that Shirley 1893 (with only a poor knowledge of Queensland lichens) was struck by the number of species in common with South America. No list of African lichens was available to Shirley at the time. It appears that there is a detectable Gondwanan component not only in the cool temperate to antarctic taxa but in others as well, Hale (1975a) noticing the similarity of the *Hypotrachyna* flora in Africa and south America. The distribution map for the genus *Bulbothrix* presented by Hale (1976b) is consistent with a Gondwanan origin for that taxon. *Bulbothrix* is well developed only in the former Gondwana areas and in Southeast Asia. *Relicina* occurs commonly in Australia, Southeast Asia and less so in South America but not India or Africa and may, therefore, also represent a Gondwanan genus. The genus *Cladia* has its centre of diversity in Australia and New Zealand, but occurs in Africa and around the Pacific basin, and may thus be seen as a Gondwanan genus that has spread out of Australia north to Japan, and out of South America into the Caribbean. These three genera may, perhaps, be seen as the temperate and tropical expressions of the Gondwanaland lichen flora.

The lichens of Australia can, thus, be seen as a diverse assemblage distributed within the continent according to the same climatic and edaphic factors as the higher plants. A notable exception to this is the absence of lichens from the dry monsoonal forests and woodlands where the sensitivity of lichen to heat when wet precludes their development. The affinities of the flora indicate that there is a substantial southern hemisphere component to be found not only in the genera *Placopsis*, *Menegazzia* and *Pseudocyphellaria*, traditionally associated with southern hemisphere biogeography, but also in some of the more temperate to tropical genera such as *Cladia*, *Bulbothrix* and *Relicina*. In other genera which are virtually global in their distribution, especially *Usnea*, there appears to be a strong southern Hemisphere component. Among the cool temperate lichen groups the affinities of Australia are mostly with New Zealand and South America, but amongst the temperate to tropical groups with Africa.

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LICHEN ECOLOGY AND BIOGEOGRAPHY

R.W.Rogers

Introduction

Lichens can be found growing on a broad range of substrata in almost every natural environment. Their distribution, like that of all organisms, has been brought about by a complex interaction of geological and biological phenomena. A few accounts of the distribution patterns of Australian lichens are available. Rogers & Stevens (1981) provided an overview of patterns within Australia and their global affinities. Galloway (1988, 1991) considered the distribution of cool temperate southern hemisphere lichens, Jørgensen (1983) the biogeography of the Pacific region, and Stevens (1987) the palaeohistory of *Ramalina* in Australia. The account given below builds on these earlier ones.

Australia has a rich lichen flora. An indication of this richness is the recognition of 310 genera in this flora, compared with 210 from New Zealand (Galloway, 1985), 290 from Europe (Poelt & Vezda, 1981), and 291 from North America (Brodo, 1985). While these figures are not strictly comparable because of recent splitting of genera, the flora of Australia is much less completely known than that of the other regions cited, and additional genera are being discovered from time to time: Filson (1988) reported a total of 268 genera, whereas McCarthy (1991) reported 313.

Lichens are photosynthetic systems consisting of two different organisms living together. This produces a complex structure with a distinctive physiology. The mycobiont (the fungal component) and the photobiont (the algal or cyanobacterial component) may be capable of life outside the lichen, but when they occur together they show new properties. Apparently a lichen thallus can form and continue to exist only under circumstances which are unsuited to the independent growth of the two symbionts. If the balance is shifted too far in favour of one organism or the other, the lichen structure and physiology is destroyed. A consequence of this organisation is that lichens are extremely resistant organisms in some ways, but very delicate in others.

To live a lichen must have light, water, carbon dioxide, inorganic nutrients and oxygen. The photobiont lives in an environment provided by the mycobiont, and produces carbohydrates and amino acids needed by the mycobiont. These nutrients may be released through the photobiont's cell membranes to clasping mycobiont hyphae, or they may be absorbed by the mycobiont from within the photobiont's cell by penetrating haustoria. The advantage to the mycobiont in this arrangement is obvious. The advantage to a photobiont is less clear. However, an evolutionary advantage is present if the lichen thallus provides a place in which the photobiont's cells can live and reproduce where they otherwise could not. Lichenisation provides a photobiont with a place to live in which it is shielded from excessive sunlight and in which water availability is improved. It is not surprising that evolution of algae adapted to life in lichens has occurred as this enables the algae to colonise otherwise unsuitable locations.

Ecological strategies of lichens

The evolution of the vegetative phase of plants has been influenced by the interactions of two factors: stress which reduces the size of an organism by reducing the rate of photosynthesis, and disturbance which reduces the size of the organism by partial or total destruction of its biomass (Grime, 1979). In an environment where a plant is stressed (e.g. one with a shortage of nutrients, light, heat or water), plants evolve which have characteristics that make them stress-tolerant. These plants are slow-growing and usually small. They reproduce when conditions are favourable and have strong defences to protect their accumulated biomass. If plants live in an environment in which they are disturbed (grazed, buried, or if they are growing on unstable surfaces) they evolve strategies that enable them to complete their life cycles quickly: they grow fast, reproduce early, do not invest in defence, and adopt a weedy or ruderal strategy. If a plant lives in an environment where neither stress nor disturbance strongly influences it, interference from other plants becomes critical and the plant develops a competitive strategy. It tends to grow fast and to spread over those about it.

Lichens as a group are all stress-tolerant organisms when compared with the flowering plants, but they show a range of ecological strategies amongst themselves (Rogers, 1990). Lichens that grow on rainforest leaves, for example, are extreme ruderals with relatively high growth rates. These lichens reproduce when the thallus is only a few millimetres in diameter. Species from deserts and from alpine areas are more stress-tolerant than others and have slow growth rates and small thalli. Those from long-existing surfaces in cool temperate regions are competitors with large thalli and high growth rates.

Nutrition

Most lichen thalli can absorb all their requirements for life from the air and water. Water may be absorbed from the atmosphere, from dew, rain or run-off. When water is absorbed whatever is dissolved in it is also absorbed. This enables a lichen to gain its mineral nutrients. However, mineral nutrients in rain are in very low concentrations, and there are also low concentrations of nutrients in dew and in trickles of water gathered from soil, leaves and stems. In response to these low concentrations of nutrients, lichens have apparently evolved highly effective but indiscriminate mechanisms for absorption of minerals. This means that any air pollutants are also absorbed, with devastating results in many cases. This makes lichens among the most sensitive of all organisms to air pollution.

Those lichens which involve a cyanobacterium capable of nitrogen fixation as either their sole photobiont or as a secondary photobiont (e.g. in cephalodia) have their own nitrogen supply. This makes these lichens perhaps the most independent of all macroscopic biological systems. It is possible that a few lichens are partial parasites, especially those living beneath the cuticles of leaves. However, there is little evidence that other lichen species gain anything directly from their substratum.

Substrata

Lichens are able to occupy many diverse surfaces because they do not usually rely on their substrata for anything more than a place to attach. Lichens commonly occur on twigs, bark and wood of shrubs or trees. In many parts of Australia they completely cover exposed rock surfaces, and also grow on artificial surfaces such as roof tiles, bricks, walls, roadways and concrete. Less commonly, and only in very humid areas, lichens grow on metallic surfaces such as galvanised iron roofs and electricity transmission cables. In rainforests, lichens are common on leaves, and in alpine areas lichens are found on dead grass and peat. Lichens cover the soil surface in areas where soil remains exposed for an

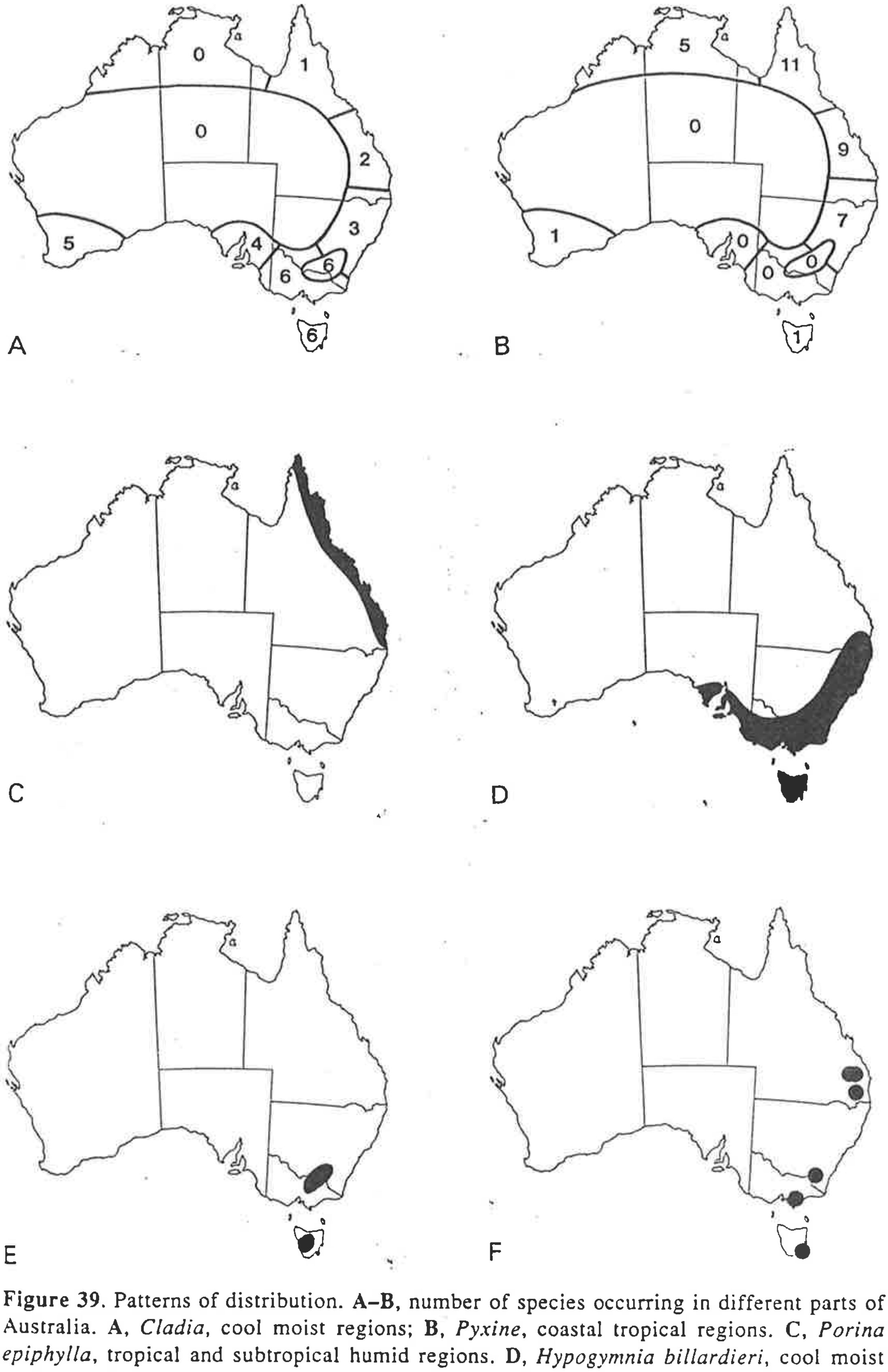

Figure 39. Patterns of distribution. **A–B**, number of species occurring in different parts of Australia. **A**, *Cladia*, cool moist regions; **B**, *Pyxine*, coastal tropical regions. **C**, *Porina epiphylla*, tropical and subtropical humid regions. **D**, *Hypogymnia billardieri*, cool moist eucalypt forests and woodlands. **E**, *Thamnolia vermicularis*, alpine regions. **F**, *Haematomma sorediatum*, cool forest fringes. Drawn by R.Rogers.

extended period and the surface is stable. This is most common in arid and semi-arid areas. Lichens may also be found in old rubbish tips on leather, glass, bones, cardboard, and even old nylon stockings. Charcoal provides an important surface for a number of Australian lichens.

Although lichens can colonise a wide range of substrata, most species occupy only a limited variety of surfaces and some are quite substratum-specific. The reason for substratum specificity is unknown. Species of *Xanthoparmelia*, for instance, grow almost exclusively on rock or soil. *Heterodea muelleri* (Hampe) Nyl. is almost always found on soil or over leaf litter, but occasionally may be found on the mud-splashed base of a tree trunk. *Thysanothecium scutellatum* (Fries) D.J.Galloway is almost always found on charcoal in Australia—even when apparently growing on soil a careful check is likely to find a charcoal fragment at its base. A number of species are apparently restricted to leaves. Substratum, therefore, is an important aspect of a lichen habitat.

Distribution patterns and environment

As with other groups of organisms, lichen distribution is determined by variations in the environment: some lichens are more drought-resistant than others, some more tolerant of heat or cold, some are able to cope with higher or lower light intensities, and some tolerate different combinations of heat and moisture.

Provided that suitable substrata are available, lichen distributions are determined by essentially the same factors as those that determine the distribution of higher plants. The basic patterns within Australia are determined by climate. Microclimate apparently plays a more significant role for lichens than for flowering plants, with tiny arid or humid pockets found in a great variety of locations. One particularly impressive example of microclimatic specialisation is shown by the byssine lichens in the genera *Sagenidium* and *Sagenidiopsis*. These occur only in cool temperate rainforests, and within these only on surfaces not wet by rain or trickles of water. Misty, windswept ridges appear to offer one of the environments most favourable for lichen growth.

The effect of climatic variation, especially of temperature, is evident when studying the macrolichens that grow on mangroves along the eastern coast of Australia. No macrolichen species from the northern tropical regions is also found in the far southern mangroves. A gradual replacement series occurs from north to south (Rogers & Stevens, 1981). There are no clear-cut biogeographic lichen groupings in Australian lichens, but some patterns can be recognised. Patterns of latitudinal distribution in the number of species present in a genus may be striking. Contrasting patterns are evident in the temperate genus *Cladia* (Fig. 39A) and in the tropical genus *Pyxine* (Fig. 39B).

The tropical and subtropical humid zone has a well-developed lichen flora, especially associated with rainforests and eucalypt communities in humid climates. Characteristic genera include *Parmotrema*, *Bulbothrix*, *Myelorrhiza*, *Pyxine* and *Dirinaria*. In these communities we also find the best development of foliicolous (leaf colonising) lichens (e.g. *Porina epiphylla* (Fée) Fée, Fig. 39C), and those which have perithecia as fruiting bodies.

In the cool temperate rainforests and associated eucalypt communities the genera *Sticta*, *Pseudocyphellaria*, *Psoroma*, *Pannaria* and *Sphaerophorus* are common and may dominate the flora. Cool moist eucalypt forests frequently have a flora rich in *Cladonia*, *Cladia*, *Menegazzia*, *Nephroma* and *Hypogymnia*. In these communities *Neophyllis* often forms an extensive cover on old eucalypt logs. The distribution of *Hypogymnia billardieri* (Mont.)

Filson, characteristic of cool moist forests, is shown in Figure 39D. At higher altitudes, an alpine assemblage is present which includes such genera as *Thamnolia* (Fig. 39E), *Neuropogon* and *Umbilicaria*. *Haematomma sorediatum* R.W.Rogers is a species of the fringe of cool forests. It occurs on mountain tops in south-eastern Queensland and at progressively lower altitudes further south, until it becomes a coastal species in Gippsland (Victoria) and Tasmania (Fig. 39F).

The drier aspects of eucalypt communities, especially in mediterranean climates, are dominated by such genera as *Paraparmelia*, *Canoparmelia*, *Xanthoparmelia*, *Teloschistes*, *Cladia* and *Heterodea*. The distribution of *Teloschistes chrysophthalmus* (L.) Th.Fr. and *Heterodea beaugleholei* Filson is shown in Figures 40A and 40B. Perhaps the most common lichen in these communities, however, is the extremely polymorphic *Cladia aggregata* (Sw.) Nyl. which forms extensive patches on rocks, soil and litter.

The fruticose genera *Usnea* and *Ramalina* are likely to be found in all moister regions of the continent and into the semi-arid zone. Crustose genera such as *Pertusaria*, *Lecanora*, *Tephromela*, *Caloplaca*, *Rinodina*, *Porpidia* and *Fuscidea* are similarly widespread across climatic zones.

Arid regions have a flora with many species of *Xanthoparmelia* on rock and soil. The genera *Acarospora*, *Psora*, *Peltula*, *Diploschistes*, *Eremastrella* and *Collema* are also characteristic of such areas. The distribution of *Eremastrella crystallifera* (Taylor) Schneider is shown in Figure 40C.

The northern wet-dry tropical regions have not yet been extensively explored for lichens, but the evidence suggests that the lichen flora is poor in species, and limited in distribution. This may be explained by the apparent sensitivity of lichens to heat when the thallus is wet. However, lichens do occur in the dry woodlands of Cape York Peninsula (Queensland), in Arnhem Land, near Darwin (Northern Territory), and in northern Western Australia. The most common species in these areas is the small but spectacularly pigmented *Pyxine coccifera* (Fée) Nyl. (Fig. 40D) which ranges in colour from pinkish grey to scarlet. *Roccella montagnei* Bél. (Fig. 40E) is another spectacular species of the tropics. It is confined to locations within a few metres of the sea and is especially common in mangroves.

The lichen flora of south-western Australia appears to be relatively poor in species, and only a few of these are endemic there. This contrasts markedly with the angiosperm flora which is rich both in numbers of species and in endemics. *Haematomma eremaeum* R.W.Rogers (Fig. 40F) and *H. pruinosum* R.W.Rogers, however, are both endemic in the semi-arid regions of Western Australia. In Australia, the other species of this genus are restricted to humid regions along the eastern coastline.

Marine environments have an interesting lichen flora. Mangrove communities characteristically have a rich flora, related to that of the surrounding landscape. The genera *Lichina* and *Verrucaria* are common on intertidal rocks in southern regions but are not common in the tropics, although *Verrucaria halizoa* Leight. is known from beach rock on Heron Island. Freshwater runnels across rock surfaces may have a flora in which representatives of the family Lichinaceae are prominent.

In southern Australia, a complex of species associated with towns and cities is apparent. The most obvious of these species is *Xanthoria parietina* (L.) Th.Fr., which may turn the trunk and branches of deciduous trees orange. *Hyperphyscia adglutinata* (Flörke) Hafellner, *Physcia adscendens* (Th.Fr.) H.Olivier, *Physcia stellaris* (L.) Nyl. and *Teloschistes chrysophthalmus* (L.) Th.Fr. show similar associations. Most lichens, however, tend to be disadvantaged when living in urban environments, and genera such as

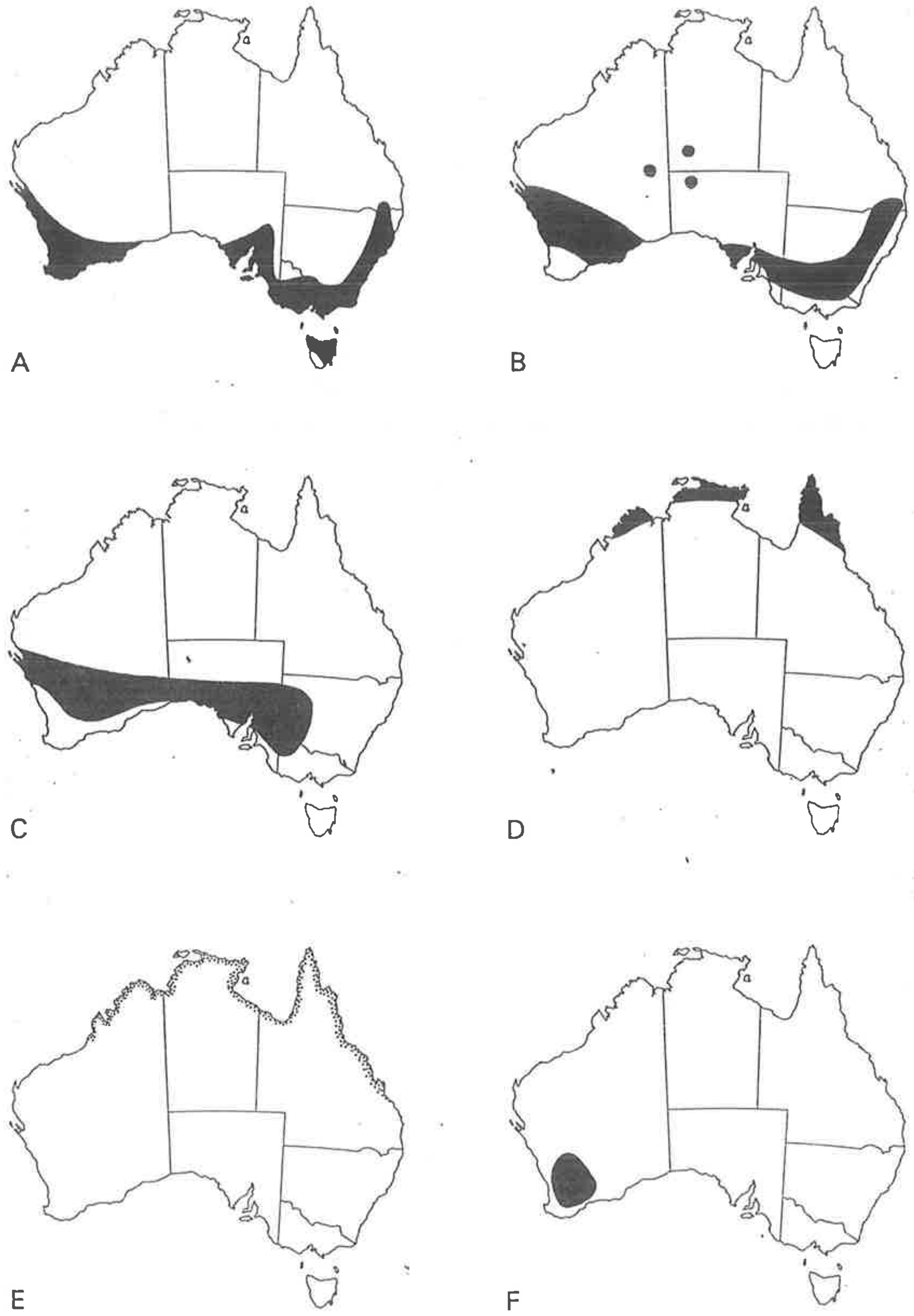

Figure 40. Patterns of distribution. **A**, *Teloschistes chrysophthalmus*, cool dry eucalypt communities; **B**, *Heterodea beaugleholei* occurs in dry forests. **C**, *Eremastrella crystallifera*, arid and semi-arid rgions without summer rain. **D**, *Pyxine coccifera* usually occurs in tropical regions with hot, wet summers and warm, dry winters. **E**, *Rocella montagnei* is restricted to tropical coastline. **F**, *Haematomma eremaeum* is endemic in semi-arid regions of W.A. Drawn by R.Rogers.

Usnea and *Ramalina* disappear from towns and cities, perhaps because of air pollution. Thus, the lichens floras in the centre of our major cities are much depleted. The fruticose species and some crustose species disappear first and are followed by most of the foliose species. This leaves only a few pollution-tolerant species such as *Candelaria concolor* (Dickson) Arnold and *Hyperphyscia adglutinata* (Flörke) Hafellner in more polluted areas.

Relationship with other regions

The level of endemism at generic level is not high in Australia. Only a few rarely collected genera appear to be restricted to Australia: these include *Sagenidiopsis* from the *Nothofagus* forests of Tasmania, *Conotremopsis* from the McPherson Range in northern New South Wales and southern Queensland, and *Myelorrhiza* from the rainforests of northern Queensland. *Chondropsis* is widespread in semi-arid and subalpine or dry highland regions of Australia and in cool dry regions of the South Island of New Zealand. *Miltidea* has a disjunct distribution, occurring in Tasmania and New Zealand, while *Sarrameana* occurs from Tasmania to New Caledonia. *Heterodea*, like *Chondropsis*, occurs widely on bare soil in Australia and also occurs in New Caledonia and New Zealand.

Radiation of species within genera, however, has occurred extensively in Australia. The most spectacular case is probably *Xanthoparmelia*. Elix *et al.* (1986) reported 117 species from Australia, which is more than from any other continent. All 47 species from New Zealand also occur in Australia. All species of *Cladia* occur in Australia. Other foliose genera (e.g. *Paraparmelia* and *Canoparmelia*) of the Parmeliaceae have also undergone substantial species radiation in Australia, as have the crustose genera *Megalospora* (Sipman, 1983) and *Haematomma* (Rogers, 1982b).

When considering the similarities between the lichen flora of Australia and other regions, it is important to remember that lichens show climatic limits in their distribution patterns. The lichen flora of Australia shows strong links to that of similar climatic zones in other regions. The genera listed in Table 1 demonstrate the strong relationships between the Australian flora and those of Africa, New Zealand and South America. The relationship of the Australian flora to the flora of Africa is particularly interesting. The link occurs not only with the tropical genera *Pyxine*, *Dirinaria*, *Letrouitia*, and *Parmotrema*, but also with the cosmopolitan genera *Collema*, *Ramalina*, and *Heterodermia*. There is, however, only a weak relationship between the Australian cool temperate flora and that of Africa. This is not surprising as Africa has few humid, cool temperate habitats. It would be expected that the flora of cool temperate Australia would resemble that of New Zealand and cool temperate South America. A strong link with the flora of tropical South America might also be expected as that continent has a large tropical zone.

There is a significant circumantarctic lichen element represented in Australia by such genera as *Placopsis* and *Neuropogon* (Fig. 41A). One species associated with this element, *Alectoria nigricans* (Ach.) Nyl., has a bipolar distribution (Fig. 41B). The alpine *Thamnolia vermicularis* (Sw.) Schaerer is common on high mountains throughout the world. It has no specialised reproductive structure and has presumably been dispersed as fragments from one continent to another.

Australia's cool temperate flora (which is especially well-developed in Tasmania) shows strong links with New Zealand in such genera as *Sticta*, *Pseudocyphellaria*, *Menegazzia* and *Psoroma*. The genus *Cladia* shows its richest development in the cool temperate regions, but it also extends beyond them and has a disjunct distribution, occurring in Asia,

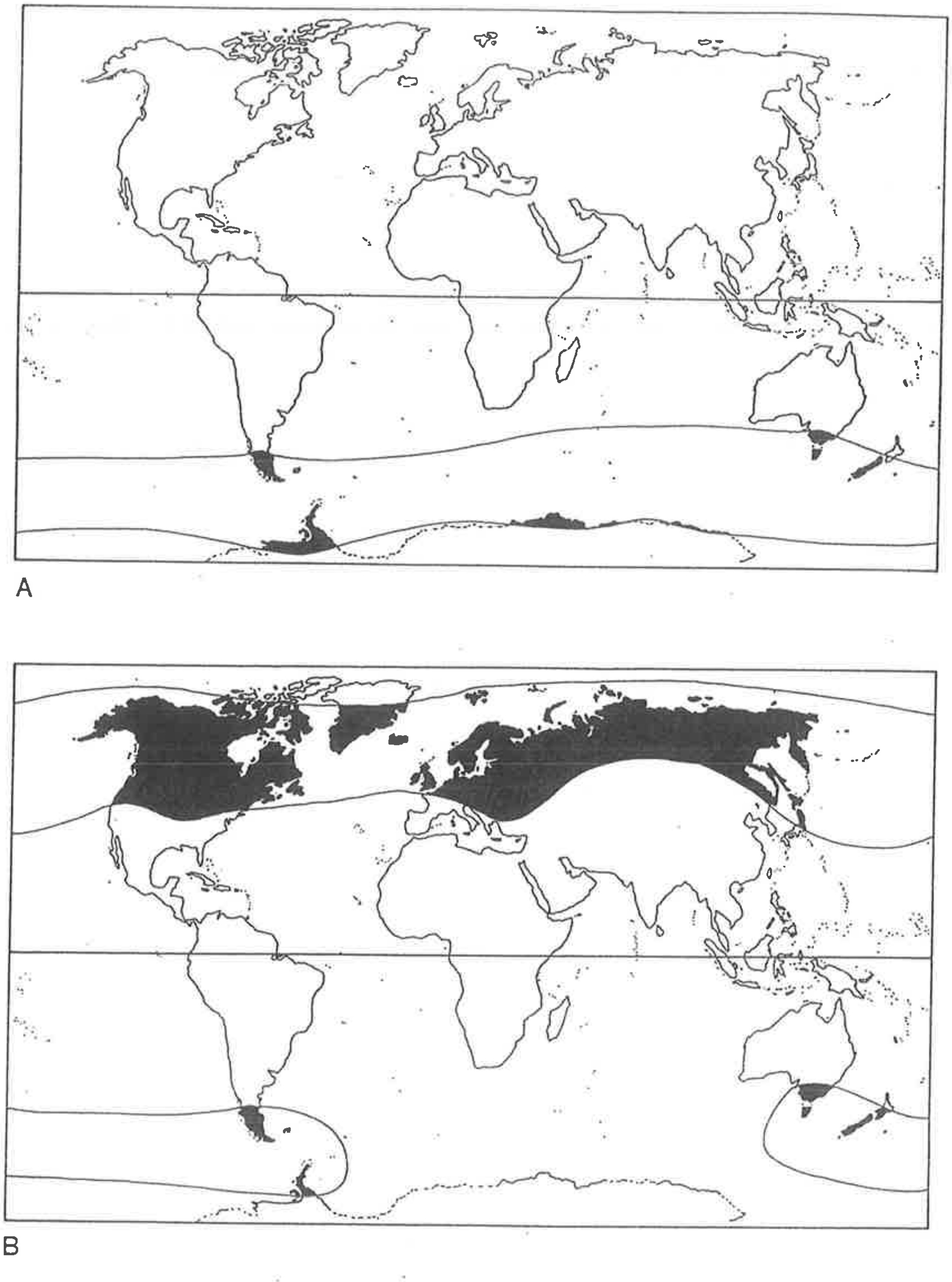

Figure 41. **A**, circumantarctic distribution of *Neuropogon acromelanus*. **B**, bipolar distribution of *Alectoria nigricans*. Drawn by L.Crisp.

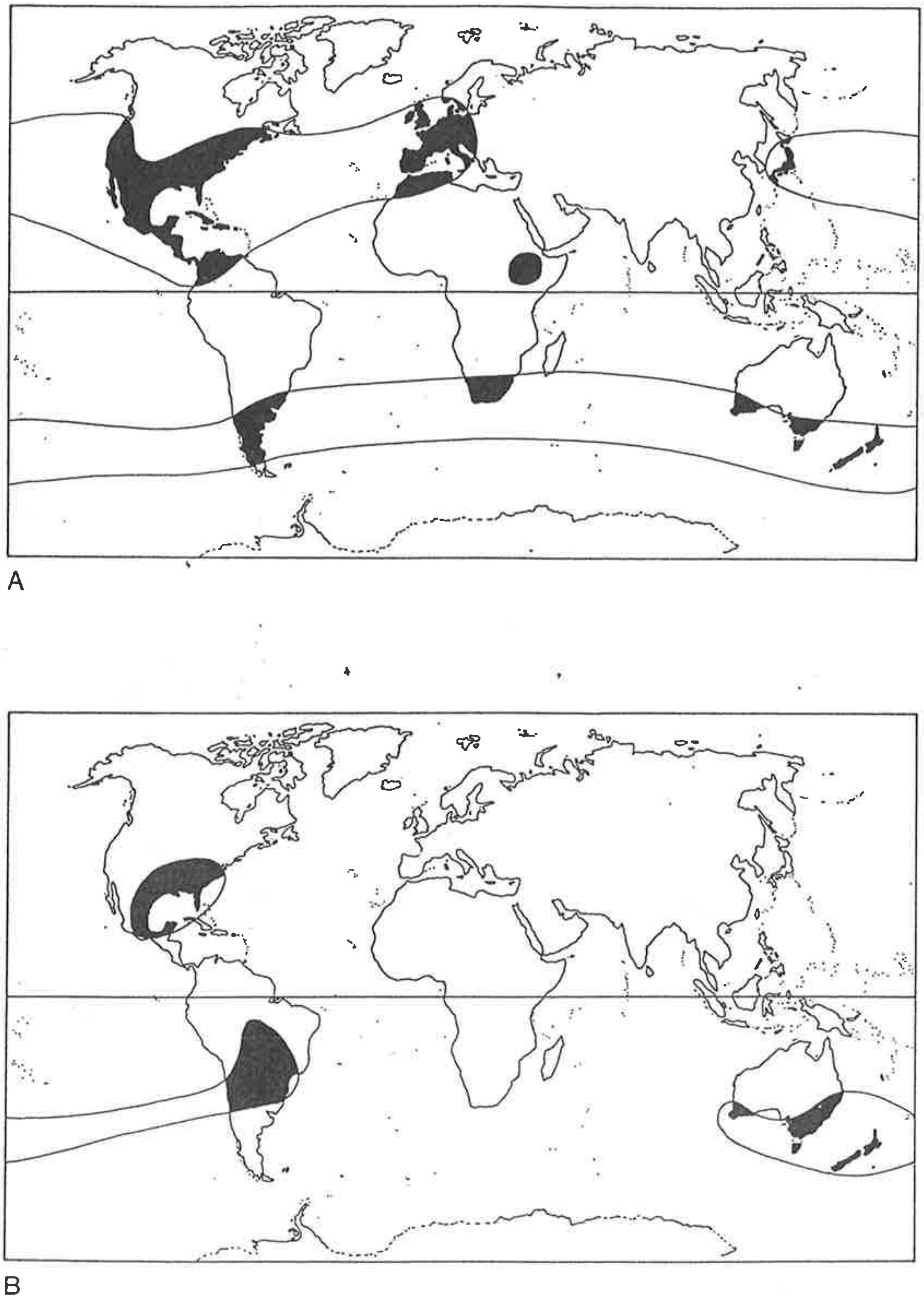

Figure 42. **A**, cool temperate distribution in both hemispheres of *Parmotrema chinense*. **B**, disjunct distribution in temperate Australia and North and South America of *Flavoparmelia rutidota*. Drawn by L.Crisp.

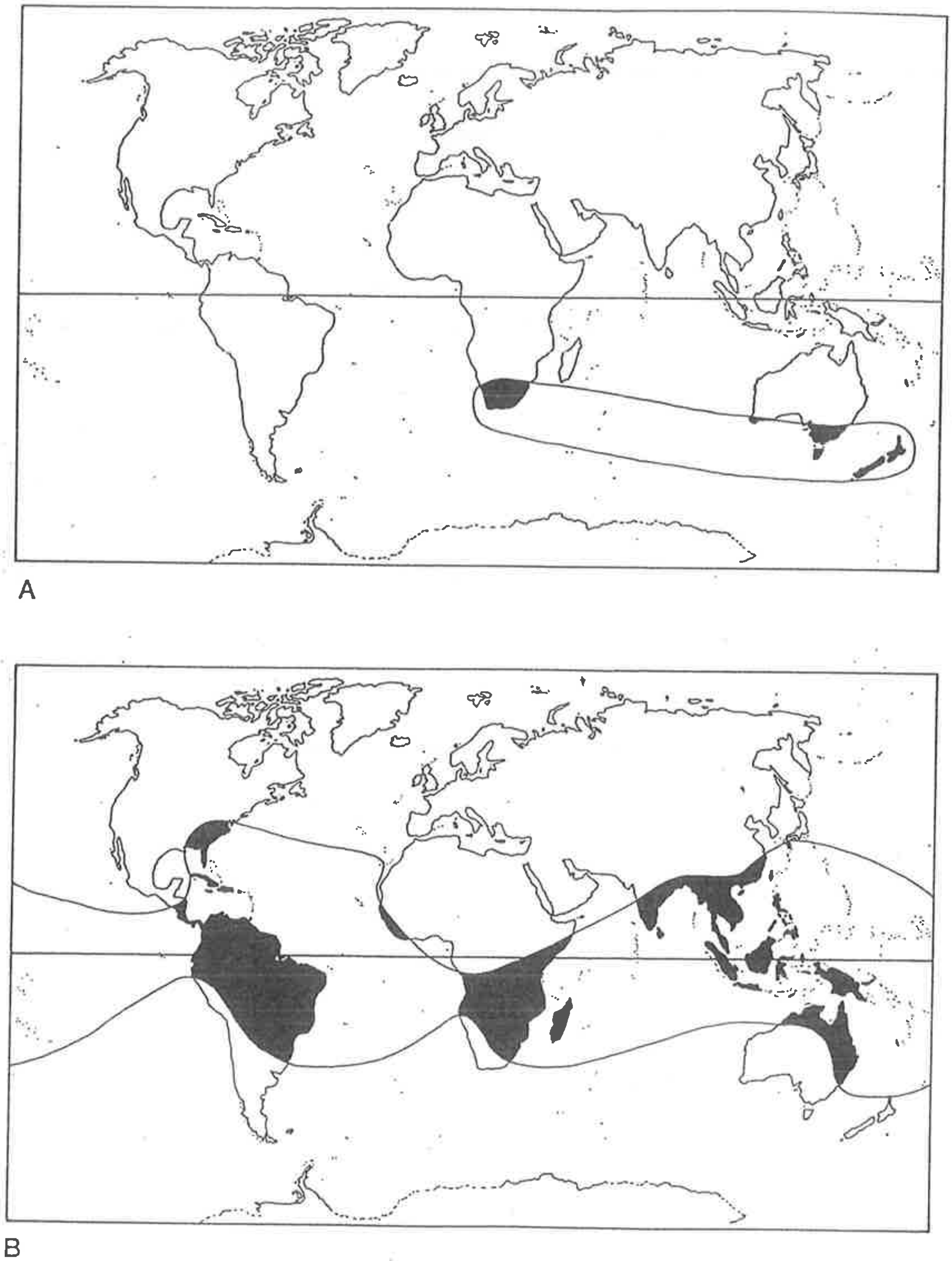

Figure 43. **A**, disjunct distribution in Australia, New Zealand and southern Africa of *Collema leucocarpum*. **B**, pantropical distribution of *Dirinaria applanata*. Drawn by L.Crisp.

New Zealand and South America. The connection with the New Zealand flora also shows in the disjunctions involving *Knightiella*, *Chondropsis* and *Miltidea*, three genera restricted to Australia and New Zealand.

The temperate species *Parmotrema chinense* (Osbeck) Hale & Ahti (Fig. 42A) is widespread in both hemispheres, whereas *Flavoparmelia rutidota* (Hook.f. & Taylor) Hale (Fig. 42B) is apparently restricted to Australia, New Zealand, and regions of both North and South America. *Collema leucocarpum* Hook.f. & Taylor on the other hand has a disjunct distribution and occurs in Australia, New Zealand and southern Africa (Fig. 43A). Variations on these patterns are common, with many species being widely distributed around the world.

Taxa from the warmer regions of Australia generally show a stronger affinity with Africa than with South America or New Zealand. This similarity is evident in a range of taxa (Table 1), and has been reinforced by studies on *Xanthoparmelia* (Elix *et al.*, 1986), a genus for which Australia has many species in common with southern Africa but few in common with South America. *Dirinaria applanata* (Fée) Awasthi has a pan-tropical distribution (Fig. 43B).

As with the angiosperm flora, the lichen flora of Australia is a mixture of elements with different histories. Some appear to be part of the ancient Gondwanan flora and were moved about with complex biological assemblages. Others are more recent arrivals. These more recent arrivals may have been transported to Australia in a west wind drift from Africa, and then exported to New Zealand. Others like *Chondropsis semiviridis* (Nyl.) Nyl. and *Thamnolia vermicularis* (Sw.) Schaerer, which reproduce by thallus fragments, were presumably carried about by birds. There is a strong suspicion that *Xanthoria parietina* (L.) Th.Fr., which is restricted to settled areas, is a species introduced since European settlement. In addition to arrivals from a range of sources, a great deal of speciation has also occurred within Australia, resulting in a rich and fascinating lichen flora.

Conservation

Australia's lichen flora cannot survive unless its habitats survive. Those lichens which show a degree of substratum specificity are obviously at risk, but so too are those with specific microclimatic requirements which may be met only on old trees or in dense thickets. *Cladia ferdinandii* (Müll. Arg.) Filson, for example, is restricted to a few small patches of low, coastal, eucalypt woodlands on calcareous sands in southern Australia, and so is in a habitat which is at risk from development and fire. As this species is spectacular, it is also at risk from collectors. Species which occur on soil are susceptible to destruction by trampling stock, and all lichens are subject to destruction by bush fires. Air pollution is a threat to many species near cities. We know insufficient about the Australian lichen flora and about lichen distributions in particular. This means that conservation of lichens currently can be most satisfactorily approached by conserving habitats.

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