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OBSERVATIONS ON THE FUNGI OF MACQUARIE ISLAND

by

J. S. BUNT

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J. S. BUNT

Antarctic Division, Department of External Affairs, Melbourne
and
School of Agriculture, University of Sydney

ABSTRACT

Expeditions have collected fungi in antarctic regions since Hooker accompanied the British Antarctic Expedition, 1839-1843, led by Captain Sir James Clark Ross, R.N.

Twenty-seven genera of fungi from Macquarie Island are listed in the present account and include plant parasites, saprophytes and soil-inhabiting fungi, both those with macroscopic fruiting bodies and those which must be isolated from the soil by appropriate laboratory techniques.

The numbers of micro-fungi in a range of soils were comparable with figures obtained for more temperate regions. The genus *Penicillium* was found to be the dominant form. Antibiotic activity was recorded in 36 per cent. of the soil isolates. The effects of various ecological factors on the fungi of Macquarie Island are considered and the age and stability of the fungal flora are indicated. The distribution of fungi in antarctic regions is discussed and the need for further exploration indicated.

CONTENTS

I. INTRODUCTION

Fungi were first collected in subantarctic regions by Hooker during the important exploratory voyage of H.M.S. *Erebus* and *Terror* serving with the British Antarctic Expedition, 1839-43, led by Captain Sir James Clark Ross, R.N. The species listed were found on the Auckland and Campbell Islands south of New Zealand, at the southernmost tip of South America and on the Falkland Islands. Some years later, the *Challenger* Expedition (1872-6) made small collections at Marion Island and Iles de Kerguelen, the species being described by Berkeley (1876). The Rev. A. E. Eaton of the Transit-of-Venus Expedition (1874-5) also brought back several types from Kerguelen and these too were examined by Berkeley (1876). During 1880, Scott (1882) paid a brief visit to Macquarie Island on a sealing ship and the account of his varied observations includes a short list of plant pathogens. Unfortunately, he did not state who identified the material and did not include the names of authorities with his list. The next reference to fungi in the Antarctic did not appear until Bommer and Rousseau (1905) published the results of their examination of material gathered in the vicinity of Tierra del Fuego and the Antarctic Peninsula (the Danco coast) during the voyage of the S.Y. *Belgica* (1897-9). Following this report came the account of certain fungi collected at Kerguelen by the Deutsche Sud-Polar Expeditionen (1901-3). Only the illustrations from this publication, including several agarics, a peziza-like fungus and some plant pathogens, were available to the author. McLean (1919) mentions "yeasts" isolated from snow, soil and air at Terre Adélie and records the incidence of moulds on his culture media but only as contaminants from the air of the crowded expedition hut. More recently, Singer (1952, 1953, 1954, 1955) and Smith & Singer (1958) have described species of Agaricales from S. Georgia, Patagonia and Tierra del Fuego, and di Menna (1960) has isolated yeasts from soil from the McMurdo Sound area of Antarctica. Most of the fungi listed have been plant parasites or saprophytes with large fruiting bodies collected towards the northern limits of the subantarctic zone. Those forms occurring as normal constituents of the microflora of soils have been largely neglected. In most cases the accounts of early authors have been limited to a description or identification of the species gathered, no attempt having been made to investigate the ecology of the antarctic fungal flora.

Macquarie Island, situated in lat. 54° 30′S, long. 158° 57′E, lies at a point approximately 900 miles south-east of Tasmania between Australia and the antarctic continent. The closest land masses are the subantarctic islands of New Zealand, some 400 miles to the north-east. In the zone bounded by the line of latitude 54°S and the antarctic circle, Macquarie

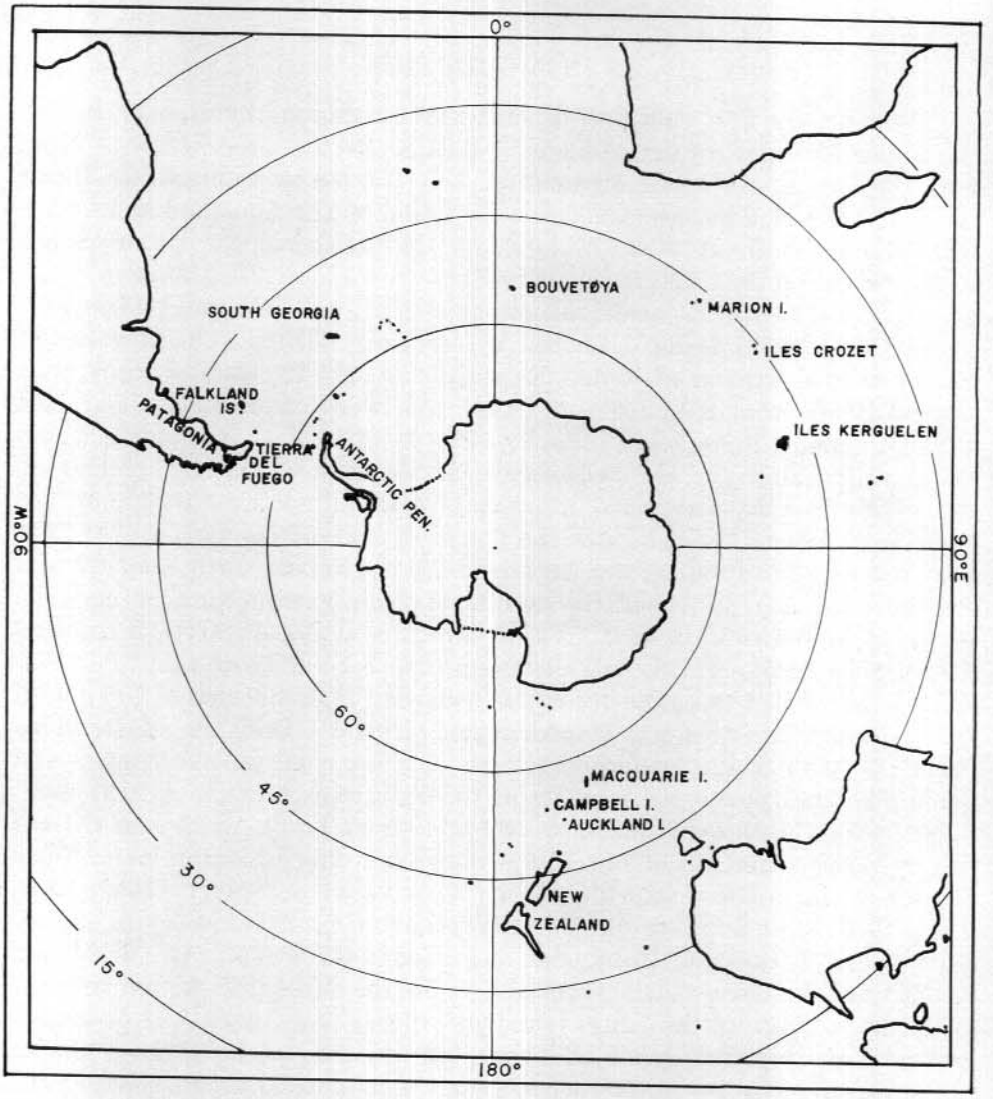

FIG. 1. Map showing location of subantarctic islands mentioned in text.

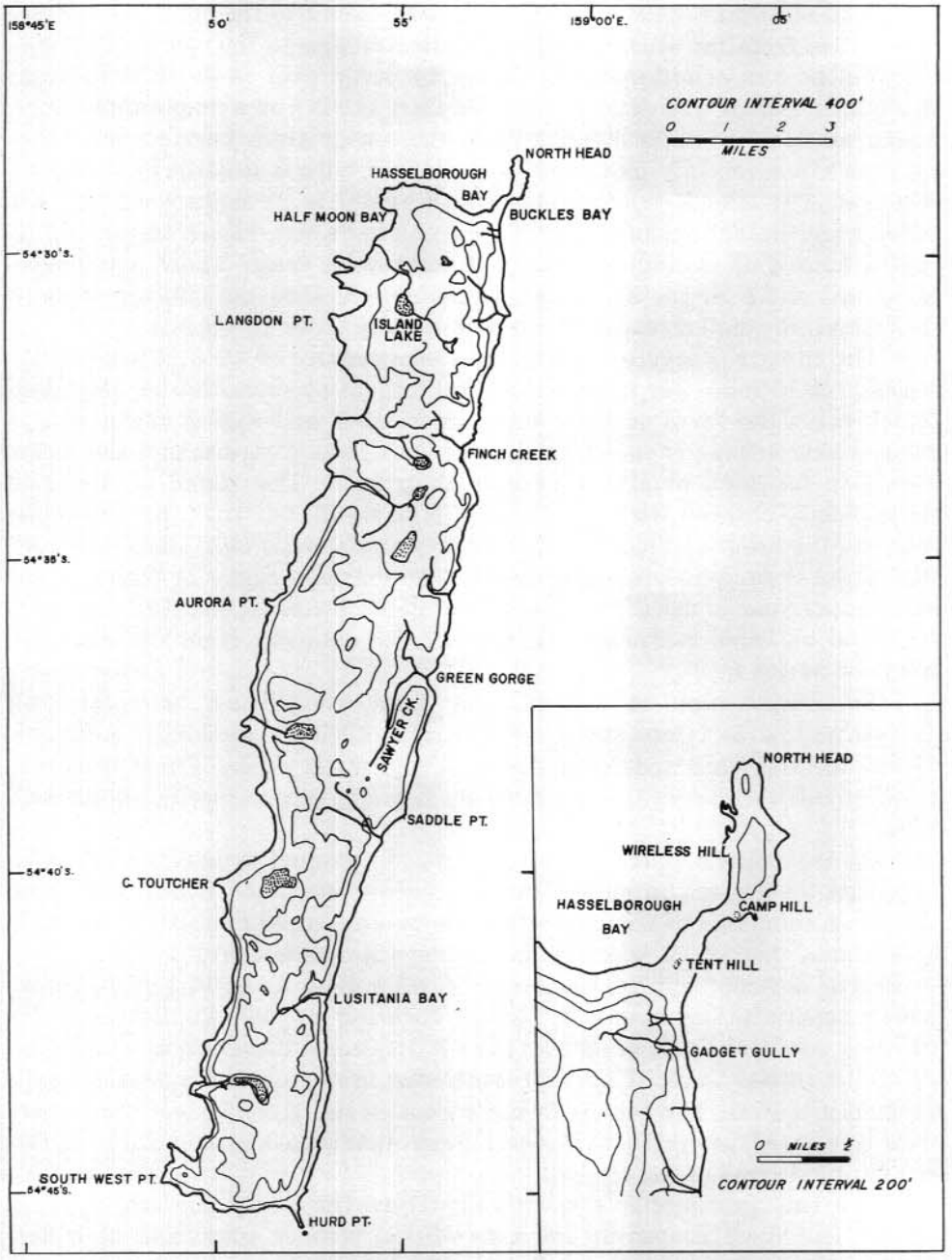

FIG. 2. Map of Macquarie Island with place names referred to in text.

Island stands alone, 3000 miles from Heard Island to the west and almost 5000 miles from the southern tip of South America to the east.

Volcanic in origin and surrounded by ocean over 2000 fathoms deep, Macquarie Island was described by Mawson (1943) as a "mountain range rising abruptly in cliffs directly from the sea or from narrow, low-lying beaches" to a recently glaciated hilly plateau with a general elevation of 800 feet. The island, oriented north and south, is 21 miles long and 2-4 miles wide. Recent geological uplift has created a flat, raised terrace up to half a mile wide extending along the north-west coast. There are glacial lakes and tarns in the highlands, sometimes lacking outlets, but usually draining into small streams which flow rapidly down to the sea.

The climate is severe, with a mean temperature of 40°F, a mean wind velocity of 15 miles per hour and a total annual precipitation of 45 inches which takes the form of rain, sleet, snow, mist and fog. A mean of approximately 1 hour of sunshine per day has been recorded and the mean humidity for each month is greater than 90%. The island is nowhere permanently covered with snow or ice. It is significant that the difference between the mean summer and winter temperatures is only about 5°F and that diurnal variations are also small. The extreme range in temperature during any year is usually no more than 25°F. Seasonal weather data will be found in Table 9. Further details may be obtained from the ANARE Reports, Series D.

The distribution of the vascular flora, comprising 38 species of grasses and herbs (Cheeseman, 1919; Taylor, 1955), is strikingly governed by the local climate and the position of the water table. There is also a close correlation, under these conditions, between plant association and soil type.

On the highest parts of the plateau, the ground is bare or partially colonised by the button moss, *Dicranoweisia antarctica* (C.M.) Par., and the soil is composed of scarcely altered, coarse-textured to rocky glacial till, often many feet thick. Slightly lower elevations are characterized by an extensive development of the large, cushion-like *Azorella selago* Hook. which generally forms only a partial covering of the till. Between the growing surface of this plant and the till, there is a dark, organic soil zone up to 12 inches thick. This represents the first stage of a more highly developed organic soil which forms a continuous layer beneath the *Azorella selago*. *Pleurophyllum Hookeri* Buch. dominated associations on the less exposed areas of the plateau.

The less precipitous slopes rising from the coast and the narrow coastal belt itself constitute the zone of wet tussock grassland in which the principal species are *Poa foliosa* Hook. f., a massive tussock grass, and the luxuriant *Stilbocarpa polaris* A. Gray. On the hillsides, these plants form a continuous band of red-brown peat up to 5 feet thick, but on the coast, in areas dominated by *Poa foliosa*, characteristic bogs are often found. Here, peaty material tends to be built up immediately beneath the

tussocks, the hollows thus formed between plants becoming filled with foul-smelling stagnant drainage water heavily loaded with putrifying plant residues and frequently also with the excrement of seals and penguins. The raised terrace of the north-west coast is clearly distinguishable from the remainder of the coastal belt because of the sharp transition from grass-land to sub-glacial herbfield, dominated by *Pleurophyllum Hookeri* and bog communities which have together produced a characteristic deposit of soft to semi-liquid peat some 15 feet thick.

Certain species, notably *Puccinellia macquariensis* Cheesem. and *Colobanthus muscoides Hook.* f., form open communities on the coastal rocks immediately adjacent to the sea. They are able to colonise practically bare rock and, by gradually building up pockets of sandy material and partly decomposed organic matter, pave the way for succession by less hardy species.

Material and specimens for the following account were collected by the author as a member of the 1951-52 ANARE party at Macquarie Island. Further soil samples and specimens were collected during a return visit to the island in March 1953 and again in December 1954. In addition, a number of preserved agarics were made available from the field collections of previous ANARE biologists, Messrs. N. Haysom, T. Manefield and Dr. B. W. Taylor.

II. METHODS AND MATERIALS

Collection, storage and description of soil samples. During February 1952, a number of soil samples was collected from the surface six inches within representative ecological areas of the island. Subsamples were later transferred without drying to sterile 2 lb jars for storage. In Australia, the jars were maintained at 40°F. A brief description is given in Table I of the samples chosen for examination.

Examination of the soils. The numbers of fungi in the soils were estimated by means of the normal plate count technique using Czapek's agar with glucose as carbon source and a pH of 4·5 to inhibit the development of bacteria. Suitable dilutions were counted after incubation at 26°C. To study qualitative differences between soils, a maximum number of 20 single colonies was picked at random from plates at the 10^{-4} dilution level from each soil and studied separately on neutral Czapek's agar. From samples numbered 2, 4, 5, 8 and 9, low counts made it possible to obtain only 10, 17, 3, 15 and 12 isolates respectively. Several fungi appearing only in the lowest dilutions were also identified.

Wickerham's medium (Raper and Thom, 1949) was used in testing the antibiotic activity of the isolates against a range of gram positive and gram negative bacteria and several plant pathogens.

Systematics. In the present account, with the exception of the agarics, which were examined in detail by Singer, identification generally has not

been taken beyond the generic level. A description of the incompletely identified organisms has been given by Bunt (1955). The list which follows includes plant parasites and saprophytes as well as soil macro- and microfungi. Although it is believed to reflect the general character and range of the Macquarie Island fungal flora, it should not be regarded as complete. In fact, more detailed studies in this field are clearly necessary, not only at Macquarie Island, but throughout the subantarctic zone.

III. LIST OF FUNGI COLLECTED FROM MACQUARIE ISLAND (1951-54)

I. ASCOMYCETES

SPHAERIACEAE

Chaetomium Kze. First observed on cellulosic material soaked with mineral nutrient solution incubated under anaerobic conditions with soil inoculum. Later observed growing as a vigorous saprophyte on *Poa foliosa* leaves December 1953.

Mycosphaerella Johans. Occurring on upper surface of seedling leaves of *Cardamine corymbosa* Hook. f., Gadget Gully, 22.8.51. Plants not visibly affected by parasite.

Mycosphaerella Johans. Black spots on the upper leaf surfaces of *Colobanthus muscoides* Hook. f. and causing slight yellowing of leaf tissues. Collected Camp Hill, 17.8.51. A different species to that occurring on *C. corymbosa.*

Several other fungi were found in this material but could not be identified because the pycnidia or perithecia were empty and the origin of released spores could not be traced.

Pleospora Rabh. Black spots on dead and dying leaves of *Puccinellia macquariensis* Cheesem. Collected from Hasselborough Bay area, 15.8.51. A species of *Pleospora* apparently identical with that occurring on *P. macquariensis* was also found on *Poa foliosa* and *Poa hamiltoni* T. Kirk.

HYSTERIACEAE

Hypodermella Tubeuf. Occurs usually as groups of hysterothecia on the large veins of the leaves and on the petioles of *Stilbocarpa polaris,* causing localized necrosis. Wireless Hill, 17.8.51. Finch Creek, 14.9.51.

HELOTIACEAE

Sarcoscypha Fr. A saprophyte on the leaves of *Poa foliosa.* Collected 28.12.54.

PEZIZACEAE

Lachnea Fr. (*Scutellinia* Cke). Widespread, occurring even on exposed uplands but then in the shelter of such plants as *Azorella selago* and *Pleurophyllum Hookeri.* Very similar to *Lachnea scutellata* L., except for

TABLE 1

Description of Macquarie Island soil samples

Sample number	General soil description	Dominant plant species	Elevation in feet	Moisture conditions	Soil* temp. °C	pH	Organic carbon %	Total N, %	C/N Ratio
1	Glacial till	*Dicranoweisia antarctica*	1000	Continually wet	4·0	6·8	3·6	0·30	12·0
2	Organic zone over till	*Azorella selago*	700-800	Continually wet	5·0	6·2	12·5	0·78	16·0
3	Boggy peat	*Pleurophyllum Hookeri*	500	Constantly saturated	6·0	7·1	18·5	1·56	12·0
4	*Poa* bog, bare ground between tussocks	*Poa foliosa*	5-10	Constantly saturated	8·4	4·3	18·6†	1·58†	11·6
5	Peat over glacial till	*Pieurophyllum Hookeri, Azorella selago*	750	Continually wet	5·4	5·8	24·1	2·19	11·0
6	Black beach sand	*Poa foliosa*	5-10	Moist	8·0	4·3	1·3	0·11	11·8
7	Organo-mineral debris	*Puccinellia macquariensis*	Shoreline rocks	Variable, exposed to sea spray	8·0	7·2	4·4	0·69	6·4
8	Red-brown peat	*Poa foliosa*	600	Moist to wet	4·8	4·4	44·6	3·33	13·4
9	Red-brown peat	*Poa foliosa, Stilbocarpa polaris*	100	Wet	4·8	4·0	43·6	3·33	13·1
10	Soft bog peat	*Pleurophyllum Hookeri*	40	Constantly saturated	9·0	4·7	39·4	1·79	22·0

* Single readings (February).

† From Piper (1938).

the slightly larger size and general lack of teeth on the setae in the Macquarie Island material. A similar species in many respects, *Lachnea kerguelensis* Berk. has been recorded from Hermit Island, Kerguelen and New Zealand.

II. BASIDIOMYCETES

UREDINALES

PUCCINIACEAE

Puccinia Pers. Occurs rarely on upper surfaces of leaves of *Puccinellia macquariensis*. Collected Hasselborough Bay, 15.8.51.

AGARICALES (by R. Singer)

HYGROPHORACEAE

Hygrocybe conica (Scop. ex Fr.) Kummer, Führ. Pilzk. p. 111. 1871.

Hygrophorus conicus Scop. ex Fr., Syst. Mycol. 1: 103. 1821. West Point, 14.2.1952; Langdon Point, 19.3.1950, both on raised coast terrace on humus; three collections.

This represents what is probably a subantarctic race of the common and almost cosmopolitan "linnaeon" which is known under this name. In order to describe this race as a special subspecies or variety, it would be necessary to have additional observations on the colors of the carpophores before blackening and on the constancy of the spore shape and the relative viscidity of the pileus.

The Macquarie collections have the appearance of *H. nigrescens*, and very short ellipsoid spores (8·8-10·5 (12·5) × 6·2-7 μ; 10·2-11·7 × 8-8·8 μ). Basidia 4-spored, only in one collection some 2-spored basidia are present. Epicuticular layer not gelatinized in KOH mounts from formol material. Some scattered cystidiole-like elements in the hymenium occasionally seen; hymenophoral trama regular.

The occurrence of *H. conica* was not previously published.

Hygrocybe sp.

Another, or two other species of *Hygrocybe* which could not be determined but are preserved (LIL) under the provisional names *H. alutacea* Sing. ad. int. and *H. buntii* Sing. ad. int. were collected at Gadget Gully, 30-3-1951, and West Point, 31-3-53, on *Pleurophyllum* peat and on peats of the raised coastal terrace respectively.

These species seem to be related with *H. ceracea*; they may be identical with each other.

TRICHOLOMATACEAE

Lepista fibrosissima Sing., Sydowia: 8: 104. 1954.

Wireless Hill, humicolous, growing in the shelter of *Stilbocarpa polaris*, 28.3.1950. No. MI/49/437.

This species was first described from Patagonia, South America, and its existence on Macquarie is quite significant from a phytogeographic point of view.

AGARICACEAE

Cystoderma amianthinum (Scop. ex Fr.) Fayod ex aut.

Island Lake, 13.2.1952. No. MB/52/B8.

This is a widely distributed species of the temperate and frigid regions, including the higher regions of the Andes (near tree line, by 3000 m alt. in Bolivia; also in Tierra del Fuego). It is somewhat variable in spore shape, and the Macquarie collection may belong to a separate variety. It is here cited for the first time, and represents a further remarkable extension of area.

COPRINACEAE

Panaeolus moellerianus Sing., Lilloa 30: 123. 1960.

Wireless Hill, 28.3.1950 and 28.12.1954; Halfmoon Bay 28.3.1950; Tent Hill 19.12.1949; Finch Creek 26.11.1951.

This species, or a form of it, appears to occur in the subarctic zone of the Northern Hemisphere where it was described by Möller (Fungi of the Faröes 1: 172. 1945) as *Panaeolus subbalteatus* which, however, is a thermophilous species, not identical with the subarctic-subantarctic species mentioned here.

Psathyrella macquariensis Sing., Mycologia 51: 392. 1959 (publ. 1960) Near Tent Hill, 15.11.1951.

An interesting species, not known from elsewhere.

STROPHARIACEAE

Psilocybe longinqua Sing., Mycologia 51: 578. 1959 (publ. 1960). Northern slopes of plateau, at 800 ft. elevation, 1.5.1949. This seems to be comparable with *Naematoloma laeticolor* Möller but is distinguished by broader spores. Not known from elsewhere.

RHODOPHYLLACEAE

Rhodophyllus sericeus ssp. *antarcticus* (Sing.) Sing. comb. nov. (= *Acurtis sericeus* ssp. *antarcticus* Sing. Mycologia 51: 587. 1959, publ. 1960).

Half Moon Bay 31.1.1951; Hills above Green Gorge, 29.12.1954; Sawyer Creek, 29.12.1954.

There are several antarctic, subantarctic, and alpine forms, comparable with this subantarctic race, in the northern hemisphere, which would indicate a bipolar-disjunction of areas, as far as the species as such is concerned.

CORTINARIACEAE

Galerina longinqua Smith and Sing., Mycologia 50: 477. 1958. Hills north of Green Gorge, 29.3.1954.

This species seems to be more widely distributed in the antarctic-subantarctic regions and has its nearest relative in Tierra del Fuego and Patagonia. It is probably an element of the ancient Austral-Antarctic flora.

Galerina macquariensis Smith and Sing., Mycologia 50: 478. 1958.

Langdon Point and West Point, 19.3.1950 and 13.4.1951; Half Moon Bay 13.4.1951; and an additional collection, together with *Lepista fibrosissima*.

Not encountered elsewhere.

Galerina vittaeformis var. *pachyspora* Smith and Sing., Mycologia 50: 488. 1958.

West Point, 31.3.1953; Half Moon Bay, 31.1.1951.

G. vittaeformis is widely distributed in temperate and boreal woods, including in Tierra del Fuego. The broad-spored variety does not seem to be restricted to Macquarie Island, but its exact distribution cannot be determined, for the whole group of *Galerina* with pruinose stipe and pleurocystidia is poorly studied in the pertinent herbaria, since the existence of pilocystidia (dermatocystidia of the pileus surface) has not been checked consistently. It is possible therefore, that broad-spored specimens were confused with the similar *G. atkinsoniana*.

III. FUNGI IMPERFECTI

PHOMACEAE

Phyllosticta Pers. Collected Wireless Hill, 17.8.51. Associated with *Camarosporium* Harkn. on leaves of *Agrostis magellanica* Lam.

Diplodia Fr. On leaves of *Colobanthus billardieri* Feuzl. Gadget Gully, 22.8.51.

Camarosporium Harkn. On leaves of *Agrostis magellanica,* Wireless Hill, 17.8.51.

MONILIACEAE

Polyscytalum Riess. Isolated from rotting seaweed. One species.

Aspergillus sydowi (Bainier and Sartory) Thom and Church. Isolated from soil.

Cephalosporium Corda. Two species or strains from soil.

Cylindrophora Bon. One species from soil.

Hyalopus Corda. One species from soil. Also on leaf debris of *Poa foliosa*.

Monosporium Bon. Four species or strains from soil.

Penicillium frequentans series. Two species or strains from soil.

Penicillium (*Ramigena* series). From soil. A single species or strain.

Penicillium janthinellum series. Three species or strains from soil.

Penicillium viridicatum series. Ten species or strains from soil.

Penicillium cyclopium series. A single species or strain from soil.

Penicillium granulatum series. Twelve species or strains from soil.

NOTE: Determination of series within the genus *Penicillium* according to Raper and Thom, 1949.

Paecilomyces Bainier. One species from soil.

DEMATIACEAE

Cladosporium Link. One species from soil.

IV. NUMBERS OF FUNGI IN MACQUARIE ISLAND SOILS

The numbers of fungi, estimated by plate counts with acidified Czapek's agar, in a range of 10 soils from Macquarie Island, are presented in Table 2. An analysis of the results has shown that there are significant differences ($P = 0{\cdot}01$) between the populations from different localities.

TABLE 2

Numbers of fungi in the soils of Macquarie Island

Soil sample number	Number of fungi per g of soil (oven-dry basis)			Soil sample number	Number of fungi per g of soil (oven-dry basis)		
	Duplicates		Mean		Duplicates		Mean
	a	b			a	b	
1	23,500	23,100	23,300	6	17,000	14,200	15,600
2	36,200	54,000	45,100	7	42,200	49,000	45,600
3	9,860	14,400	12,100	8	13,800	12,000	12,600
4	159,000	123,000	141,000	9	14,000	12,500	13,300
5	5,300	2,650	4,000	10	148,000	134,000	141,000

The numbers of fungi were found to range from 141,000 per g soil in samples 4 and 10 to 4,000 per g in sample 5. It should be noted that samples 1, 6 and 7, which represent scarcely altered glacial till, black beach sand poor in organic material and the rubble surrounding the roots of *Puccinellia macquariensis*, respectively, contain larger numbers of fungi than samples 3, 5, 8 and 9 taken from soils in a more advanced stage of development. The general differences between soils are further emphasized in Table 3 which includes estimates of the numbers of bacteria and algae

TABLE 3

Comparison between the numbers per gram of bacteria, fungi and algae in 10 Macquarie Island soils.

Soil sample number	Bacteria* 10^6	Fungi* 10^6	Algae† 10^6	Fungi/ Bacteria %	Fungi/ Algae %	Fungi/total population %
1	1·2	0·023	0·218	2·0	10·5	1·5
2	3·1	0·045	0·025	1·5	180·0	1·4
3	9·6	0·012	1·000	0·1	1·2	0·1
4	15·2	0·141	0·031	0·9	470·0	0·9
5	4·3	0·004	<0·0001	0·1	>4000·0	0·1
6	7·1	0·016	<0·0001	0·2	>16000·0	0·2
7	0·4	0·046	0·025	11·5	153·0	9·8
8	7·1	0·013	<0·0001	0·2	>13000·0	0·2
9	17·9	0·013	0·004	0·1	325·0	0·1
10	11·7	0·141	0·091	1·2	157·0	1·2

*plate count † direct microscopic count by fluorescent technique (Tchan, 1952)

per gram from the same 10 soils and illustrates the range in proportions existing between the fungi and the other two groups.

As far as may be deduced from the evidence of plate counts, the fungi make up only 0·1-1·5 per cent. of the total microflora in these soils with the exception of soil 7, "*Puccinellia* rubble", in which nearly 10 per cent. of the total population are fungi. Although the figures for the algae are comparatively high, a reflection of the counting technique, it is clear that there is great variation in the ratio fungi/algae in the soils and that the quantitative composition of the microflora exhibits considerable diversity in the localities examined.

It is difficult to trace the influence of any ecological factor, such as pH, on the numbers of fungi in the soil. An attempt was made to obtain a partial regression equation by means of which the fungal population could be predicted, given any combination of values for pH, per cent. organic carbon and per cent. moisture in the soil. The result made it clear that the populations are dependent on a larger number of factors, no one of which seems to exert sufficient influence as a rule, to make its effect apparent in the presence of the others. However, several comparisons are rather suggestive. An examination of Table 1 will show that samples 3 and 4 are very similar in several characteristics but are quite different in reaction. In sample 4 (pH 4·3) there is a higher proportion of fungi to bacteria (0·9 per cent.) than in sample 3 (pH 7·1) in which the proportion is only 0·1 per cent. In comparing samples 8 and 9 with 10, there is a marked difference in C/N ratio. Where the ratio is wide in sample 10, the fungi make up a considerably larger proportion of the total population than in samples 8 and 9 where the ratio C/N is relatively narrow.

V. QUALITATIVE COMPOSITION OF THE FUNGI OF THE SOILS

Table 4 shows the types of micro-fungi which occur most commonly in the soils of Macquarie Island. The populations include only 9 genera capable of growing on Czapek's agar. No soil contained more than three genera at the dilution chosen for study. At lower dilutions, there was a slightly greater diversity of genera within each soil, including *Cladosporium*, shown by crosses in Table 4, and *Monosporium* which was present in every soil examined. Apart from *Polyscytalum*, which was isolated from decomposing seaweed, no other genera were found.

Of the colonies isolated, 62 per cent. were species or strains of *Penicillium*. Those grouped in the *Penicillium viridicatum* and *Penicillium granulatum* series were most widespread and dominated the flora in most of the soils. Soil 5, an upland peat, was also rich in *Penicillium* at lower dilutions but isolations could not be made because of the vigorous development of large numbers of acid-tolerant bacteria. Soil 9 was rather exceptional with a population dominated by *Cylindrophora*, although *Penicillium* was common at lower dilutions.

TABLE 4

Qualitative composition of the fungal flora of 10 Macquarie Island soils

(Number of colonies of each type isolated by random picking from plates containing 1 ml. of 1:10,000 soil suspension)

Name of fungus	Soil Sample number:										kelp
	1	2	3	4	5	6	7	8	9	10	
Aspergillus sydowi					1			2			
Cephalosporium sp. strain 1			1							8	
Cephalosporium sp. strain 2									1		
Cladosporium sp.	×*	×	×		×		×			×	
Cylindrophora sp.									7		
Hyalopus sp.			6								
Monosporium sp. strain 1						3					
Monosporium sp. strain 2						3					
Monosporium sp. strain 3								5			
Monosporium sp. strain 4							5				
Penicillium frequentans series			2				3				
Ramigena series			1								
Penicillium janthinellum series	6	2									
Penicillium viridicatum series	4	6	5	7		8	8	3		4	2
Penicillium cyclopium series										4	
Penicillium granulatum series	10	2	1	9		2	2	5		4	2
Polyscytalum sp.											2
Spicaria sp.							1				
Unidentified sterile colonies or bacteria			4	1	2	4	1		4		
Total number of colonies isolated from each sample	20	10	20	17	3	20	20	15	12	20	6

* Recorded at lower dilutions.

Although few gross qualitative differences could be found between soils, it is apparent that local conditions may favour the development of particular strains within the genera. Thus, in soil 4 from the "*Poa* bogs", 7 of the 9 isolated cultures of *Penicillium granulatum* series belong to one strain of this group, whilst in soil 6, a beach sand poor in organic matter, all the cultures of *Penicillium viridicatum* series belong to one strain. Two strains or species of *Monosporium* were found separately in two distinct

situations. Since quite closely related strains of soil fungi may differ considerably in biochemical activity, such fine qualitative differences between situations may be of some significance in processes of decomposition within the soil.

VI. PRODUCTION OF ANTIBIOTIC SUBSTANCES

Fifty-nine cultures of fungi were tested for their ability to inhibit the growth of a range of Gram-positive and Gram-negative bacteria. Cultures giving positive results were also tested against two fungi which cause plant disease. The results have been summarized in Table 5. It was found that 36 per cent. of the isolates had some effect on one or more bacteria and that, of this group, 63 per cent. were, to some extent, effective against one or both of the plant parasites. It is possible that a proportion of the isolates ineffective against the bacteria may have been effective against the parasitic fungi. This was not investigated.

TABLE 5

Percentages of soil fungi that produce antibiotic substances

Test organism	Percentage of isolates:			
	causing some inhibition	zone of inhibition:		
		10 mm	20 mm	30 mm
Bacilius subtilis	19·0	7·4	3·7	2·5
Bacillus cereus	19·6	4·3	1·8	1·8
Staphylococcus aureus	19·6	6·1	4·3	2·5
Staphylococcus albus	28·2	14·7	7·4	3·1
Total of Gram-positives	86·4	32·5	17·2	9·9
Escherichia coli	1·8	0·6	—	—
Pseudomonas aeruginosa	2·5	1·8	0·6	—
Serratia marcescens	1·2	1·2	—	—
Total of Gram-negatives	5·5	3·6	0·6	—
Helminthosporium sativum	10·4	2·5	—	—
Monilia Sp.	20·2	3·1	1·2	—
Total of fungi	30·6	5·6	1·2	—

Tests on Wickenham's medium (Raper & Thom, 1949).

The distribution of effective inhibition is presented in Table 5, showing that most of the fungi produced substances which inhibit Gram-positive bacteria, a much smaller proportion affecting the growth of Gram-negative organisms, whilst quite a large percentage had antifungal properties. Almost 10 per cent. of the isolates prevented the growth of Gram-positive test organisms in a zone extending 30 mm or more from the colony margins. The effectiveness against Gram-negative organisms and parasitic fungi was far less pronounced. None of the isolates was able to inhibit all the test organisms, although a single culture belonging to the *Penicillium cyclopium* series and the culture of *Paecilomyces* were able to affect 8 of the 9 organisms tested and almost 30 per cent. were to some extent effective

against 5 or more organisms. The fungi most effective against the Gram-negative bacteria were several members of the *Penicillium cyclopium* series, *Cephalosporium* strain 2 and two cultures of *Monosporium* strain 2.

Isolates grouped together on the basis of colony and morphological characteristics commonly exhibited a range of antibiotic properties. Thus, in strain 3 of the *Penicillium granulatum* series, individual cultures were found to be either completely ineffective or effective to some extent against from 1-6 test organisms. Where several cultures from a single strain were effective against the same test organisms, it was found that the effectiveness, or efficiency of antibiotic production, sometimes varied.

The reactions of the test bacteria were checked against penicillin, streptomycin, terramycin, aureomycin, bacitracin and chloromycetin. The results were not comparable with those obtained with the Macquarie Island soil isolates. Either the substances produced by these fungi are unlike the commoner antibiotics or, more probably, the reactions reported in this paper represent the effects of combinations of substances acting simultaneously.

A study was not made to discover whether the production of antibiotic substances takes place under natural conditions, although this seems probable from evidence presented by Newman and Norman (1943) and others.

VII. DISCUSSION

The line of latitude on which Macquarie Island is situated corresponds with a line in the Northern Hemisphere passing through the north of England, the extreme north of Germany, central Russia and southern Canada. This fact points to the marked contrast in land: sea distribution between arctic and antarctic regions. The geographic North Pole occurs in the Arctic ocean and is closely surrounded by the great land masses of Asia, North America and Greenland, whereas the geographic South Pole is roughly in the centre of the antarctic continent which is completely surrounded by ocean. The climate of the higher southern latitudes is characterized by continuous low temperatures, high winds and, on the subantarctic islands, a remarkably small diurnal and annual range in temperature. These factors, combined, largely explain the simplicity of the antarctic or subantarctic vascular florula compared with those of equivalend northern latitudes.

In discussing the limited nature of the fungal flora of Macquarie Island, greater emphasis must be placed upon the influence of climatic conditions than on geographic isolation which sets a limit to the introduction of the seeds of vascular plants but not of microscopic spores. However, the process may be sufficiently slow under conditions of extreme isolation to enable early introductions to become so well established that they cause the failure of later arrivals by direct competition. The implications of this possibility will be referred to again. Remoteness from other land

masses has, of course, affected the number of species of pathogenic fungi on Macquarie Island as the range of host species available for infection is small.

Climate, acting directly through one of its main components, temperature, is perhaps the principal factor limiting the number of genera and species of fungi occurring on Macquarie Island. This effect is most clearly illustrated by the fact that, although a wide range of soil types was examined, the total number of genera obtained was relatively small and the same genus, *Penicillium*, was dominant in almost all localities. Indirectly, the effects of climate are expressed in many ways. By limiting the vascular flora, a restriction is also placed on the range of parasitic fungi, although successful forms are probably favoured by the continually humid conditions. The distribution of the vascular flora is controlled mainly by wind and the position of the ground water table, and, as there is a marked correlation between plant association and soil type, climate may be said to influence the local composition of the fungal flora of the soil and also its distribution.

The general distribution of the fruiting bodies of the gill fungi is noticeably controlled by local or micro-climatic conditions, although the organisms may be much more widespread as sterile hyphae within the soil. Members of this group were mostly observed on the raised terrace of the north-west coast, and in the shelter of the wet tussock grassland of the slopes, but occasionally in the sub-glacial herbfields of the plateau in situations offering protection from the wind. As some forms were found growing only on dead leaves of *Poa foliosa* and on decaying vegetation near creeks, it is possible that factors such as plant association and type of organic substrate may also affect distribution. However, other forms were found in several quite dissimilar habitats implying the lack of specific nutrient requirements.

The numbers of fungi recorded from the soils are sufficiently high to warrant the assumption that they play some part in processes of decomposition under subantarctic conditions. Additional evidence of their activity is indicated by the frequent occurrence of fungal hyphae in slides of a wide range of soils prepared by the technique of Jones and Mollison (1948) and the ease with which isolates may be grown at 5°C, which approximates the mean temperature of the surface soil at Macquarie Island. Unfortunately, it has not been possible to investigate, in any detail, the chemical composition, especially of the organic fractions of the soils, and the biochemical activities of the fungi.

It has been clear, from personal observations, that parasitic and, more particularly, saprophytic fungi are both widespread and abundant and fulfil an important function as primary agents of decay. Their activities are most apparent in the wet tussock grassland. *Pleurophyllum Hookeri* and *Azorella selago* appear to be resistant to attack by parasites, and saprophytes seem to have little effect until the dead vegetative parts become

incorporated or partly buried in the upper layer of soil. Although the soils of Macquarie Island are typically high in organic matter, the C/N ratios are not as a rule exceptionally high, except in the peats of the raised coast terrace. Thus, fairly active humification is indicated and it is unlikely that the fungi are not partly responsible for the continuation of this process. The excessive build-up of organic matter in the soils reflects the inability of the total microflora to keep pace with the rate at which litter is deposited by higher plants. In this connection it has been shown by Bunt and Rovira (1955) that the microflora of these soils is not fully adapted to sub-antarctic conditions since maximum metabolic activity was found to occur at temperatures considerably higher than those encountered at Macquarie Island. The vascular flora, on the other hand, is well-adjusted to the severity of the climate.

It has become evident from examination and analysis of the counts of soil fungi that a number of factors operate in deciding the magnitude of the population in any soil situation and that no one factor is of sufficient importance to make its effect generally evident in the presence of the others. Of the components of microclimate, temperature and precipitation require some mention.

Soil temperature measurements taken during February 1952, in 44 situations range from a mean of 8·1°C in the zone 0-150 feet above sea level to 5·0°C at 650-850 feet. A consideration of the relationship between air and soil temperatures, and of mean annual climatic differences between the elevated and low-lying parts of Macquarie Island, indicate that measurements extended over a longer period would widen this range and place the soil temperatures of the higher evaluations very close to zero. Under such conditions, small temperature differences may play an important part in affecting the relative size and activity of the fungus populations.

Precipitation records were obtained from April to December 1953 at 10, 50, 100, 200 and 300 feet above sea level. The figures ranged from 10 to 23 inches, decreasing from 23 to 10 inches between 10 and 100 feet and then increasing to 19 inches at 300 feet. The levels of soil moisture depend partly upon such variations but also on the physical condition of the soils and local topography. Certain bog peats were found to contain only 6 per cent. solid matter, whilst mineral soils in well-drained situations sometimes contained only 10 per cent. moisture. However, most of the soils are well-supplied with water, thus favouring the fungi, even, apparently, under conditions of permanent waterlogging, since high numbers were recorded in soil 10 from the raised coast terrace.

From analyses of rain water collected during 1953, it has been possible to calculate that, at sea level, about 70 tons of salt are deposited from sea spray per acre per annum. At 300 feet, the figure is about 25 tons. The salinity of the conditions does not appear to have caused any reduction in the numbers of fungi. In fact the largest populations were recorded near

sea level and several types of *Penicillium* and a species of *Polyscytalum* were found to be abundant in decomposing kelp accumulated in salt water pools just above tide level. It was not possible to correlate increasing salinity with increase in numbers of fungi in the soil.

No attempt has been made to discover whether fungi are more numerous in the rhizosphere of Macquarie Island vascular plants, although Bunt and Rovira (1955) have shown that there are significant increases in the numbers of micro-organisms near the roots of *Azorella selago, Pleurophyllum Hookeri* and *Poa foliosa*. Unfortunately, no discrimination was made between bacteria and fungi when counting the plates.

In establishing a considerable degree of antibiotic activity amongst the soil fungi from Macquarie Island, it is clear that forms from such isolated regions warrant further investigation aimed at discovering new antibiotics useful in the control of human, animal and plant disease. Also, the results suggest that such substances, if produced under natural conditions, might be important in controlling the levels of other soil-inhabiting organisms. However, no evidence has been obtained in support of such a function in these soils.

Finally, some consideration should be given to our knowledge of the distribution of fungi in antarctic and subantarctic regions. Table 6 contains weather data from a range of subantarctic stations and shows the general uniformity of the climate throughout this zone. The figures were extracted from ANARE weather data and from Cheeseman's (1919) account of the vascular flora of Macquarie Island. This account, besides indicating the simplicity of the subantarctic vascular flora, contains certain other facts pertinent to the present discussion. Fifteen of the species on Macquarie Island are circumpolar in distribution, including *Azorella selago* and many plants occurring as sub-dominants on the raised terrace of the north-west coast, an area especially favourable to the growth of agarics. Three important species, *Poa foliosa, Pleurophyllum Hookeri* and *Stilbocarpa polaris*, occur only on Macquarie Island and the Auckland, Campbell Group south of New Zealand. The largest number of species has been recorded in the vicinity of Tierra del Fuego and on the subantarctic islands of New Zealand. Despite differences in the distribution of species, Piper (1938) has been able to show a general similarity in the character of widely separated subantarctic soils. With these facts, it will be obvious that further exploration is necessary for, on the evidence of climate, vascular flora and soils, fungi should be present on the Crozets, Heard Island and Bouvet Island. Further species should be expected also in the areas from which collections have already been made for, compared with Macquarie Island, all are favoured by either slightly less severe climatic conditions or considerably larger vascular floras. Those species occurring as components of the soil microflora have been entirely neglected.

As far as the Basidiomycetes are concerned, Singer has contributed the following unedited observations in a personal communication to the

TABLE 6

Weather data from subantarctic stations

Season	Temperature in °F											
	Macquarie Is. (1)			Orange Harbour Fuegia (2)			South Georgia (3)			Heard Is. (4)		
	Mean	Mean max.	Mean min.	Mean	Mean max.	Mean min.	Mean	Mean max.	Mean min.	Mean	Mean max.	Mean min.
Spring	39·9	42·9	36·8	42·2	52·3	35·7	34·0	38·9	29·2	32·9	36·1	29·5
Summer	43·9	47·0	41·3	46·8	55·7	39·0	40·2	45·1	35·5	37·4	41·2	34·6
Autumn	40·9	43·3	38·4	41·1	47·7	35·7	34·3	38·8	30·1	37·6	41·0	34·5
Winter	38·6	40·7	34·9	37·1	42·3	33·0	29·6	34·2	24·7	33·6	36·8	30·7
Year	40·7	43·5	37·9	41·8	49·5	35·9	34·5	39·3	29·9	35·4	38·8	32·3

Season	Precipitation in inches				Wind in miles per day			
	Macquarie Is.	Orange Harbour	South Georgia	Heard Is.	Macquarie Is.	Orange Harbour	South Georgia	Heard Is.
Spring	9·9	12·5	12·4	11·7	385	345	340	367
Summer	12·0	15·7	9·5	19·0	416	480	363	336
Autumn	12·9	17·5	9·6	19·0	488	326	357	365
Winter	11·1	11·7	7·4	17·2	449	309	376	398
Year	45·9	57·4	38·9	66·9	435	358	359	367

(1) 1912-wind; precipitation—1915.
(2) 1882-83
(3) 1882-83.
(4) 1951

author: "The scarcity or absence of Heterobasidiomycetes and Aphyllophorales at Macquarie Island is not surprising, since a similar phenomenon has been observed in other parts of the arctic and antarctic regions and must be due to the fact that the evolution of these groups has been closely linked with the presence of forested areas. The first fungi observed on the Antarctic Continent have likewise been found to belong to the Agaricales (also some hitherto unpublished Ascomycetes and Imperfecti). It cannot be assumed that the present list gives an exhaustive account of the basidiomycetous flora of Macquarie, but it is considered representative.

"The incomplete exploration of the fungus flora of the Antarctic and Subantarctic as a whole does not permit negative statements in the sense of any assurance given as to the absence of these species from regions other than Macquarie Island. But in several cases, records are now available from other regions and these records make it possible to come to some conclusions of a more general character:

"Generic composition of the flora: Comparing the agaric flora of Macquarie Island with that of other comparable regions, one may find nothing remarkable about the genera here represented; these genera are generally of a pattern to be expected, since they all are boreal in character and have been found in other similar localities in the Arctic, Subarctic,

Antarctic and Subantarctic, or else the particular group or section of the respective genera which is represented by the Macquarie material is to be considered typically boreal-alpine. What seems remarkable, however, is the absence from the agaric flora of Macquarie of such characteristic elements of both hemispheres as *Omphalina, Camarophyllus* and related genera, *Mycena, Clitocybe, Laccaria, Leptotus, Melanoleuca, Cystoderma, Coprinus,* to mention only a few, and without mentioning those ectotroph formers which, because of the absence of the dwarf Salicales and Fagales, could not possibly be expected on Macquarie Island, such as *Alnicola, Cortinarius, Russula* and *Lactarius.*

"Among the species observed on Macquarie, we can distinguish the following elements:

(1) Species restricted, as far as we now know, to Macquarie Island. Obviously, it would be premature to call these elements endemic. On the other hand, they do not reveal any useful facts about the history of the flora of the Australian Subantarctic, at least as far as our present knowledge is concerned.

(2) Species with evident extensions of area in the Antarctic—Antarctic (Palmer) Peninsula, or Kerguelen, South Georgia etc., or with demonstrable links with the mycoflora of Tierra del Fuego and Patagonia, but without any known records outside these regions. We would refer to this group: *Lepista fibrosissima* and *Galerina longinqua.* They are apparently representatives of the Austral-Antarctic flora and may be considered the first examples, among Basidiomycetes, of the element of that flora that occurs in the frigid zone and independently of forested areas.

(3) Species representative of the group of plants with bipolar area disjunction. Their distribution is of course quite puzzling as far as historical plant geography is concerned, but they are by no means unique, inasmuch as other basidiomycetous fungi have already been indicated by Singer (1952, 1953, 1954) as belonging to this element of the fungus flora.

"A tentative explanation of the bipolar area disjunction has been given by Singer (1954, pp. 458-459). Once it can be proved that certain of these elements are lacking on Macquarie, but present in Tierra del Fuego and adjacent subantarctic islands and the Palmer Peninsula, it would perhaps become possible to distinguish between those forms that are truly ancient elements retreating in both directions from the now warm regions of the earth and those that may have arrived in the subantarctic and arctic regions by migration from the north, as must be assumed in the case of *Cystoderma* and perhaps *Favolaschia antarctica* and *Pholiota privigna.*

"Examples of bipolar disjunction, among the Macquarie fungi, are: *Rhodophyllus sericeus, Panaeolus moellerianus.*

(4) Species of almost cosmopolitan distribution. Here, we would be inclined to mention *Hygrocybe conica* although the Macquarie specimens seem to represent a special race of this widely distributed species."

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IX. REFERENCES

BERKELEY, M. J. (1876). Enumeration of fungi collected during the Expedition of H.M.S. 'Challenger'. *J. Linn. Soc. Bot.* **15**: 55.

BERKELEY, M. J. (1876). Report on the fungi collected in Kerguelen Island by Rev. A. E. Eaton during the stay of the Transit-of-Venus Expedition of 1874-5. *J. Linn. Soc. Bot.* **15**: 222.

BOMMER, E. and ROUSSEAU, M. (1905). Champignons. Résultats du Voyage du S.Y. 'Belgica' 1897-9. Expedition Antarctique Belge. Also in Acad. Roy. de Belg. Bull., 1900: 640-646.

BUNT, J. S. (1954). A comparative account of the terrestial diatoms of Macquarie Island. *Proc. Linn. Soc. N.S.W.* **79**: 34-57.

BUNT, J. S. and ROVIRA, A. D. (1955). Microbiological studies of some subantarctic soils. *J. Soil Sci.* **6**: 119-128.

BUNT, J. S. (1955). Microscopic and submacroscopic organisms in the soils of the Macquarie Island ecosystem. Ph.D. thesis, University of Sydney.

BUNT, J. S. and ROVIRA, A. D. (1955). The effect of temperature and heat treatment on soil metabolism. *J. Soil Sci.* **6**: 129-136.

CHEESEMAN, T. F. (1919). The vascular flora of Macquarie Island. Australasian Antarctic Exp., 1911-14. Scientific Reports, Series C, vol. 7, pt. 3.

CLEMENTS, F. E. and SHEAR, C. L. (1931). The Genera of Fungi. New York: H. W. Wilson Co.

DEUTSCHE SUD-POLAR EXPEDITIONEN (1901-3). Fungi from Kerguelen. Full reference not known.

HOOKER, J. D. (1839-43). The botany of the antarctic voyage of H.M. discovery ships 'Erebus' and 'Terror'. (Flora Antarctica). Fungi, by M. J. Berkeley. Vol. 1, p. 169 (1845) and vol. 2, p. 447 (1846-7).

JONES, P. C. T. and MOLLISON, J. E. (1948). A technique for the quantitative estimation of soil micro-organisms. *J. Gen. Microbiol.* **2**: 54-69.

MAWSON, D. (1943). Macquarie Island, its geography and geology. Australasian Antarctic Exp., 1911-14. Scientific Reports, Series A vol. 5.

MCLEAN, A. L. (1919). Bacteriological and other researches. Australasian Antarctic Exp., 1911-14. Scientific Reports, Series C, vol. 7, pt. 4.

DI MENNA, MARGARET E. (1960). Yeasts from Antarctica. *J. Gen. Microbiol.* **23**: 295-300.

NEWMAN, A. S., and NORMAN, A. G. (1943). The activity of subsurface soil populations. *Soil Sci.* **55**: 377-391.

PIPER, C. S. (1938). Soils from subantarctic islands. B.A.N.Z.A.R. Exp., 1929-31. Reports, Series A. vol. 2, pt. 7.

RAPER, K. B. and THOM, C. (1949). A Manual of the Penicillia. Baltimore: The Williams and Wilkins Co.

RIDGWAY, R. (1912). Colour Standards and Colour Nomenclature. Washington, D.C.

SACCARDO, P. A. Syllogue fungorum omnium hucusque cognitorum. (Lithoprinted by Edwards Bros. Michigan 1944).

SCOTT, J. H. (1882). Macquarie Island. *Trans. Proc. N.Z. Inst.* **15**: 484-493.

SINGER, R. (1952). The agarics of the Argentine sector of Tierra del Fuego and limitrophous regions of the Magallanes Area. *Sydowia* **6**: 165-226.

SINGER, R. (1953). The agarics of the Argentine sector of Tierra del Fuego and limitrophous regions of the Magallanes area, part 2. *Sydowia* **7**: 206-265.

SINGER, R. (1954a). The cryptogamic flora of the Arctic, VI. Fungi. *Bot. Rev.*, **20**, 451-462.

SINGER, R. (1954b). Agaricales von Nahuel Huapi. *Sydowia* 8: 100-157.

SINGER, R. (1955). A fungus collected in the Antarctic. *Sydowia* (Festchrift für F. Petrak): 16-23.

SINGER, R. (1960a). New and interesting species of Basidiomycetes VI-VII. *Mycologia* **51**: 375-400, 578-594. 1959.

SINGER, R. (1960b). Sobre algunas especies de hongos presumiblemente psicótropicos. *Lilloa* **30**: 117-127.

SMITH, A. H. and SINGER, R. (1958). New species of Galerina. *Mycologia* **50**: 469-489.

TAYLOR, B. W. (1955). The flora vegetation and soils of Macquarie Island. ANARE Exp. Reports, Series B (2).

TCHAN, Y. T. (1952). Study of soil algae. 1. *Proc. Linn. Soc. N.S.W.*, **77**, 265-269.