

A GROUP

of

XEROPHYTIC FERNS

of the

PORT HILLS, CANTERBURY.

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GENERAL PREFACE.

Projecting from the East Coast of the South Island of New Zealand is a peninsula known as Banks Peninsula. (Fig.1.) Cutting deep into the land on the northern side, is the Lyttelton Harbour, (Fig.2 and 3.) surrounded on three sides, by a horse-shoe shaped range of hills.(Fig.3.) The portion of this range that separates Port Lyttelton from the city and suburbs of Christchurch, is known as the Port Hills. (Fig.4.) Banks Peninsula has a characteristic vegetation, not the least interesting part of which is its fern flora. On the Port Hills in particular, are to be found many interesting forms. Certain of these ferns, growing on spurs and valleys of the hills in the vicinity of Christchurch, have been investigated by the author. It is the main object of this paper to give a general account, morphological, anatomical, and ecological, of these ferns, together with a brief summary of the general fern vegetation of Banks Peninsula and the Port Hills.

The species under special consideration

are : -

As named in Engler and Prantl's
"Die Natürlichen Pflanzenfamilien."

Synonyms.

Cheilanthes sieberi, Kunze

Notholaena distans, R.Br.

Pleurosorus rutaefolius, Fee

Gymnogramme rutaefolia,
Hook and Grev.

Anogramme leptophylla, Link

Gymnogramme leptophylla
Desv.

P A R T 1.

THE FERN VEGETATION OF BANKS PENINSULA,

- with -

SPECIAL REFERENCE TO THE PORT HILLS.

A. INTRODUCTORY REMARKS ON NEW ZEALAND.

(1) General, from the botanical viewpoint.

(a) The Botanical interest of New Zealand.

The botany of New Zealand holds, for several reasons, a special interest for all lovers of the science. There is a distinctiveness about the vegetation to be found in the three islands comprising this group. It differs in many cases, very markedly from the vegetation of older and better known land masses.

This special character of the New Zealand plant covering is due to several factors. For one thing the three Islands, North Island, South Island, and Stewart Island, occupy a very isolated position in the Pacific Ocean, far from neighbouring land-masses. For this reason the country has developed a particular vegetation of its own, in some cases quite unique. The plants have developed without the effects of competition with new arrivals in the plant world. Also grazing mammals were not formerly pres-

New Zealand plant-covering, which must be studied where it remains in its original virgin form.

There is another viewpoint from which the study of New Zealand vegetation offers a special interest. New Zealand is a country of remarkable physiological features; "the coast line is greatly indented and within comparatively short distances, shows great variety of rocky cliffs, sandy beaches, wooded shores, tidal bays and mud-flats. The land surface extends from sea-level to mountains reaching to a height of 12,000 feet, and includes extensive plains, some presenting features of deserts, other rich, well-watered lands, swamps, rivers and large fresh-water lakes. Consequently the vegetation varies exceedingly, and shows greater diversity than can be met with in any other portion of the globe, of similar area." (Chilton 1921.) Thus the country obviously provides a splendid field for botanical investigation. Further there are many unusual types of local habitat to be met with, such as the shingle slips and fans, and the volcanic areas. All these regions have a vegetation that is typically their own, and that differs from that of any other part of the world. Thus the botanist finds New Zealand a most suitable place for investigation into such problems as the relation of the plant covering to its environment, and for ecological work in general.

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(b) Physical Geography of New Zealand.

General:

The New Zealand botanical region, according to Cockayne (1921), comprises those islands lying in the South West Pacific between the parallels of 30° and 55° South latitude, and $158^{\circ}56'$ East and 176° west longitude. The archipelago, if it may be so called, consists of the following groups of islands: Kermadecs, New Zealand proper, Subantarctic Islands, and Chatham Islands.

New Zealand proper consists of two large Islands, the South and North, and a third much smaller island, Stewart Island. (Fig.1.) These with some small islets, including the "Three Kings", lie between parallels $34^{\circ}6'$ and $47^{\circ}20'$ South latitude and meridians 166° and 179° East longitude.

The long isolation of New Zealand far from other land masses, is a matter of profound significance with regard to the flora. Tasmania, the nearest land mass, is 1500 Km., distant; Australia is 1650 Km., distant; South America is 7700 Km., distant, and the Antarctic continent is 3700 Km., distant.

Physical Features of New Zealand proper.

North Island:

(1) Mountains. The land surface is much broken and

mountainous in parts. The central part is a volcanic plateau, where there is still much thermal activity in the way of hot springs, geysers, etc.

There are numerous large mountains, some active volcanoes, others now extinct.

The extreme north of the island consists of a narrow table-land.

(II) Plains. There is an extensive plain, the Wanganui, in the South West of the Island, cut into by a network of deep gorges. The Waikato plain, wet and swampy, is in the South of the Auckland province. There are also river plains East and West of the Main range.

(III) Rivers. The island is well watered, many of the rivers having deep gorges. There are also extensive swamp lands, eg. Manawatu, Waikato, Thames, etc.

(IV) Lakes. The largest is Lake Taupo, on the volcanic plateau.

(V) Sea Coast. There are extensive dune areas along the West and far North and North-East coasts. Then cliffs and shale characterise the South and South-East coasts.

South Island.

(1) Mountains. The surface is very mountainous. There are two main chains, the long chain of Southern

Alps on the West, and the range running from Dunedin across to the Alps, joining the latter between Lakes Wanaka and Wakatipu.

There are many outstandingly, lofty peaks, (eg. Mount Cook, 3766 m.). Many lofty ranges and spurs extend eastward. There are also the Kaikouras in the North-East.

Banks Peninsula on the East of the Canterbury province consists of much denuded volcanic rocks of Tertiary age, reaching a height of 900m. (Fig.1.)

(11) Plains. An important and striking feature is presented by the gravel plains formed by glacial or snow rivers.

Eg: The extensive Canterbury plain (c. 161 x 48 Km.)

The Westland Coastal plain (c.200 km. x 10 km.)

and the Southland Plain, from the lakes to Foveaux Strait.

(111) Rivers. The rivers are numerous, issuing from glaciers, or fed by melting snow, or by frequent down-pours. These rivers are at first torrential, leaping and foaming. By degrees, the valleys widen to, perhaps, flat stony bed over which the river wanders. The river may flow between high terraces which it has built. At the mouth of almost every gully, shingle fans are present.

(1V) Lakes. There are several large and important lakes in the South of the island.

(V) Coast line. The only places where this is much broken, are in the region of the Marlborough Sounds, (drowned river valleys), and the South-West Otago fiords (glacial origin).

Banks Peninsula is a specially interesting part; it contains numerous inlets, many of which were originally volcanic craters; also a few shallow estuaries. (Fig.2.)

The coast is often low with stretches of sand-dunes. Shingly shores with great river mouths are frequent. Often the mountains come right down to the shore, forming a rocky coast line, as in South-East Otago and Banks Peninsula.

(c) Climate of New Zealand. Cockayne (1921)

A most important point from the botanical standpoint, is the climate of the country under consideration.

New Zealand possesses for the most part, a maritime climate, owing to its situation far from other lands, in a wide ocean, and also to its extreme narrowness. In no part of New Zealand is the land further than 120 km., from the sea.

It is to be noted, however, that the climate is by no means uniform; there are marked differences throughout the country. This fact is due, firstly, to the extreme length of the whole country from North to South; many degrees of latitude are passed through; and secondly, to the lofty mountain chains in both islands, lying athwart the prevailing winds.

Rainfall. The rainfall is correlated with the mountain ranges. In the South Island, the mountains comprising the Southern Alps, and North West ranges, lie broadside to the prevailing Westerly wind, (Fig.1.) On their windward slopes, are condensed the vapours collected over the ocean. The climate is thus very wet on the West, where the rainfall is from 250 to 500 cm., per annum, and by comparison very dry on the East, where, in places, the rainfall is only about

one tenth of that of the West.

In the North Island, the rainfall is more even over the whole island, but is heavier near Mount Egmont, the Dividing Range and high summits in general.

The mean annual rainfall of New Zealand, is about 121 cm. This fall is far from uniform through the seasons.

Temperature. In the matter of temperature, extremes are absent throught New Zealand, the climate being oceanic. Certain parts of the East of the South Island posses a slightly more continental climate with a big range of temperature.

Frosts are common in the Southern parts of New Zealand, and inland.

Wind is of importance in many districts. Strong Westerly winds of the South Island, sweep across the Eastern plains as hot winds, causing the maximum degree of transpiration.

All these climatic factors, temperature, wind, rain-fall are most important ecological factors.

There are frequent sudden changes of temperature, when conditions approaching mir-winter occur in the middle of summer. Such changes are, of course, of great physiological importance. Then, as has been mention-

ed, the hot dry westerly winds that sweep across the plains have a marked effect, causing the maximum of transpiration.

(d) Soil of New Zealand.

A note on the soil of New Zealand is of interest from the botanical view point.

Widely spread soils are: loess, pumice, clays, marls, sand, and stony debris.

Common soils are: alluvial loams, humus peaty soils, volcanic rock soils, salt soils, and rock.

Quite local soils : sulphur (near hot springs), soil manured by sea birds.

Loess soil is spread over a wide area in the South Island; pumice is important in the centre of the North Island; while clay of various kinds is common throughout both islands.

Alluvial loams form the bulk of lowland valleys in the North and South Islands, while humus is widespread. An important point to be noted is that volcanic soils are specially fertile; these are of frequent occurrence, but local and limited.

(2) THE BOTANICAL DISTRICTS OF NEW ZEALAND.

(a) List of districts, with notes on their climate.

Cockayne (1921) divides New Zealand into the following botanical districts. (Fig.1.)

1. The Kermadec districts -- Climate mild with
much rain.
2. The Three Kings district.
3. North Auckland district.
 - (a) Northern portion -- Climate warm and equable, sub-tropical breezes in Summer.
 - (b) Southern portion -- Climate mild and humid.
4. South Auckland district.
 - (a) Waikato sub-district -- Range of temperature greater than in district No.3.
 - (b) Thames sub-district -- Mountainous district, with local climatic differences.
5. Volcanic Plateau district -- Climate far from uniform, frosts frequent, snow on high summits.
6. East Cape district -- much modification of climate owing to hilly nature of area.
7. Egmont-Wanganui district -- Rain from Westerly direction, heavier round hilly parts.
8. Ruahine-Cook district (excluding Marlborough Sounds) Weather predominantly Westerly, sometimes sub-tropical, Characteristic high winds.
9. North-Eastern district -- Extremely mountainous and sheltered, dry and semi-continental climate.

10. Eastern district -- Semi-continental climate.
The hot wind is an important
feature. Constant extremes
of climate.
11. North-western district -- Humid climate, heavy
rainfall. Open to
Westerly winds.
12. Western district -- Climate similar to No.1., but
rainfall still heavier.
13. Fjord district -- Maximum rainfall of New Zealand.
14. North Otago district -- The driest district of New
Zealand; temperatures some-
what extreme.
15. South Otago district -- Cold rainy winds frequent.
Climate of somewhat sub-
antarctic type.
16. Stewart district -- Sub-antarctic climate, excessive
number of rainy days.
- { 17. Chatham district.
- { 18. Sub-antarctic province, including Campbell district
and Macquarie Island. }

Districts 1 - 4 belong to the Northern Mainland Province.

Districts 5 - 8 belong to the Central Mainland Province.

Districts 9 -16 belong to the Southern Mainland Province.

(b) The Eastern District of the South Island.

The botanical district of special interest in connection with this paper is number 11, the Eastern district (South Island). This includes the extensive Canterbury Plains and a small peninsula projecting into the Ocean on the East. (Fig.1.) This is Banks Peninsula, a well-defined sub-district of this botanical region. The Port Hills, with which this paper especially deals, form a portion of this peninsula. On Banks Peninsula in general, and on the Port Hills in particular are to be found various interesting plant associations, in which ferns play an important part. These associations have a character of their own and differ in many respects from the associations of other lowland hills of New Zealand. A note from Cockayne (1921) upon the ferns of lowlands and lowland hills throughout New Zealand generally may be instructive.

(3) THE FERNS OF THE LOWLANDS AND LOWER HILLS
OF NEW ZEALAND.

In the Northern botanical province, all the hills, with the exception of one or two summits of the Thames mountains, bear vegetation of a lowland stamp. In the central province, characteristic lowland vegetation ascends to about 800 m. In the Southern province about 600 m. is the upper limit for this type of vegetation, but the foothills, the basis of the high mountains and the valleys often possess a vegetation rather sub-alpine than lowland at a height considerably less than 600 m.

In these lowland formations, the smaller ferns are often exceedingly conspicuous, although the forest is the principal home of many of them. Moist gullies, dry slopes, rocks wet or dry, exposed spots or swampy places all have their especial species. Fern-heath is a very common plant formation on these lowland areas and lower hills. Except in specially exposed localities, the ferns are ever-green. In many cases the fern-heath is quite pure, for the leaves grow so closely as to inhibit all undergrowth.

Examples of ferns confined to low-lands and lower hills are : - Adiantum, Cheilanthes, Pellaea, Notholaena, Todaea, Lygodium, etc.

"In general the lowland ferns show distinct response to seasons, more from 'habit' than from differences in temperature, etc. Some even grow best in Winter." (Cockayne, 1921)

In referring to the rock vegetation of lowland and lower hills throughout New Zealand, Cockayne (1921) says : "Rock offers moist diverse ecological conditions for plants. Roughly the associations may be divided into dry-rock and wet rock associations." The dry-rock ferns differ greatly from the wet-rock types. There are altogether twenty eight ferns occurring on lower rocks throughout the country. Some of the more important examples are : -

Asplenium flabellifolium, Anogramme leptophylla, Cheilanthes sieberi, Notholaena distans, Blechnum capense, Polypodium diversifolium, Polystrichum Richardii, Pleurosorus rutaeifolius, Hymenophyllum multifidum, Asplenium lucidum, etc.

B. **BANKS' PENINSULA.**

(1) **Physiography of Banks' Peninsula.**

(Figures 2 and 3).

Banks' Peninsula, on the East coast of the Eastern botanical district is a well-defined and isolated area, and as such of special interest to botanists. Its chief physiographic features are as follows:
"The Peninsula stretches out to the South East from the centre of the eastern side of the Canterbury Plains. It is oval in shape and about 35 miles long and 20 wide. It consists of a congeries of hills rising at the centre in Mount Herbert to a height of about 1000 miles, and in Mounts Sinclair and Fitzgerald to a slightly less height. From these and other peaks long ridges with steep sides run out in all directions, enclosing occasionally, narrow flats. Beyond the flats and between the outer ridges are the smaller bays. On the seaward side the ridges terminate in cliffs 100 to 170 m., high; and on the landward side slope down to the plains, cliffs being absent. Two large harbours, on the sites of old volcanic claderas, break into

the hills, and are surrounded by steep walls which rise in rocky cliffs and escarpments to the height of 670 m., in Akaroa Harbour, and somewhat less in Lyttelton harbour." (Laing, 1919)

It will be seen then that the area under consideration consists mainly of mountains and lower hills, steep slopes, and rocky cliffs. On three sides, North, South, and East, the Peninsula is surrounded by the ocean; on the Western side, it meets the Canterbury Plains. (Fig. 3)

(2) Climate of Banks' Peninsula. (from Laing, 1919)

Temperature: The climate is typically insular and warm-temperate, differing from the more continental type of the Canterbury Plains. On winter nights the hills are much warmer than the adjacent plains. In some places on the hills round Christchurch, frost is rarely seen. On the hill tops, of course, the temperature is lower than on the plains, both in summer and winter. In the warm sheltered valleys of the North side of the Peninsula the conditions approach the warm temperate.

Rainfall: The rainfall varies in different localities, averaging from 60 cm. to 125 or 150 cm. (on the top of Mt. Herbert.) The Akaroa hills cut off much of the Easterly rain. This district and the hills round the Lyttelton harbour have much the same conditions, although the latter hills are hotter and dryer, the aspect being Northern. Snow falls every year on the hill-tops, but not often at the bases of the hills.

Wind: This is an important climatic factor here. The prevailing wind is from the North East. This, in summer time, is usually a sea-breeze, with-

out rain, but when this wind is part of a cyclone, it frequently brings continuous, though often light, rains.

The North East wind may pass into the less frequent North West, which is hot and dry. This wind has a most important effect on the distribution of the plants. The cold South Wester brings much rain. The rainfall is irregular in its distribution throughout the year. The months of December to March are usually fairly dry, droughts being not uncommon, particularly on the North West faces of the Peninsula. This has tended to produce a distinctly xerophytic type of vegetation on the Port Hills, (or Lyttelton Hills), though elsewhere it tends to the mesophytic.

(3) Ferns of Banks Peninsula. (Laing, 1919.)

Numerous ferns are found growing in all sorts of situations on the Peninsula. These are chiefly : Hymenophyllum (13 species); Trichomanes (1 sp.); Cyathea (spp.); Hemitelia (1 sp.); Dicksonia (3 spp.); Davallia (1 sp.); Adiantum (3 spp); Hypolepis (2); Cheilanthes (2); Pellaea (1); Pteridium (1); Pteris (1); Blechnum (7); Asplenium (8); Polystichum (4); Dryopteris (3); Nephrodium (1); Polypodium (6); Notholaena (1); Fleurosorus (1); Anogramma (1); Gleichenia (1); and a few others.

The situations of the more important of these ferns may be classified after Laing's system (1919).

1. On salt meadows and sand dunes, ferns are for the most part absent.
2. On the coastal rocks, there are two classes of situation, the wet rocks, and the dry. On the wetter rocks, only Asplenium obtusatum grows. The drier coastal rocks are the home of certain species of somewhat rare ferns. In addition to Asplenium obtusatum and A. lucidum, the following ferns, though found elsewhere, particularly haunt

such situations : Cheilanthes sieberi;
Nothoclaena distans; Polystichum Richardi;
Polypodium serpens and Adiantum affine.

3. In tussock grasslands, ferns are very rare,
Pleurosorus rutaefolius and Anogramme leptophylla
being two of the few ferns found in such situations.
These two are found exceedingly rarely in such
places.

4. Inland cliff and rock is a characteristic
situation for a number of ferns, as follows:
Pleurosorus rutaefolius; Polystichum Richardi;
Cheilanthes sieberi; Polypodium graminifolium;
Hymenophyllum multifidum.

5. In the forest areas, Blechnum discolor and
Polystichum vestitum are found in large quantities
on the floor, while beside the streams grow
B. fluviatile; B. lanceolatum; B. capense
and Asplenium bulbiferum.

Epiphytic ferns are numerous, e.g. Asplenium
falcatum; A. flaccidum; etc.

6. In lowland scrub and heath, are to be found
Blechnum capense; Pteridium esculentum; and
Pteris scaberula (= Paesia scaberula, A. Rich.)

C. THE PORT HILLS.

Particulars of the Hills surrounding the Lyttelton Harbour, including the part known as the Port Hills.

(1) Physiography. (Haast 1879, and Speight 1917.)

On Banks' Peninsula, there are two large harbours on the sites of old volcanic calderas. (fig. 2.) One of these, the Lyttelton Harbour caldera, is the oldest crater of which the principal boundaries can be traced at the present time. The general diameter of this old crater is about 3 Km., and the centre is situated a little to the South of Quail Island. (Figures 2 and 3).

Around this harbour, rising steeply from the water, there is a horse-shoe shaped range of hills, known as the Lyttelton Hills. (Fig. 4.) They have been picturesquely described as follows : - "Rising suddenly up from a corner of the Canterbury plains, the Port Hills rear for miles along the sky their tawny, semi-circular rampart of rocky and jagged crests, and send down into the flat, a succession of long tawny spurs, enclosing long tawny-green valleys. Their fantastic skyline suggests at once a volcanic origin; and they are in fact, the out-

lying spurs of Banks Peninsula, that old volcanic excrescence upon the East Coast of the South Island of New Zealand. The height of them reaches sometimes an altitude of nearly two thousand feet; it is never less than one thousand."(Baughan 1914)

From Godley Head at the North of the entrance to the harbour, a road called the Summit Road extends along the hills, right round to Cooper's Knob, a distance of nearly 40 Km., and about half way round the whole range. (Fig.) This road runs close to the summits all the way, truncating only some of the higher peaks, overlooking now the Harbour, now the Plains. From various parts of Christchurch and its suburbs, the summit road may be reached by other roads and tracks leading up to it, particularly from Sumner, Redcliffs, Clifton, Opawa, Cashmere and other places.

With regard to these roads, one writer has wisely remarked, "Admirable as the tracks are for taking the traveller from point to point, nothing can be done by sticking to them. Both the rocks and the bush must be tackled at close quarters; the most difficult and steep and most thickly obstructed routes must often be followed; nettles (Urtica ferox) five feet high, bracken over one's

head, biddy biddies (Acaena sp.) and lawyers
(Rubus sp.) beyond belief, must be fearlessly
faced, precipitous rocks must be skirted, craned
over, scanned from above and below, and climbed
if the work is to be thoroughly done; old clothes
are desirable and not too many of them for the
slopes are often terribly steep. All these little
difficulties and drawbacks only add to the fascin-
ation of the work, if done in the proper spirit,
and the person who will not face them does not
deserve to find the first and commonest fern!"
(Wall, 1918.)

(2) Conditions for Plant Life.

(a) Climatic.

The climate of the Port Hills corresponds in general with that given for the whole of Banks' Peninsula, that is, it is typically insular and warm temperate. On frosty nights the temperature of the Cashmere Hills is from 3° to 5° higher than that of Christchurch, while on the hills at Redcliffs and Summer it is still warmer. The lowest temperature that may be observed on the Cashmere Hills is about 8° C. Thus for plant life the temperature is fairly favourable. Most of the forms are in fairly sunny situations, so that the ground is often fairly warm, and the atmosphere warm during the day. There may be somewhat sharp contrasts at night in Winter.

The rainfall is not very extensive and the Lyttelton Hills therefore are, comparatively speaking, fairly warm and dry. Rocky situations with a sunny aspect are very dry; the crevices and bases of the rocks are not quite so dry; while in shady places there are quite moist situations, for instances in caves which catch the drips from over-

hanging edges of rock.

Besides temperature and rainfall, a most important factor influencing the plant life is the wind. In general, wind always has the following effects; it influences :

- i. The Erectness or otherwise of the plants.
- ii. The transpiration rate.
- iii. The spreading of spores and seeds.
- iv. The temperature of the air and soil.

(Schimper, 1903.)

In addition to these general effects of wind, it is necessary to consider the great importance of the particular winds which blow over the Port Hills, for they affect the vegetation in this case to an extent that is remarkable. The aspect of a slope may be said to determine its vegetation to a far greater extent than any other factor. On the spurs which run down into the Canterbury Plains and thus face towards the West, the vegetation is comparatively scanty and dry looking. The slopes are covered with a grassland association, with few trees and only a suggestion of bush. Xerophytic ferns and herbs grow among the grasses and rocks, but there is an absence of

any luxuriance in the whole appearance of the vegetation. (Fig.)

Now if one climbs one of these ridges and passes over a saddle to the spur that slope steeply down to the harbour, one feels that one is in a totally new country. A luxuriant vegetation covers the hillsides. Green masses of bush, full of trees, shrubs, lianes and ferns fill the gullies. In damp caves under overhanging rocks grow numerous liverworts and ferns. The grass-land is more mesophytic in character. The whole appearance of the vegetation is in the sharpest contrast to that of the Western slopes.(Fig.)

And this pronounced difference is due to the winds. The slopes that face the plains are exposed to the sweep of the strong, hot and dry Nor' Wester, the well-known wind that sweeps across the whole of the Canterbury Plains after leaving its moisture on the Western side of the Southern Alps. The slopes that face the harbour, escape this drying wind with the result that their vegetation exhibits considerably more luxuriance.

(b) Edaphic: (Marshall 1912, and Speight (1917.)

i. The soil varies considerably in physical and chemical characters in different parts. Where there are no rocks near the surface, the soil is a light loam for about half a metre or so, and below this there is clay. In crevices of rocks and such spots, the soil is fairly rich and is composed of humus and decaying remains of plants. Such is, to some extent, also the case under overhanging rocks. On the dry, sunny rocks, the soil is very dry, scanty, and scrappy. On the whole, the soil being volcanic in nature, is of a good fertility.

ii. The rocks (Fig.) of the Port Hills are a most important feature and may be briefly described. "The Lyttelton caldera has all the features of a composite cone built up of layers of lava and fragmentary material. The lava flows and ash-beds of which the cone is constructed are exclusively basic in character; they vary from fine-grained basalts to those in which feldspar phenocrysts form a considerable bulk of the rock. On account of this feature and their consequent high percentage of silica (up to 55 per cent), they

have been classified as andesites, but they contain normally, a considerable amount of olivine, so they should more properly be called basalts of andesitic habit." (Speight 1917.) Olivine andesite is then the typical rock of the Port Hills, dolerite also is abundant, while white rhyolites occur at the head of the Lyttelton Harbour.

(3) The Ferns of the Port Hills.

A recent worker (Wall 1918) on the ferns of the Port Hills has conveniently placed them into three categories, as follows : -

i. The very common ferns growing wherever the locality suits them. e.g. Cyathea dealbata;
Pellaea rotundifolia; Pteridium esculentum;
Blechnum lanceolatum; B. discolor; B. capense;
B. fluviatile; Asplenium flabellifolium; A. Hookerianum;
A. bulbiferum; A. flaccidum; Polystichum vestitum;
P. Richardi; Polypodium serpens;
P. grammidiis; Notholaena distans; Cheilanthes sieberi; etc.

ii. The comparatively uncommon ferns; e.g.
Dicksonia squarrosa; Blechnum membranaceum;
Asplenium obtusatum; Adiantum affine; Cyathea Cunninghamii; etc.

iii. Ferns that are rare or very uncommon, or local in this district, e.g. Cheilanthes tenuifolia;
Pleurosorus rutaefolius; Anogramme leptophylla;
Hymenophyllum sanguinolentum; and Leptopteris hymenophylloides.

From the foregoing, it will be seen that the two ferns Cheilanthes sieberi and Notholaena distans are quite common, while Pleurosorus rutaeifolius and Anogramme leptophylla are more difficult to find. Many interesting questions are suggested by a review of the ferns of the Port Hills. This paper it is hoped, will add a little to the present knowledge of four of the most interesting among the number.

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P A R T 11.

GENERAL REMARKS.

As previously stated, it is proposed in this part of the present thesis to deal with a small group of the Port Hills ferns. viz:-

Cheilanthes sieberi.

Nothoclaena distans.

Pleuroseras rataefolius.

Anogramme leptophylla.

All four of these ferns show certain xerophytic characteristics wherein lies their particular interest. It is the main purpose of this paper to point out these characteristics and to discuss them in relation to the habitat of each plant. The method adopted is to give morphological, anatomical and ecological descriptions of the ferns, viewed both individually and comparatively. The conclusion points out the significance of the features described, with regard to the important ecological question of the relation of a plant to its environment.

A. TAXONOMY AND DISTRIBUTION.

1. Taxonomy.

The taxonomic position of the ferns accord-

ing to the classification given in Engler and Prantl's "Pflanzen-familien" (1912) may be seen from the table given below, which sets out the subdivisions of the group Filicales Leptosporangiatæ. Of the 8 families comprising the Eufilicineæ the Polypodiaceæ constitutes by far the largest and most important. It includes among an immense number and variety of ferns, the four under discussion here. The further subdivisions of this family have therefore been set out in full, in order to make clear the exact taxonomic position of the four genera: Cheilanthes, Nothoclaena, Pleurosorus, and Anogramme.

FILICALES LEPTOSPORANGIATAE.

(a) Eufilicineae

Family 1. Hymenophyllaceae

" 2. Ctathaceae

" 3. Polypodiaceae

Sub-family i. Woodsieae

" ii. Aspidieae

" " iii. Oleandreae

" iv. Davallieae

" v. Asplenieae

Class a. Blechninae

Genus: Blechnum

" b. Aspleniinae

Genus: Pleurosorus

Sub-family vi. Pterideae

Class a. Gymnogramminae

Genera: Anogramme

Gymnogramme et

" b. Cheilanthesinae

Genera: Cheilanthes

Notholaena

Pellaea.

Cryptogramme et

" c. Adiantinae

Genus: Adiantum

" d. Pteridinae

Genera: Pteris

Pteridium

et.

Sub-family vii. Vittarieae

" viii. Polypodiaceae

" ix. Acrosticheae

Family 4. Parkeriaceae

" 5. Matoniaceae

" 6. Gleicheniaceae

" 7. Schizaeaceae

" 8. Osmundaceae

(b) Hydropteridinae.

A brief description of the characters upon which the foregoing classification is based will account for the position accorded to the four genera under consideration.

The eight large families are distinguished according to the nature of the sporangium, particularly with regard to the type of annulus.

Family 3. Polypodiaceae. Here the sporangium has an incomplete vertical annulus, extending not quite down to the base on one side. This annulus is seldom absent. A few ferns are arborescent, but most grow in a shrub-like fashion.

Sub-family v. Asplenieae. The sori arise laterally on the veins, the sporangia being flask-shaped. An indusium is usually present. The petiole is unjointed and there is considerable leaf-division.

Class b. Aspleniinae. The sori are placed along the lateral veins.

Genus: Pleurosorus. There is no indusium and the leaves are much divided.

General characters of the genus (from Engler 1912):
The sori are oblong and situated on the lateral veins, without any indusium. The unjointed petioles arise from a rhizome. The leaf is much divided, and is furnished with few or many hairs, while membranous scales may be present.

Sub-family vi. Pterideae. The sori are oblong linear, at the ends of the veins. There is usually no special indusium, but the leaf margin is often modified and much reflexed to cover the sorus. The unjointed petioles arise from a rhizome. The leaves are very rarely undivided, and may have a covering of membranous scales or hairs, the latter sometimes secreting wax.

Class a. Gymnogramminae. The sori extend almost the whole length of the veins.

Genus: Anogramme. The leaf is quite smooth and bare. General characters of the genus (from Engler 1912): the sori are situated on the veins extending almost their whole length. The spores are tetrahedral. The prothallus may persist for a number of years, and consists of a much-lobed expanded portion, and tuberos shoots which bear archegonia. The sporophyte generation is usually annual. (Note. This matter of the persisting gametophyte and the short-lived sporophyte is to be gone into fully in the chapter on morphology, Part 11 B.) The rhizome is shortened, very delicate and bears long bristles. The petioles are unjointed. The leaves are almost wholly

✕ bear, and are many-times perinate, the veins being repeatedly dichotomous.

Class b. Cheilanthinae. The sori are placed on the distal ends of the veins, where they sometimes spread out till they become confluent.

Genus 1. Cheilanthes: The leaf-margin is always reflexed.

General characters of the genus (from Engler 1912): The sori are on the thickened ends of the veins and are rounded to oblong, finally becoming confluent. They are always covered over by the reflexed margin of the leaf. The rhizome is usually short, either ascending or creeping, and with membranous scales. The petiole is unjointed, and leaves may be simple, but are usually many times They may be or less hairy.

Genus 2. Notholaena: The leaves have membranous scales.

General characters of the genus: The sori are terminal on the thickened ends of the veins, and are rounded to oblong, finally becoming confluent. They may be uncovered, or may be covered by the reflexed leaf-margin. The leaves are more or less divided, and are more or less hairy or scaly.

As Engler (1912) points out it is very difficult to separate Nothoclaena sharply from several related genera.

It is especially difficult with regard to Cheilanthes, which, as will be seen from the foregoing descriptions, resembles Nothoclaena very strongly. The genus Cheilanthes comprises an abundance of forms, certain of which resemble species of Nothoclaena so closely that it is almost impossible to keep the two genera sharply separate.

2. Distribution.

Of the four genera, Pleurosorus is the least in number of species, there being only 3; Anogramme has 5 species. In the genus Cheilanthes however there are 40 species, and in Nothoclaena 30 species.

(Willis (1919) gives later figures :
Pleurosorus 3 sp; Anogramme 10sp; Cheilanthes 120 sp;
Nothoclaena 50 sp.)

The distribution of the principal species of all four genera (as given in Engler and Prantl 1912) is as follows :

i. Pleurosorus.

The three species are feebly distinguished from each other. They are mostly of limited distribution. The distribution therefore of the whole genus is very disconnected, thus: Australia, New Zealand, Southern Chili, South of Spain.

P. pozoii: Found in crevices in the mountains of Southern Spain.

P. rutsefolius: Common in Australia and New Zealand.

P. papaverifolium: Southern Chili.

ii. Anogramme.

A. leptophylla: Western Europe, through the Mediterranean region, on moist clayey soil or on rocks; on the snow mountains in Abyssinia, and in South Africa, in Capetown, and Madagascar, West Asia, India,

East Australia, New Zealand, America
from Mexico to the Argentine.

A. ascensious: On the Green Mountains of the
Ascension.

A. chaerophylla: In warmer America from the Antilles
to Northern Argentine.

A. Schizophylla: Jamaica, Cuba, on the mountains and
in cultivation.

A. microphylla: On trees in Eastern Himalayas, and
Khasia Mountains.

iii. Nothoclaena.

N. sinuata: From Arizona Southwards over the Andes
to Chili and Northern Argentine, on the
dry soil of the mountains.

N. ferruginea: Distribution as in N. sinuata, also
some islands surrounding the West Indies.

N. trichomanoides: Central America, both on the continent
and the outlying islands.

N. Rawsoni: South West Africa.

N. languinosa: The whole Southern Mediterranean region
to the North West Himalayas.

N. Vellea: Scattered through almost the whole of
Australia.

N. Mollis: On the volcanoes of Gnatelmala and in
Chili.

N.hypoleuca: Also native in Chili.

N.Aschenborniana: Central America in Texas and Mexico.

N.Parryi: In North America.

N. squamosa: Central America, from the Andes to the
Argentina.

N.hirsuta: East coast of Malaysia from Hong Kong to
Polynesia.

N. distans: Rock-plants on the Phillipines, New
Caledonia, Australia, New Zealand.

N. ecklonia: Africa from Angola southwards.

N. inequalis: Africa from Angola southwards to the
South West Coast on dry rocks.

N.Buchanani: Natal.

N.chinensis: Central China.

N.erophora: Central Brazil.

N.Sulphurea: Dry mountains of California and Texas
through Mexico along the Andes to Chili;
Galapagos Island. A series of related
forms is found in North Mexico and South
West United States.

Cheilanthes.

Ch.primata: On the Andes from Peru to the Argentine
on the higher rocks.

Ch.micropteris: On the Andes from the Equator to the

Argentine, not at so high an altitude as
Ch. pruinata.

Ch. alabamensis: Southern America, and Arizona.

Ch. fragrans: On rocks of the Mediterranean region to
the Kashmir-Himalaya.

Ch. lanosa: North America from New York to Texas.

Ch. hirta: In Africa from Angola Southwards, very
common in Cape Colony, and also penetrating
into the Karroo neighbourhood. Also in
cultivation.

Ch. welwitschii: West Africa in the hilly country of
Huilla, at altitude 1000 - 2000 metres.

Ch. mysurensis: Common in dry places throughout
Southern India, in Ceylon, China and Japan.

Ch. pulchella: Canaries, fairly common on rocks.

Ch. arabica: Abyssinia, South West Arabia, and Somali
highlands.

Ch. varians: From further India and Southern China
through Malaysia to the Phillipines.

Ch. microphylla: America from Southern United States
to Columbia and Peru. Also in cultivation.

Ch. tenuifolia: From Eastern Himalayas, Southern India,
Southern China, through Malaysia to Australia
and New Zealand.

Ch. Delevayi: South West China.

Ch. multifida: Rocky places in the South and on the
highlands of tropical Africa; St. Helena,
Java.

Ch. trichophylla: South West China.

Ch. hespanica: Portygal, Southern Spain.

Ch. farinosa: Very widely distributed in all tropical
lands and very richly represented in the
mountains of Northern India, and Southern
China, (here being at an altitude of 3000
metres);

Ch. rufa: In the Himalayas.

Ch. argentea: Peculiar distribution in the East part
of Asia; Phillipines on hilly country;
Northern India through China and Japan;
also Alaska.

Ch. viscosa: In dry regions, Central America, from
New Mexico to Venezuela.

Ch. Regneltiana: Dry rocks in Brazil.

Ch. recurvata: Paraguay.

Ch. induta: Shady rocks in hilly parts of Cape
Colony.

Ch. Bolusii: West of Cape Colony.

Ch. gracillima: West of North America, at an altitude
of 1800 - 2500 metres. Central America.

Ch. fendleri: In Colombo, California and Texas.

Ch. Clevelandii: Southern California.

Ch. lanuginosa: In North America from Illinois
Minnesota and British Columbia South West
to Texas and Arizona.

Ch. persica: Mediterranean, Algeria, East Italy,
Dalmatia, Crete, through South West Asia
to the Kashmir-Himalaya district (up to
2000 metres).

Ch. microphylla: In the Andes from California to
Chili and South Argentine.

Ch. tomentosa: North America from Missouri and
Virginia to Texas and Mexico.

Ch. Catoni: Southern United States from Arizona
almost to Arkansas.

Ch. scariosa: On the Andes from Mexico to Peru.

Ch. Sieberi: Australia, New Zealand, New Caledonia
and the Isle of Pines.

A general glance at the distribution of
the four genera shows that they are very widely spread
over the old and new worlds. Also they occupy the

most varied habitats; many species, especially of the genera Cheilanthes and Notholaena, grow in dry places, or on rocks, or in crevices, and some on mountains of considerable altitude, while forms of Anogramme, for example grow on wet soil.

(Note: The four species to be described in detail are marked with an asterisk.)

B. MORPHOLOGY.

1. Cheilanthes sieberi.

a. Typical form (Fig.) (This form grows in sunny situations.)

Habit: (Fig.) This fern grows in a tufted form, the petioles springing close together from the underground stem. The tufts are of varying sizes, ranging from exceedingly small, scrappy plants no more than 3 or 4 cm. in height (Fig.) up to tall thick clusters fully as high as 24 cm. In general appearance the fern has a somewhat untidy look, due to the persistence of brown withered leaves among the fresh green ones.

Stem: (Fig.) The stem is a short thick rhizome up to 3 cm. long and covered thickly over with a coating of short dark brown scales. It is completely hidden by the bases of the petioles which arise very close together on the upper surface. From the lower surface springs a dense mass of roots.

Roots: (Fig.) The roots are narrow, about 1 mm. wide, and up to 8 or 10 cm. in length. They are dark brown, irregularly bent and with numerous fine secondary rootlets.

Petiole:(Fig.) The petiole is slender, being only about 1 to 1.5 mm. through. It is however stiff and wiry, and is of a polished chestnut brown colour. Along the petiole there may be one or two very fine scales, these being scarcely noticeable. Some of the petioles grow straight up while others may be bent and twisted (fig.). The petiole is slightly down the ventral side. The distance from the base of the petiole to the lowest pair of pinnae varies greatly and may be from 1 or 2 cm. to as much as 10cm.

Leaf: (Fig.) The petiole is continued up as the mid-rib which is therefore exactly similar to the petiole in colour, shape etc. Towards the tip however, it becomes gradually narrower, while the brown colour merges into green.

The leaves are lanceolate to linear, narrowing evenly from the wide base to the pointed tip. They vary in length from 2 to 14 cm. and in width from 1 to 5 cm. They are considerably divided, being bi-pinnate to tri-pinnate.

The primary pinnae are in nearly opposite pairs, varying in number from 3 to 15 pairs to the whole leaf. The lower pairs are spaced fairly far apart, while the upper pairs are more crowded. (Fig.)

The pinnae are long-deltoid in shape, and ascend at an angle with the midrib of about 45° . The lower ones are deeply sub-divided into more or less oblong segments. The margins are slightly notched into rounded teeth, and are very much reflexed over the back of the pinnule.

The colour of the leaves is a fairly deep green, the surface is smooth and glossy, and the texture firm and coriaceous, although the leaves are not thick.

Sori; (Fig.) On the back of the pinnae at the ends of the veins are to be found the sori. These are distinct rounded groups of sporangia at first, but afterwards become confluent and extend all round the margin where they sometimes cover almost the whole pinnule with their bright brownish sporangia. The reflexed leaf margin curls over the sori and thus acts

as the indusium. A special indusium is absent.

Sporangia: (Fig.) The Sporangium is of the usual Polypodiaceous type, being the shape of an inverted flask, with a short stalk, and an incomplete vertical annulus (golden with dark bars), extending from the base at one side, over the top, to about half way down the other side. Here below the end of the annulus is the stomium, where the sporangium splits transversely.

Spores: (Fig.) The ripe spores are bilateral and dark coloured, with many protuberances and markings on the perinium.

b. "Deltoid" or "Intermediate" Form. (Fig.)

Forms of Cheilanthes sieberi varying from the typical are to be found in shaded places. In very shady situations there is to be found a form showing marked variation from the typical; while in moderately shady places there grown a "deltoid" form which is more or less intermediate between the typical and the fully shaded plant.

On comparing this "deltoid" form with the typical Ch. sieberi, several points of difference may be

observed, particularly in the shape of the leaf.

In the deltoid form the leaf is of course deltoid, being shorter, broader and more compact, with pinnae larger in proportion to the whole leaf and, (especially the lower pairs) much more closely set together so that the pinnules overlap to a certain extent. (Fig.) The pinnae are sub-divided as in the typical form, but the margins are not reflexed to so great an extent. The green colour is of a brighter, fresher shade, and the texture of the leaf is softer, while the surface is less glossy. In many cases the petiole is less stiff and wiry.

c. Shade form. (Fig.)

On comparing the fully shaded form with the typical, it will be found that the points of difference enumerated above are accentuated. In the shade form the petiole is thin and fine. The leaves are soft and delicate and of a fresh green colour, the surface being smooth but not glossy. The margins are not reflexed at all, the result being that the flat pinnules appear much wider than the curled ones in the typical form. (Fig.) The whole plant has a much finer and more delicate appearance.

The differences between the fully shaded and the typical forms of Ch. sieberi may be tabulated as follows :

Typical form.	Shade form.
Petiole: Wiry, about 1 mm.thick.	Slender, less stiff, about mm.thick.
Leaves: Deep green; Somewhat coriaceous; Glossy surface;	bright, fresh green; soft and delicate; smooth, dull surface;
Pinnules: Narrow oblong in appearance; Much reflexed margins; veins not easily seen.	Broad and rounded in appearance; margins not reflexed; veins more distinct.
Whole plant: Robust and firm.	Fine and delicate.

2. Nothoclaena distans.

a. Typical form (Fig.) (Growing in full sunshine.)

Habit: This fern is similar to the preceding (Ch.sieberi) in many ways. It never reaches to so large a size as Ch.sieberi, but grows in the same manner; i.e. in tufts of crowded leaves, the petioles springing closely together from the underground stem. Younger plants present a different appearance from older ones, however, as their leaves, instead of being erect, are spread out at an angle (say from 30° to 60°) with the ground. (Fig.)

These young plants sometimes grow together in large numbers thus covering a considerable area like a mat. (Fig.)

The height of these younger spreading plants is up to 3 cm. while the older plants grow up to a height of 16 cm.

Like Ch. sieberi, this fern has a rather untidy appearance due to the persistence of withered leaves with the fresh green ones. Though resembling Ch.sieberi, it can be distinguished at a glance, for its petioles and

leaves are thickly covered with fawn-coloured scales, which give the fern a shaggy appearance. (Fig.)

Stem: (Fig.) As in Ch.sieberi, the stem is a short, thick, creeping rhizome covered with short, brown-coloured scales. From the upper part arise close together, the petioles, which are fairly numerous in the older plants, (Fig.) while from the lower surface spring numerous roots. The rhizome is completely hidden under the bases of the petioles and roots.

Roots: (Fig.) These are narrow, about 1 mm. thick or less, and up to 7 cm. long. They are dark brown, very bent and wavy in form, and with numerous fine secondary rootlets.

Petiole: (Fig.) The petiole is slender, from 1 to 1.5 mm. thick, but it is stiff and wiry, and of a dark-chestnut brown with numerous fawn or brown scales. Some of the petioles are bent (fig.) but most of them in the older plant grow straight up. (fig.) There is a slight concave groove down the ventral side. The length of the petiole

from the base to the lowest pinnae varies in different cases from 1 cm. to 6 cm.

Leaf: (Fig.) The petiole continues as the midrib, the brown colour of which merges into green near the top, exactly as in Ch. sieberi.

The shape of the leaf is deltoid in young plants, but much longer and narrower, narrowly lanceolate in older plants, where it narrows to a pointed tip. The length varies from 2 cm. (in young plants) to 10 cm; and the width varies from 1 to 3 cm.

The leaves are bi-pinnate, occasionally tri-pinnate, the primary pinnae being in very nearly opposite pairs, and varying in number from 3 to 9 pairs.

The lower pairs are somewhat far apart while the upper ones are crowded together. In shape the pinnae are long-deltoid, and are ascending. The pinnules are narrow with a blunted apex, and when normally dry are usually curled up to some extent. (Fig.) The margins are very slightly indented, and are much reflexed. The leaves are green, but

the colour is largely hidden by the thick coating linear fawn-coloured scales which grown out of the backs of the pinnules, The upper surface of the pinnules is without scales, but has a few hairs, and is not glossy.

Sori: (Fig.) The sori are marginal, terminating the veins, and are at first rounded or oval, but finally become confluent, covering the backs of the pinnules with a brown mass of sporangia. The margin is reflexed to cover the sori and thus acts as the indusium.

Sporangia : (Fig.) These are exactly similar to those of Ch. sieberi, being typically.

Polypodiaceous, flask-shaped- stalked, and with an incomplete vertical annulus, (golden with dark bars .) Dehiscence is transverse.

Spores : (Fig.) The spores are bilateral, dark-coloured with protuberances and markings on the perinium. It will be seen from the foregoing descriptions that the typical forms of Ch. sieberi and N. distans are exceedingly similar. In Engler's classification they are placed as very near relatives (see table in A.) From the descriptions of the shade forms of N. distans which follow, it will be seen that the shade forms of Ch. sieberi and N. distans are even more alike, and indeed very easy to confuse.

b "Intermediate" forms of N. distans (Fig.)

Various forms connecting up the typical N. distans to the fully shaded form have been found in situations of varying degrees of shade. Two such " intermediate " forms have been sketched in fig. which shows in a, b, c. and d, a series from the typical to the fully shaded form.

- i. The first " intermediate ", (as shown in Fig.) is a leaf of a slightly shaded plant. The pinnules are not curled up, the pinnae stand out more from the midrib, and the margins are not so much reflexed. Also the scales are fewer in number.
- ii. The second intermediate (Fig.) is a leaf of a more shaded plant. Such leaves are frequently found hidden amongst the petioles of a typical sun-exposed plant, where they receive a good deal of shade. (Fig.)
The leaf here is wider and more deltoid with less recurved margins, resulting in the broader appearance of the pinnules. The scales are quite few in number.

- c. Fully shaded form. Here the leaf is deltoid, the pinnae being divided into broad rounded pinnules, whose margins are not at all reflexed. The petiole is slender and practically without any scales, while there are only a few pale silky scales on the backs of the pinnae. The leaf is a delicate green colour, smooth surfaced (not glossy) and delicate in texture.

The following table shows the differences between the fully shaded and typical forms of N. distans.

Typical form	Shade form
Petiole : Wiry, about 1 mm. thick with numerous broad fawn-coloured scales.	Slender, less stiff about 5 mm. thick with one or two fine silky scales.
Leaves : Coriaceous in texture ; thickly coated with broad scales on the backs of the pinnules and midrib.	fine and delicate ; Only a very few pale-coloured silky scales.
Pinnules : Margins much reflexed ; narrow in shape with blunted points.	Margins not reflexed ; broad and rounded.

It is most interesting to compare the shade forms of Ch. sieberi and N. distans. (cf. Figs. &) As will be seen from the figures and descriptions, the similarity is striking. In fact it is only the presence of a few silky scales that distinguishes N. distans.

In his "Manual of the New Zealand Flora "(1906 Cheesman remarks that Ch. sieberi and N. distans are often confused. Indeed the presence of such variability in both ferns and the remarkable similarity in their shade forms leads to a puzzling problem. Beginning with the typical form of either fern, a series passing through the shade forms of both to the typical form of the other, can be traced with quite easy gradations all the way..

For example (see Fig.) a series can be traced from the typical N. distans, through the " intermediates " to the shade form () thence, easily to the shade form of Ch. sieberi, () and thus through the " deltoid " to the typical Ch. sieberi.

The problem is what significance to attach to the presence of such connecting links between the two ferns, As far as the author is able to judge from field observations, the non-typical forms of both Ch. sieberi and N. distans owe

their deviations from the normal to environmental influences. This brings the problem with the realm of ecology ; it will therefore be dealt with in the ecological part of this thesis.

3, Pleurosorus rutaefolius.

a. Typical form (growing in full sunshine.)

Habit : (Fig.) This fern grows in low clumps of various sizes. Some of the leaves may be fairly erect but most have their petioles curving out over the ground at an angle (from about 20° upwards .) Thus the appearance of the clump is low and spread out over a fair area, It is however compact as a rule and not straggling here and there (Fig.) The clump varies in size from 5 to 14 cm. across and from 3 to 8 cm. in height.

In general appearance the plant scarcely looks like a fern, for its pinnae are undivided and of an unusual shape ; they are also very woolly- looking owing to their thick covering of light silvery_-brown hairs.

Stem : There is a very short rhizome, scarcely noticeable in young plants. It is more ascending than creeping, and is covered with dark, pointed scales. From it arise numerous crowded petioles and numerous fine roots completely hiding the rhizome.

Roots : (Fig.) The roots are narrow, about 1 mm. wide and up to 4 or 5 cm. long. They are dark brown, bent and wavy, and with secondary roots.

Petiole : The petiole is of interest, being rather soft

and pliable, although of a fair thickness in proportion to its length. The transverse section is circular and may be up to 1 . 5 mm, across, while the length of the petiole from its base to the lowest finnae varies from 1 . 5 to 4 cm. The petioles may be fairly erect, but most of them curve outwards over the ground and then upwards (Fig.)

The petioles are green for their whole length and are thickly covered with light silvery- brown hairs.

Leaf : The leaf has a green midrib similar to the petiole, In shape the whole leaf is narrowly oblong, from 2 to 4 cm. long and up to 1 cm. broad. It is pinnate, the pinnae being in almost exactly opposite pairs, ascending, and carying in number from 2 to 5 pairs. The pinnae show only slight indication of further division into two lobes. They are fan or wedge-shaped, broader than long, being up to 5 mm. long and up to 8 mm. wide. The margins are very finely crenate, and not reflexed.

In colour the green of the leaves is rendered rather dull by the thick coating of fine, woolly, light silvery brown hairs which covers both upper and under surfaces. In texture the leaves are thick and soft.

Sori : (Fig.) On the veins at the back of the pinnae are to be found the sori, which are simply naked groups of sporangia without an indusium of any kind. The sori are rounded, or oval, and may become more or less confluent. The number of sori to each pinna is from 2 to 5 or 6.

Sporangia : (Fig.) These are typical Polypodiaceous, being flask-shaped, stalked, with an incomplete vertical annulus (golden with dark bars), and transverse dehiscence.

Spores : These are tetrahedral dark in colour when ripe with numerous markings and protuberances on the peridium.

c. Intermediate form Between the typical P. rutaefolius and the form found in very shady situations, are various intermediate forms which grow in more or less shaded places. Fig. shows a leaf of a somewhat shaded plant. In such plants the petiole is slightly thinner and less hairy, the pinnae are larger but thinner, and are less hairy and a darker green than in the typical form.

C.

Shade form.

In the fully shaded form

P. rutaefolius shows more striking differences from the typical (Fig.) Such forms are to be found in quite deep, shaded crevices of rock. The whole plant is larger but much more delicate than the typical, and not so compact in growth form.

The petioles are more slender and very pliable, the leaves lying rather limply against the rock. Both petioles and leaves are a rich dark green, and only slightly covered with pale-coloured hairs. The pinnae, compared with those of the typical form, are very large, the largest being fully 1.2 cm. long and 1.5 cm. broad. They are thin and delicate and rather limp.

The differences between the typical and fully shaded forms of P. rutaefolius are tabulated below.

Typical Form.

Shade Form.

Whole plant : Low and compact

Petiole : Thick (about 1.5 mm.
through); somewhat pliable ;
very hairy ; dull green.

Pinnæ : Small, up to 5 mm. long by
8 mm. broad ; very hairy ;
dull green thick and soft
in texture ; veins not
easily seen.

long leaved and
spreading
Thinner (about 1 mm.
through very pliable ;
only slightly hairy,
darker green.

Large, up to 1.2 cm.
long by 1.5 cm. broad
only slightly hairy ;
rich dark green ;
thin and rather limp ;
veins distinct.

4. Anogramme leptophylla.

A special interest attaches to this fern, for here the usual order of duration of life of the two generations is reversed. In the great majority of ferns the gametophyte lives but a short time, while the sporophyte is perennial. In ferns of the genus Anogramme however, the sporophyte dies down after one year (hence the generic name), while the gametophyte is capable, if not fertilised, of continuing its growth for a number of years.

Instead of the usual annual gametophyte and perennial sporophyte, this genus has an annual sporophyte and a perennial gametophyte. This interesting reversal of the usual order invites investigation.

a. The sporophyte of A. leptophylla (Fig.)

Habit : This is an exceedingly small and delicate plant which grows in little tufts of fine leaves with slender petioles. the tallest reaching to a height of about 6 cm. The little plant with its fine foliage and delicate colour presents a most graceful appearance,

Stem and Root : (Fig.) The rhizome is exceedingly reduced. A few petioles with their small leaves grow up into the air, while a small number of fibrous roots penetrate the soil.

This is all there is of the whole plant.

Petiole : (Fig.) The petiole is erect and very thin being about .5 mm. in thickness. It is however fairly firm, and is a shining light brown colour, and quite smooth. The length up to the lowest pinnae is from 1 to 3 cm.

Leaf : The midrib is brown like the petiole for a short distance and then merges into the delicate pale green of the leaf. The leaf is from 1 to 3 cm. long and is pinnate, the fan_- shaped pinnae being cut, sometimes almost to the base, into 2,4,8 etc. oblong lobes.

The pinnae are in almost exactly opposite pairs, there being 1 to 3 pairs to the whole leaf. They are, like those of P. rutaefolius, fan or wedge - shaped and broader than long, being from .5 to 1.2 cm. wide and from .3 to 1 cm. long. The margins are entire, except for the divisions into lobes. The leaves are pale green in colour, shining, and of an exceedingly delicate, almost transparent texture. The surface is quite smooth. The venation is repeatedly dichotomous, there being one veinlet running into each lobe.

Sori : (Fig.) The sori are on the backs of the pinnae situated on the veins, generally up towards the lobes. They are rounded to oval at first, but generally become more or less confluent.

Sporangia : These are typically Polypodiaceous-, flask- with a stalk, an incomplete vertical annulus , (golden with dark bars), and transverse dehiscence.

Spores : These are tetrahedral, dark-coloured when ripe, with markings and protuberances on the perinium.

b. The gametophyte of A. leptophylla (Fig.)

The prothallus of A. leptophylla is exceedingly interesting, as it differs from the normal fern prothallus in some remarkable respects,

At first the prothallus consists of a spatulate, expanded cell-surface, bright green in colour, and sometimes irregular and lobed in outline. This cell- surface does not become heart-shaped as in the normal fern prothallus. It is possessed of basal meristem (Goebel 1905 P. 217), so that at its base there arise numbers of adventitious

off shoots, green and expanded, and similar to the primary cell-surface, Thus the prothallus becomes quite extensive, the numerous cell-surfaces being of various shapes- sometimes rounded, sometimes irregularly lobed, and usually slightly spatulate or funnel-shaped, (Fig.)

The youngest of these adventitious off shoots forms on its under side a tuberos body, the " archegoniophore " which forces its way into the ground. As Goebel (1905) expresses it: From one spore there proceed therefore a large number of surface-prothalli which are connected at their base, and the youngest of these produces the "archegoniophore " (Fig.)

It will be seen then that the prothallus of A.leptophylla is unusually extensive. It is in fact one of the largest fern prothalli and possess accordingly a proportionately large assimilatory surface. Thus it is enabled, as Engler (1912) points out, to convey quickly and in abundance reserve food to the archegoniophore. Thus the archegoniophore develops into a fair-sized tuber, plainly visible to the naked eye. (Fig.

Details of the Archegoniophore. (Fig.) The

archegoniophore upon investigation is seen to be a brownish, tuber like body, roughly egg-shaped with irregular outline and up to 3 mm. in length. It works down below the surface of the ground, where it loses nearly all its chlorophyll and becomes provided with numerous fine rhizoids, growing from the lower surface (Fig.)

When crushed and treated with iodine and Sadan 111 , the cell contents show the presence of an abundance of starch and oil (Fig.) a trace of chlorophyll may also be seen in the inner cells.

Archegonia : (Fig.) On the upper side of the tuber, near the bases of the green cell-surfaces, appear the archegonia, just visible to the naked eye as little dark spots. The archegonia are of the usual type, flask-shaped in side view and with a neck of about four rows of cells.

Antheridia : (Fig.) The antheridia do not occur on the archegoniophore, but are found on the green expanded portions down near their place of attachment to the tuber. (Fig. and). In side view the antheridia are the usual rounded shape,

with a short broad stalk of about one cell-high, and with one layer of cells surrounding the contents. The spermatazoids appear as a mass of rounded bodies (Fig.)

If an archegonium is fertilised a sporophyte develops, remaining attached to the tuber, from which it is able to draw considerable nourishment. (Fig.). The prothallus, both tuber and cell-surfaces, is gradually used up by the young sporophyte and finally disappears.

If however none of the archegonia are fertilised, the prothallus continues its life by the following process. (Engler 1923):

" There is first a certain resting period, after which the archegoniophore tuber produces numerous new expanded cell-surfaces. From the youngest of these again in time a new archegoniophore arises and develops archegonia as before. " If in turn none of these are fertilised, another group of new cell-surfaces is produced and so on for a number of times. The ecological significance of this remarkable ability of the prothallus to extend its duration of life will be discussed in another part of this thesis.

Corrected

C. ANATOMY.

1. Cheilanthes sieberi.

a. Typical form.

i. Rhizome: (Fig.) The general internal structure of the rhizome as seen in transverse section is as follows:

Towards the growing point of the rhizome (Fig.) a transverse section shows the irregular outline, roughly pentagonal in shape. It is bounded by a dark-coloured somewhat thickened epidermis. Within this there is a parenchymatous ground tissue with several more or less oval vascular bundles. At the outer points and in the centre of the section may be noted slight indications of xlerenchymatous development.

In transverse section the older portions of the rhizome (Fig.) show much the same structure as the younger parts, the difference lying in the much more extensive development of mechanical tissue. The epidermis is greatly thickened and dark brown in colour, while the outer cortical cells have become changed into xlerenchyma, which forms several hypodermal layers distinctly separated from the

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cortical parenchyma. The central sclerenchyma (Fig.) also extends considerably and joins up with the hypodermal sclerenchyma by means of strands running between the vascular bundles.

The rhizome thus becomes largely made up of mechanical sclerenchymatous tissue, the cortical parenchyma being reduced to a narrow zone of cells surrounding each vascular bundle.

In structure, the sclerenchyma is made up of somewhat elongated cells, without intercellular spaces and with very thick walls, (with distinct central lamellae), bright yellowish-brown in colour. (Fig.)

The cortical parenchyma surrounding each vascular bundle is made up of somewhat larger, thin-walled cells. (Fig.)

Each vascular bundle is enclosed within an endodermis of small, elongated, narrow cells placed end to end and very regular in shape and arrangement. The walls are not thickened. The surrounding cortical cells (Fig.) are much larger than the endodermal cells.

Vascular bundles: There are some half-dozen rounded or oval vascular bundles arranged in a ring surrounding the central mass of sclerenchyma, and separated from each other laterally by 2 strands of cortical

parenchyma and one strand of sclerenchyma.(Fig.)
In construction the bundles are concentric, with the xylem in the centre. The xylem elements form a roughly crescent-shaped mass. In the middle of this are the larger tracheides, while at the points are smaller vessels indicating the position of the protoxylem elements. The tracheides are 4 or 5 sided in transverse section and have fairly thick walls. Surrounding the xylem is the phloem, which is made up of small, thin-walled elements. Outside the phloem comes a layer or two of larger thin-walled parenchymatous cells, which, when treated with iodine, show the presence of starch grains. These layers constitute an indefinite pericycle, or may be called the "phloem-sheath" (Haberlandt, 1914, p. 350.)

Several of the outermost layers of the sclerenchymatous cortex become compressed into a solid wall which forms the exodermis. Many of the outer cells grow out into fairly broad, brown, hair-like organs. These are rhizoidal appendages and are present in large numbers all along the root.(Figs. and)
ii. Root: (Fig.) In transverse section the root is roughly circular with irregularities in out-

line. The whole of the cortex from exodermis to endodermis becomes changed into sclerenchyma. There are about 6 even layers made up of very regular, elongated cells placed end to end around the root. (Fig.) These cells have much thickened walls, reddish-brown in colour, and are without intercellular spaces. Thus the whole of the cortex is mechanical tissue.

The next inward layer is the endodermis which surrounds the one central vascular cylinder. The endodermal cells are very long and narrow, being about the same length as the sclerenchyma cells, but only about half the width. They can also be clearly distinguished by their thin walls.

Vascular bundle: Within the endodermis is one central vascular bundle running the length of the root. In structure the bundle is concentric with an elliptical mass of xylem in the centre. There are large, thick-walled tracheides in the middle, and smaller elements at the points of the ellipse marking the position of the protoxylem. The root is thus diarch. Placed along the sides of the xylem-mass are the two phloem masses (above and below the xylem in Fig.) The phloem con-

sists of small, thin-walled elements.

The xylem and phloem elements are surrounded by several layers of cells, larger than those of the phloem, thin-walled and parenchymatous in nature. These constitute the pericycle and show the presence of starch grains. They are thinner-walled than the surrounding endodermis, and less regular in shape and arrangement.

iii. Petiole: (Fig.) In transverse section the petiole shows a general structure somewhat similar to that of the rhizome, especially as regards the vascular bundles.

The section is roughly circular in outline with a shallow depression at the base showing the position of the groove down the ventral side of the petiole. The epidermal walls are thickened and dark-coloured. The outer walls give a very finely crenate outline to the section. Two or three hypodermal layers of the cortex become changed into thick-walled, dark-coloured sclerenchyma, the cells being small and rounded and similar to those of the epidermal layer. Within this hypodermal sclerenchyma are some half-dozen layers of cortical cells. These are circular with intercellular spaces, and have moderately thick walls. They vary in size being

smaller just below the hypodermis, larger towards the centre, and then smaller again before reaching the endodermis.

The endodermis is a very distinct circle of regular, barred-shaped cells, placed end to end. The walls are markedly thicker than those of the cortex, while the transverse walls show indications of extra thickening.

Vascular Bundle: There is a central vascular cylinder about $\frac{1}{3}$ the diameter of the whole petiole. It is concentric in structure with the xylem in the centre. It is very similar in all essentials to one of the vascular bundles of the rhizome. (cf. figs. and)

In the centre is the creseent-shaped mass of xylem with larger tracheides in the middle and smaller elements at the points of the crescent. Smaller elements are also to be seen along the concave side of the crescent. (This is the side which is towards the depression.)

The xylem is surrounded by small, thin-walled phloem cells, which in turn are surrounded by a few indefinite layers of slightly larger cells, constituting the pericycle. The pericycle is

much less definite and regular than the distinct endodermis which surrounds the whole vascular bundle.

iv. Leaf: (Fig) All the bundles of the leaf of *Cheilanthes sieberi* are concentric, except the very smallest ones, which are collateral in structure with the xylem towards the upper or adaxial surface. (Fig.)

The general appearance of the transverse section of a pinna, cut through at a point about half way along its length, may be seen in figure

The pinna is thick in proportion to its width and the margins are much recurved. No hairs or scales are to be seen on either surface.

The upper epidermis (Fig.) is composed of fairly regular, cubical cells, without chlorophyll or stomata, and with a fairly thick cuticle.

Below this, comes a well developed Palisade tissue, consisting of two layers of rectangular cells, without intercellular spaces, and with dense chlorophyll content.

The mesophyll consists of irregular cells, smaller than those of the palisade with intercellular spaces and less dense chlorophyll content.

Surrounding the vascular bundles the mesophyll cells are placed radially side by side, with their ends abutting on the endodermis (Fig.) thus forming a kind of parenchyma bundle-sheath. (Haberlandt, 1914, p. 284.)

The lower epidermis is made up of regular cells, more rectangular than those of the upper epidermis. Stomata with thick-walled guard-cells appear in the lower epidermis to which they are confined. In surface view (Fig.) the epidermal cells are seen to be of the usual dicotyledonous type, with wavy outline and with numerous stomata. The latter are variously orientated and have their sausage-shaped guard-cells packed with chlorophyll.

The vascular bundles are placed about half way between the palisade and the lower epidermis and are clearly marked off by the distinct endodermis surrounding each one. The endodermis is composed of cells very much smaller than those of the mesophyll, regular, barrel-shaped, and with their walls, especially the transverse ones, considerably thickened.

Vascular bundle: The vascular bundles of the midrib and larger veins are concentric and very similar to those of the petiole. The vascular bundles of

the smaller veinlets are collateral. The vascular bundle of the midrib of the pinna is figured in figure where it is seen to be about $\frac{1}{2}$ the thickness of the pinna, and concentric, with an elliptical mass of xylem in the centre. The larger tracheides are in the middle of this mass, and the smaller ones are at the two ends.

Surrounding the xylem is the phloem, which is composed of fairly small, thin-walled elements. Larger cells mark the position of the pericycle.

b. Shade form.

i. Petiole: (Fig. ; cf. fig.)

From the transverse section of the petiole of the shade form, it will be seen that it differs only in minor details from that of the typical form.

The shade form shows slightly less development of hypodermal sclerenchyma, and has rather larger cortical cells with thinner walls. The endodermis also is less noticeably thickened. In all other respects this petiole shows entirely similar structure to that of the typical form.

iii. Leaf: (Fig. ; cf. fig.) The transverse

section of a pinna of the shade form shows slightly more definite differences from the typical.

In the shade form, the pinna is only about half as thick in proportion to its width and the margins are not reflexed. The cuticle of the epidermal cells is less thickened. There is much less conspicuous development of palisade tissue, this being reduced to one row of rather short rectangular cells. (Fig. cf.fig.) The cells of the endodermis are markedly thinner-walled, being no thicker than the thin-walled mesophyll.

In other respects the leaf-anatomy of the shade and typical forms is essentially the same.

2. Nothoclaena distans.

a. Typical form.

Sections of the rhizome and root were cut and examined, but not figured, as they were so exactly similar to those of Ch. sieberi, with the same extensive development of sclerenchyma and the same construction of vascular tissues etc.

i. Petiole: (Fig.) In transverse section this also shows great similarities with the petiole of Ch. sieberi. This distinguished by the numerous multicellular scales growing out from the epidermis.

In outline the petiole of N. distans is roughly circular, wider at the base, where there is a shallow depression marking the position of the groove that runs down the ventral side.

As in Ch. sieberi, there is marked thickening of the epidermis, and development of hypodermal sclerenchyma, while the cortical cells are also slightly thickened.

The thickened endodermis and the vascular bundle are both in all respects similar to those of

Ch.sieberi, the stele being about $1/3$ the diameter of the petiole. The bundle is concentric, with a central crescent-shaped mass of xylem, surrounded by phloem, which in turn is enclosed within an indefinite pericycle.

ii. Leaf: (Fig.) In general appearance, the transverse section of the pinna of N.distans is also very similar to that of Ch.sieberi. It is of the same thickness in proportion to its width and has reflexed margins. It is distinguished by its numerous trichomes - hairs on the upper surface and multicellular scales on the lower.

The cuticle of both epidermal layers, especially the upper, is thickened. The upper epidermis is composed of fairly regular cells, without chlorophyll or stomata.

Below this is a well-developed palisade tissue composed of about two rows of rectangular cells, without intercellular spaces, and with dense chlorophyll content.

The mesophyll is composed of more rounded cells, with intercellular spaces and less dense chlorophyll content. A circle of mesophyll cells

surrounds the vascular bundle, forming a parenchymatous bundle-sheath, within which is the clearly defined endodermis of much smaller, barrel-shaped cells, with their walls, especially the transverse ones, considerably thickened.

The lower epidermis is without chlorophyll and is possessed of numerous stomata and scales. The epidermal cells in surface view are like those of Ch.sieberi -- wavy in outline with variously orientated stomata. The guard cells are thick-walled, and are packed with chlorophyll.

Vascular bundle: Except the smallest bundles, which are collateral, the vascular bundles are concentric. The vascular bundle of the midrib of the pinna is shown in figure. It is about $\frac{1}{4}$ the width of the whole section. In the centre is the crescent-shaped mass of xylem, the middle tracheides being fairly large, and those at the points smaller.

Small thin-walled phloem elements surround the xylem, and are in turn surrounded by the thin-walled pericycle of one or two indefinite layers.

b. Shade form.

i. Petiole: (Fig. ; cf.fig.) The petiole of the shade form is very similar in transverse section

to that of the typical N. distans, but is distinguished by being devoid of scales.

In the shade form the development of hypodermal sclerenchyma is slightly less, while the cortical cells are fewer and larger. The endodermis also is thinner-walled.

Otherwise, in the size and structure of the bundles etc. the two petioles are entirely similar.

ii. Leaf: (Fig. ; cf. fig.) In transverse section the pinna of the shade form is much broader and thinner than in the typical form.

The most noticeable difference between the forms lies in the number of scales, and the extent of the palisade. In the shade forms there are apparently no scales on the upper surface, and only one or two on the lower surface. The palisade is poorly developed, and the endodermis is thinner-walled.

Otherwise the pinnae are quite similar in anatomical characters for both shade and typical forms.

3. Pleurosorus rutaefolius.

a. Typical form.

i. Petiole: (Figs. and) The petiole of P.rutaefolius differs markedly from those of Ch.sieberi and N.distans, and shows many very interesting points in its anatomy.

In transverse section, it is roughly circular, a little widened at the base, and provided with numerous hairs of various shapes, growing out from the epidermis. The epidermis and about three hypodermal layers of cells are small, even and closely packed together. They are provided with very thick walls, the openings of the cells being quite small. The walls have not the dark appearance of typical sclerenchyma, but are very light coloured, indeed almost colourless and transparent.

At two diametrically opposite points on the sides of petiole these thickened cells narrow down to one layer, two or three cells in length. Here are to be noticed one or two stomata. The presence of stomata down the sides of the petiole is one of its unusual characteristics.

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Within the hypodermis comes the cortex, which is composed of about 6 layers of much larger cells, circular in transverse section and rectangular in longitudinal section. (Fig.) These cells are all filled with chlorophyll, and possess intercellular spaces with which the stomatal openings connect. This photosynthetic nature of the cortical cells is another point of interest about this petiole.

Then the endodermis presents an unusual feature of considerable interest. At 3 points round its circumference there are dark-coloured masses of solid-looking matter. This, when treated with various reagents, gave only negative results. It appears however to be a kind of mechanical tissue, running the whole length of the petiole, and giving it a certain amount of strengthening and rigidity.

With a view to finding out the nature of this dark brown substance the author consulted the available literature on the subject.

In his paper on "The Prothallus and Young Plant of Tmesipteris" (Trans.N.Z.Inst.Vol.L), J.E. Holloway (1917) mentions (p.32) the presence of a brown deposit in the innermost cortical layers of

the aerial stem of Tmesipteris lanceolata.

Figures (Nos.91, 92, p.35.) are given showing this deposit as seen in the transverse and longitudinal sections of the stem of a mature plant. In longitudinal section it appears very much the same as in a longitudinal section of the petiole of Pleurosorus rutaefolius. (Fig.) In transverse section however, the deposit is seen in T.lanceolata to be unevenly spread along the walls and across the corners of the cells, while in P.rutaefolius it fills numbers of cells completely, becoming a solid mass without any remaining signs of cell structure. (Fig.)

Holloway refers in his paper to the paper by S. Ford on "The Anatomy of Psilotum triquetrum" (Annals of Botany, Vol.18.) Here (p.597) the author says "In the aerial shoot, the two or three layers lying next to the endodermis have their walls coloured a dark brown this brown deposit is probably of the same nature as that described by other writers as occurring in Ferns. This has been termed 'phlobaphene' ". A test given for this substance is that it dissolves in potash.

The dark matter in the petiole of

P.rutaefolius does not appear to be 'phlobaphene' for it does not answer this test. It seems probable however that it is some substance of a similar nature, present in unusually large quantities, and having a mechanical value in giving extra toughness and rigidity to the petiole.

This dark matter replaces most of the endodermal cells and projects in irregular ridges into the cortex. (Figs. and) Figure is a longitudinal section cut tangentially across the endodermal ring, and thus passing through two of the masses of mechanical tissue. The endodermal cells which are not replaced by this dark matter are barrel-shaped in transverse section, and have somewhat thickened walls.

Vascular bundle: There is a central vascular bundle, about the same width as the cortical layer, and concentric in structure. The central xylem mass is the shape of an equilateral triangle with concave sides. (Note: the masses of mechanical tissue are placed at 3 points opposite the three sides of this triangle. - Fig.) The tracheides are smaller at the apices of the triangle.

Surrounding the xylem is the very thin-

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walled phloem, the vessels spindle-shaped in longitudinal section fairly distinct pericycle encloses the vascular elements.

ii. Leaf: (Fig.) A transverse section of the pinna shows it to be thick in proportion to its width. The structure of the leaf is much more like that of Ch.sieberi or N.distant than is the structure of the petiole.

There are very numerous hairs growing out of both upper and lower epidermal layers. The cuticle of the upper epidermis is fairly thick, and the cells are cubical, and without chlorophyll or stomata.

Next comes a very conspicuous palisade composed of about three layers of rectangular cells without intercellular spaces, and with dense chlorophyll content. The palisade takes up half the thickness of the pinna.

The mesophyll is made up of irregular, mostly rounded cells, with noticeable intercellular spaces and less dense chlorophyll content. A parenchymatous bundle-sheath surrounds the stele.

The lower epidermis is similar to the

upper, but is provided with stomata with thick-walled guard cells, packed with chlorophyll. In surface view the epidermis is exactly similar to that of Ch.sieberi or N.distans. (Fig. cf.figs. and)

The endodermis is very clearly marked off as a circle of cells much smaller than those of the mesophyll and very regular. They are barrel-shaped and have thickened walls.

Vascular bundle: The smallest vascular bundles are collateral, but the others are concentric. The midrib is about $1/5$ the thickness of the whole pinna. In the centre is an elliptical mass of large xylem tracheides, surrounded by the small thin-walled phloem elements. A layer or two of larger, thin-walled cells just within the endodermis, constitute the pericycle.

b. Shade form.

i. Petiole: (Fig. cf.fig.) In transverse section the petiole of the shade form shows a few fairly definite differences from the typical. In the shade form the hairs are much fewer, and there is less depth of hypodermal, thick-walled tissue.

The stomata at the sides project just slightly.

Then in the endodermis the shade form shows very much less development of the dark-coloured masses. This fact lends support to the idea that this dark matter is a kind of mechanical tissue. There are three much smaller masses of it arranged exactly as in the typical petiole. The structure of the vascular bundles is the same in both shade and typical forms.

ii. Leaf: (Fig. cf. fig.) In transverse section, the pinna of the shade form is noticeably very much wider and thinner. It is in fact only one half the thickness, in proportion to its width, of the typical form.

In the shade form, the cuticle of the epidermal layers is quite thin, while there are only a few hairs present.

It is to be noted that palisade development is practically absent, all the cells being similar in shape and arrangement, somewhat rounded and with intercellular spaces. A circle of these cells form a parenchymatous bundle-sheath.

The endodermis also is thinner-walled, this

being the only other point of difference between
the shade and typical forms.

4. Anagramme leptophylla.

1. Petiole: (Fig.) In transverse section, the petiole appears roughly semi-circular, but broader, with a shallow depression along the base. It differs markedly from the petiole of the three preceding ferns.

The epidermal cells have their outer walls slightly thickened and brown in colour. This slight thickening is in very great contrast to the development of epidermal and hypodermal sclerenchyma in Ch.sieberi and N.distans, or of thick-walled tissue in P.rutaefolius. The epidermal cells are also immensely larger in proportion to the size of the whole section in A.leptophylla. They are large and cubical, and roughly number about 30 around the circumference, while those of Ch.sieberi roughly number about 240. Compare figure with figure .

Within the epidermis is the cortex, which is made up of only about two layers of large, rounded cells with thin walls and intercellular spaces.

The endodermis is made up of regular barrel-shaped cells, very much smaller than those of the cortex, and quite thin-walled.

Vascular bundle: There is a central vascular bundle

about $\frac{1}{3}$ the breadth of the petiole. This is typically concentric with an elliptical mass of xylem in the centre. The larger tracheides are in the middle and the smaller ones are at the points of the ellipse.

Small, thin-walled phloem elements surround the xylem, while outside the phloem is a layer or two of larger, thin-walled cells, constituting the pericycle.

11. Leaf: (Fig.) The leaf shows the fine structure that one would expect from its delicate appearance.

The upper epidermis is composed of cubical, thin-walled cells, large in proportion to the thickness of the leaf, and without chlorophyll or stomata.

There is no appearance whatever of palisade, the ground tissue being made up of about 5 irregular layers of large mesophyll cells, with intercellular spaces, and very little chlorophyll.

The lower epidermis, like the upper, is devoid of any trichomes and is composed of large cubical cells without chlorophyll. The stomata, which project slightly, are localised here. In surface view (Fig.) the epidermis is similar to

that of any of the three preceding ferns.

The endodermis is small-celled and regular, the walls being thin and the cells the usual barrel-shape.

Vascular Bundle: The smallest bundles only are collateral, the others being concentric. The midrib is about $1/3$ the thickness of the pinna. There are only a few large xylem elements in the centre of the bundle. Around these is the fine, thin-walled phloem, surrounded in turn by an indefinite pericycle of slightly bigger cells.

The foregoing descriptions of the main anatomical features of the four ferns, both typical and shade forms, raise many interesting questions. Many points are of significance from the ecological point of view, for example, the variations in palisade development, in the development of sclerenchyma etc; also the photosynthetic nature of the petiolar cortex of P.rutaxifolius, the delicate structure of A.leptophylla etc. These matters will be dealt with in the ecological chapter which follows.

D. Ecology.

This chapter deals with the ecology of the four ferns under discussion. The method adopted may be outlined as follows. Both individual and comparative accounts from the ecological point of view are given. In each case there is a preliminary note on the general localities for the fern throughout New Zealand especially on the Port Hill, followed by a detailed account of its particular habitat. The morphological and anatomical adaptations of the plant to this habitat are then pointed out, with a comparative account of the differences in the shade forms corresponding to their differences of habitat. The more general climatic and edaphic conditions of the Port Hills for plant life have already been described in Part I c (2). More particular details of these conditions will here be given as they apply to the special habitat of each fern.

1. Cheilanthes sieberi

- a. General localities : This fern is fairly common in New Zealand. It usually grows in rocky and stony ground, and very frequently close to the sea. In the North Island it is characteristic of the volcanic districts about Auckland, where it grows plentifully on the dry scoria rocks ; it extends to the North Cape but is rare at the Thames. In the South Island, it is also fairly common throughout Otago and Canterbury (Thomson 1882).

On the Port Hills Ch. sieberi is very common, although not a conspicuous plant is a rule. It is abundant in rocky clefts or dry situations, in all parts of the hills where the locality suits it (Wall 1918). It was found by the author growing plentifully in Bowen's Gully and the Heathcote Valley. In Fig. Bowen's Gully, marked ~~X~~ X, may be seen to the left of the Victoria Park ridge (14) of the Cashmere Hills. The Heathcote Valley, marked ~~B3~~ B3 is situated behind the suburb of Heathcote.

At the head of Bowen's Gully there is a rugged mass of rock, roughly in the form of an inverted U (Fig.) All round this mass for a considerable area, boulders and small rocks form the conspicuous feature of the landscape (Fig.). On the Northerly faces of the large rock mass and on the smaller rocks around, Ch.sieberi grows quite plentifully. On the key to figures and the faces where the fern may be found are marked C. On the surrounding rock-strewn ground, a portion of which is shown in figure the fern grows on practically all the rocks that have a sunny aspect.

In the Heathcote Valley, a portion of the summit track dips down and rounds the Valley near the top (Fig.) Sloping steeply down to this track are masses of rock almost forming a wall in places (Fig.) On certain of these rocks with a Northerly aspect Ch. sieberi is found in fair abundance. The general situations of the fern are marked C in Fig.

- b. Particulars of habitat: The typical Ch. sieberi is found in rocky situations that receive a great deal of sunshine. The plant association of these situations is made up of a variety of species.

Some commonly found growing in the vicinity of Ch. sieberi are species of Acaena, Maehlenbeckia, Complexa, Chenopodium triandrum, Epilobium, sp, Linum, Monogynum, and several ferns eg species of Pellaea, Asplenium, Aspidium, Pteridium, esculentum, and Nothoclaena distans.

An idea of the typical habitat may be obtained from the photographs and descriptions of certain examples chosen. Figure shows a characteristic situation at the head of Bowen's Gully. This is the rock marked C. in figure . Figure is a close up view of part of this boulder showing a clump of vegetation in the centre. The relative size may be judged by the pocket knife in the photograph. This boulder is a large, roughly cubical mass of rock, roughly 1.4 m. in length, breadth and height, with its upper surface sloping to the North at an angle of 45°. In a slight depression on this surface may be seen the small clump of vegetation.

The clump comprises mostly grass, a small plant of Wahlenbergia gracilis, and impoverished plant of Cerastium glomeratum, and a tuft of Silene gallica, while lichens form the only other vegetation on this upper surface. On the nearer edge of the clump on the side most exposed to the sun may be seen a small plant of Ch. sieberi (marked C). This plant was growing in a very shallow pocket of perfectly dry soil. At the time of observation there had been no rain for about a fortnight. The fern had a rather parched appearance, the older leaves being shrivelled and dried. The younger leaves however were green and fresh, and the whole plant looked quite healthy. The rock was exceedingly hot to the touch, especially about midday, while the sun's rays shone directly on the plant. In spite of these very xerophytic conditions of heat and drought, the plant appeared to be flourishing.

The only other plants on the North side of the rock were numerous lichens, while round the foot there grew but sparsely a few species of grass and Acaena. By way of contrast, the shaded side of the rock and its vegetation may be briefly described.

The South side the rock is in almost complete shade for a great part of the day. At the base were observed various damp crevices with an abundant herbaceous vegetation eg Oxalis corniculata, Dichondra repens, species of Acena, grasses of many kinds, and liverworts, and Chickweeds. As one worked round from this face to the sunny side of the rock, the vegetation was observed to become more and more sparse and dried looking.

Another good example of the kind of habitat adopted by Ch. sieberi was observed at Bowen's Gully and may be described as follows: A bare exposed rock surface was observed, about 2.5 m. long and 1.5 m. across, with a gentle slope towards the North East, and slightly raised above the surrounding ground level. This surface was entirely exposed to the sun, and at first sight appeared quite devoid of vegetation, except where invaded at the margins where soil encroached, by species of grass, and Acaena. A closer examination however, showed very small pockets in the rock due to the crumbling away of softer portions.

Many of these pockets contained minute plants of Ch. sieberi. One small pocket about 4 cm. across and 2 cm. deep contained a tiny plant about 1.5 cm. in height, with minute leaves, brownish and shrivelled. In other pockets and in minute fissures in the rock similar little plants appeared. These ferns were the only plants growing on the whole surface of the rock. The amount of soil was exceedingly scanty and dry, and the rock was very hot to the touch. On excavating the plants and soil particles with a knife, it was found that there were further slight crevices at the bottoms of the pockets. The roots penetrated into these for a distance of about 3 cm. Even these roots and the scanty soil within the crevices seemed absolutely dry.

Figure shows another surface of rock, facing North and forming part of the large mass of rock seen in figure. A small plant of Ch. sieberi is to be seen, growing with its petioles and pinnae fully exposed to the sun, but sending its roots down into a narrow crack. The height of this plant, as may be seen by comparing it with the size of the hand-lens in the photograph, was about 5 cm. Lichens formed the only other vegetation on this piece of work.

The soil in these very narrow cracks is dustlike and apparently quite dry. The surface of the rock is perfectly bare, dry, and exceedingly hot when the sun is shining on it, especially at noon.

11 Atmospheric conditions : The petioles and leaves of Ch. sieberi are fully exposed to the direct rays of the sun all day. Thus it has to endure considerable heat both from the direct rays of the sun and the radiation from the surface of the rock. It received also the maximum intensity of light. At night the contrast with a sunny day is considerable, both the rock and the atmosphere being much cooler. Frosts occur in Winter, but are not severe. Winds are frequent, these being sometimes cool ones from the North-East, and less frequently, hot dry ones from the North-West at certain times of the year. On the whole it is obvious that the habitat of Ch. sieberi is markedly xerophytic. It has a general hot, parched appearance ; the soil is scanty, hot and dry, the air is heated by much sunshine and there is a good deal of wind ; it must also be observed that the light is intense and lasts all day in sunny weather, while the number of sunny days is large.

C. Adaptations to Habitat : Ch. sieberi shows many well marked adaptations or characters suiting it to such situations as described above. It must be noted that many of the characters of value to a plant for reducing transpiration under xerophytic conditions, are exactly the same as those of value in lessening illumination under conditions of intense lighting. (This fact is pointed out by Warming 1919 p. 21. Thus certain morphological and anatomical features exhibited by Ch. sieberi may be regarded as adaptations for xerophytic condition or for heliophytic condition, or for both. The two sets of factors, supply of moisture and supply of light work on similar lines to a great extent in their effect on the structural features of the plant. (Warming 1909, p 24). Thus these features cannot be separated and set apart as due either to one factor or the other. Taking Ch. sieberi as a whole therefore in its adaptations to its environment, the following features are to be noted. These have already been pointed out in the earlier chapters on morphology and anatomy. Here they are given their significance from the ecological point of view .

The growth form, tufted and compact; the tough, wiry petioles; the much divided leaves with their greatly reflexed margins, leaving very little surface exposed to the sun ; the firm coriaceous texture of the leaves.

11 Anatomical features:

Petiole : The strong development of hypodermal sclerenchyma in the petioles, (and also in the rhizome and roots); the slight thickening of the cortical cells and the marked thickening of the endodermis.

Leaf : The comparative thickness of the leaf ; its well developed palisade tissue ; the thick cuticle especially on the upper surface ; the localisation of the stomata on the lower epidermis where they are protected by the much recurved margins ; the thickening of the endodermal cells.

It may be noted that the foregoing xerophytic characters in large part correspond to those noted by March (1914) in his paper on " Some Xerophilous Species of Chellanthus and Pellaea. He makes mention of the following points " Ch. lanuginosa, Ch. gracillima, Ch. persica : tomentose rachis ; subcoriaceous texture ; upper surface slightly tomentose ; lower surface densely matted with a coat of pale brown, woolly hairs ;

margins much reflexed.

Ch. fendleri : rachis clothed with acuminate entire scales ; under surface scaly, not matted ; texture subcoriaceous, margins reflexed.

" The leaf anatomy shows in each case a reduced lacunar system ; greater or less development of palisade ; localisation of the stomata on the lower surface, where they are protected by the inrolled margins alone, or by the inrolled margins and a covering of scales (as in Ch. fendleri) or hairs (~~as~~ in the other species given above) ; the cuticle is thick.

" The single vascular strand in the petiole is surrounded by a sclerenchymatous cortex."

Thus it will be seen that Ch. sieberi has many features corresponding to the above, except for the woolly or scaly tomentum.

d. Comparison with " Shade " form.

1 Differences in habitat : The shade forms of Ch. sieberi were always found in places receiving a large amount of shade. One such situation may be described. In a deep crack on the North West face of a rock mass, a slender plant of Ch. sieberi was noted, carrying its leaves towards the light.

The foinds were of the fully shaded form (Fig.) and of a green- soft and delicate appearance. Antother fully shaded form was found well hidden in a dark crack between two neighbouring rocks. There was a little soil between the rocks and on this gre a few blades of grass and a small plant of Scaena sp. Further back, almost completely hidden from the light by this vegetation, were some plants of Ch. sieberi, of the fully shaded form.

Thus these shade forms live in sheltered spots where they receive much less light, much less heat from the sun and heated rocks and less wind, but considerably more moisture than the typical. The latter fact depends on the former for the shade helps to prevent evaporation, the drying effects of the sun and wind are almost absent, while moisture is constantly seeking down from the damp rock faces surrounding the ferns.

These differences between the habitats of typical and shade forms result in difference in certain of the most important environmental factors, the effect of which is considerable differences in the configuration of the plants. The shade forms accordingly show morphological and anatomical points of difference from the

typical which have been outlined in earlier chapters. Their importance lies in the reduction of characters tending to reduce both excessive transpiration and illumination in accordance with the more mesophytic demands of the habitat of the shade form. The shade form therefore is distinctly more mesophytic in character, thus :

I Morphologically : In the shade form, the growth form is not tufted, but is straggling and less compact ; the petioles are thinner and less wiry ; the leaves are much less divided and are without reflexed margins ; they are finer in texture and darker in colour than in the typical form.

II Anatomically : In the petiole, there is less hypodermal sclerenchyma, while neither the cortex nor the endodermis are thickened ; the pinnae are thinner with thinner cuticle and endodermis and only slight development of palisade tissue.

All these differences between the typical and shade forms of Ch. sieberi are in connection with those characters that protect the plant both from excessive transpiration and from excessive illumination.

In pointing out how these characters overlap and are largely identical, Warming (1909 p. 21), says in effect. Exactly how light acts is not clearly known. Some workers say they light alone causes the above structural differences. Others say that increased light causes increased transpiration, the latter being the direct cause of these differences. Others again say that the strong assimilation resulting from strong illumination is to be regarded as the cause.

In the present case of Ch. sieberi, however, both factors, great dryness and strong illumination are either both present, or both absent. Thus they work together in their effect on the plant. The complete results here may be noted as a whole, and regarded as the effects of the environmental conditions in general, and not of any one factor.

2. Nothoclaena distans

- a. General localities : This fern is local in New Zealand. In the North Island it is found chiefly in the volcanic districts, on basaltic rocks, for which it seems to have a preference. It is abundant at Rangitoto, Titirangi, and Northwards to Whangarei. In the South Island it is recorded in several localities in Canterbury up to a height of 1000 m. It does not appear to be at all common however (Thomson 1882). The fern is also recorded by Field (1890) on Mt. Ruapehu, Mt. Egmont, Kapiti Island in Cook Strait, and the Port Hills.
- On the Port Hills, N. distans is, like Ch. sieberi, quite common, and abounds in most rocky localities. It was found by the author growing near Ch. sieberi in Bowen's Gully (Fig. and), and up the Heathcote Valley (Fig. b.). It was plentiful on the large rock mass (Fig.) on the same sunny faces as Ch. sieberi. It was not however noted with any frequency about the smaller rocks scattered over the hill (Fig.).
- b. Particulars of habitat : It is not necessary to give nearly such full accounts of the habitats of N. distans as have been given in the case of Ch. sieberi, for these two species are commonly associated together, and grow in almost exactly similar situation.

Both are typically sun-seekers but are able to grow in the shade, the form here taking on certain differences.

The only point of difference in regard to habitat observed between Ch. sieberi and N. distans, is that Ch. sieberi seems to be slightly the hardier of the two and able to grow where the amount of soil appears almost negligible ; N. distans appears as a rule to frequent slightly better filled cracks of rock, and rock surfaces with a slightly deeper covering of soil.

Figures and show good examples of the typical habitat of N. distans. As these figures show, the fern sometimes grows in cracks and sometimes on a little earth spread out over the surface of the rock. Figures and are close up photographs of part of the rock skirting the track (Fig.) The first figure shows a long, acute-angled crack in the rock. The crack was of a fair depth, with a good deal of soil in it for the roots to penetrate. The leaves however were well out towards the surface, and as the rock faced almost due North they received full sunshine practically all day.

Figure is another photograph of a similar position showing some larger plants of N. distans growing in a crack but fully exposed.

In both cases, as may be seen, the only other vegetation of the rocks was some bushes of Muchlenbeckia complexa, lichens, and a few grasses.

Figure shows a patch of young plants of N. distans growing on the slight covering of soil on a Northward facing rock surface in Bowen's Bully (Fig. , marked N.) It must be that here N. distans shows a point of difference from Ch. sieberi, for the latter never grows in patches, spreading out over the ground like this, but always in upright tufts, often solitary. These young leaves of N. distans are somewhat deltoid in shape, but otherwise do not resemble the " shade " forms at all. They soon lose this shape and grow long and narrow.

The edaphic and climatic conditions of these habitats of N. distans are exactly similar to those of Ch. sieberi, except that the soil is not quite as scanty for the former. It is however quite dry and the whole habitat presents the same xerophytic features, with strong illumination.

C. Adaptations to habitat : The adaptations of N. distans to its habitat are very similar, therefore, to those of Ch. sieberi. They may be regarded as the combined effect of the dryness, heat and strong illumination of the environment.

As may be gathered from the morphological and anatomical accounts of N. distans, its features of value to it in its habitat are exactly those of Ch. sieberi with the addition of scaly covering.

I Morphologically, N. Distans is possessed of wiry petioles ; a protective scaly covering on the under surfaces of the pinnules ; reflexed leaf margins; coriaceous texture.

II Anatomically, it shows strong development of hypodermal sclerenchyma and thickening of the endodermis in the petiole ; thickn cuticle and endodermis in the leaf ; a well-developed palisade and localisation of the stomata on the lower surfaces.

d. Comparison with " Shade " form. Here again the description and comparisons given in the case of Ch. sieberi and its " shade " form, fully cover the case of N. distans. Shade forms of the latter were found in situations exactly similar to those where plants of the shade Ch. sieberi were observed. The points wherein the shade habitats differed from the typical were exactly similar in both cases ;

hence the differences between shade and typical forms are correspondingly similar. (see p.) The morphological and anatomical differences between the shade and typical forms of N. distans are therefore not set out here. With regard to the scaly covering, it must be pointed out that this is almost entirely absent in the fully shaded forms of N. distans.

Both Ch. sieberi and N. distans, as may be seen from the foregoing descriptions, grow under exactly the same environmental conditions. The typical forms are exceedingly similar, both morphologically and anatomically, the main difference being the possession by N. distans of a distinctly xerophytic feature, the scaly coating. These two plants have both responded to their environmental influences in the same direction. It is not surprising, therefore, that the " shade " forms show convergence towards a similarity still more pronounced than that existing between the typical forms. The scaly covering that forms the main distinction between the typical forms, being a xerophytic character, almost disappears under conditions of greater shade and shelter.

As for other structural changes, these are exactly the same in both species. The result therefore is that the fully shaded forms show the remarkable similarity already commented upon in B (Part II) on Morphology.

3. Pleurosorus rutaefolius

- a. General localities : The range of this fern in New Zealand is very restricted. It occurs near Cook Strait and on the Southern Alps (Thomson 1882) ; also on the Port Hills, and in the Rangitata country at the back of the Canterbury Plains (Field 1890), Laing (1919) gives the following localities for Banks peninsula: The North side of Mt. Pleasant (Fig.) Sumner Valley, and Pigeon Bay (Fig.) Wall (1918) places this fern in his class of rare or very local and limited ferns of the Port Hills. He says " It grows in the Heathcote Valley. Shortly after crossing the road from Heathcote to Lyttelton (Fig.) the Summit Track, rounding the Heathcote Valley, passes immediately below some steep rocks (Fig.) which face North and North West ; and among these rocks, in company with Ch. sieberi and N. distans, the fern is plentiful" The fern was here found by the author. The locality is marked P. in figure

b. Particulars of habitat : As Wall says,

P. rutaefolius is " an extraordinary fern, being a typical sun-seeker ; it grows, I think, only in places which receive the full blaze of the sun all day. Like many other plants which grow in such situations, it is thickly coated everywhere with " ferruginous " or silvery brown hairs. It is a typical xerophyte. "

The typical form of the plant was found by the author in just such exposed situations as this indicates. A widely differing " shade " form however was found in a deep crevice, while " intermediate " forms were found in more or less shaded situations. The shade forms will be dealt with further on.

All the typical forms observed grew in absolutely exposed positions, right on the bare surface of the rock, always on North or North-West faces, so that they received full sunshine all day. The fern was generally a solitary plant, with no other vegetation very close to it, except for lichens on the face of the rock.

Sometimes a clump of Muehlenbeckia complexa or some Acaena was to be seen near by, as in Figure while Ch. sieberi and N. distans grew plentifully in neighbouring cracks. At first sight the plant of P. rutaefolius shown in figure appeared to be growing on nothing but the bare surface of the rock. Investigation, however, showed a shallow pocket, with a tiny crack or two, in which there was a little dry soil, and into which the short roots penetrated.

As may be gathered, the habitat of this fern is exceedingly xerophytic in nature and much exposed to the light. The rock becomes hot in the sun, and the soil is exceedingly scanty, dry and dustlike. The direct rays of the sun cause the maximum degree of transpiration.

C. Adaptations to habitat. There are numerous well-marked adaptive characteristics shown by the plant, rendering it suitable for life under these conditions. The features help both to reduce transpiration and to check too strong illumination. They may be outlined thus :

I Morphological : The growth form, a compact low clump, somewhat in the nature of a rosette ; the thick pale coloured leaves with colour masked

by a thick coating of woolly hairs on both surfaces.

11

Anatomical :

Petiole : The marked development of thick-walled epidermal and hypodermal layers ; the photosynthetic nature of the petiolar cortex and the stomata at each side ; the thickening of some of the endodermal walls, and the replacing of most of the endodermis and some of the inner cortical cells by masses of dark-coloured matter, which appears to be of a strengthening or mechanical value ;

Leaf : The thickness of the pinnae ; the very marked palisade development, the thickening of the cuticle and of the endodermal walls ; the localisation of the stomata on the lower surface.

d. Comparison with the "shade" form.

" Intermediate " forms of P. rutaefolius were found in slightly shaded positions. These showed slight differences from the typical, differences which were most pronounced in the fully shaded form. A very good fully shaded form was found by the author among the rocks in the Heathcote Valley, at no great distance from the typical plant shown in figure

This shade form was a large, full-grown plant with sori on the backs of the pinnules. The situation was a dark, horizontal crack in the rock, of some depth, and also narrow, so that very little could penetrate into it. The rock within was cold and damp to the touch although the sun was shining. The fern grew in a little damp earth and sent its roots deep into further cracks, while its leaves straggled on long limp petioles along the horizontal ledge.

On comparing this shade form with the typical, certain morphological and anatomical differences are plainly to be seen. These have already been pointed out (Part II B and C). These differences are obviously intimately connected with the darker, damper habitat, and may be briefly repeated here. The shade form shows more mesophytic characters.

I Morphological : The shade form is slender and straggling in growth form, not forming a compact clump ; the petioles are more slender, darker green, and only slightly hairy ; the pinnae are comparatively very large and thin ;

dark green and with only a slight coating of hairs.

11

Anatomical : The petiole shows less development of thick walled epidermis and hypodermis ; and much less development of the dark-coloured matter round the vascular bundle ; the pinna in transverse section is much thinner, and shows practically no development of palisade tissue, no thickening of the endodermis, and a thinner cuticle.

4. Anogramme leptophylla

- a. General localities. This fern occurs rather locally in various districts of New Zealand, chiefly in hilly or rocky places at no great distance from the sea. In the North Island it is found commonly at the head of the Manahau Harbour also more rarely near Auckland and near Napier and Cape Kidnappers on the East Coast. It also occurs about the Thames and near Wellington. In the South Island, it is found near Lyttelton and in some other parts of Canterbury. It is also found in Otago, around the Upper Clutha, and sparingly near Dunedin. (Thomson 1882).

On the Port Hills, Wall (1918) says it used to be plentiful near the Port of Lyttelton but its favorite habitats in this vicinity have been destroyed. He found it fairly abundant among the rocks between Godley Head and the Lyttelton Sumner saddle (Fig.) and in the Cashmere Gully, down the slope to the right of Victoria Park (14) on the map in figure The author found it only at Bowen's Gully (Fig. and) among the smaller rocks scattered over the tongue of

rocky ground that runs up between the ridges of the large U-shaped mass of rock (Fig.). The situation where this fern grows more marked with a A in figures and .

- b. Particulars of habitat : The habitat adopted by this delicate little fern differs greatly from those of the foregoing three species. It is always found in rather dark, shady spots right under the over-hanging ledges of the smaller rocks that are scattered among the grass and tussock. In these places there is, except during the warmest summer months, plenty of soft damp earth, watered by the seepage from the surrounding rock faces, and sheltered from the sun's rays by the over-hanging ledge and by surrounding vegetation, grass, tussock etc. Here grow numerous liverworts and mosses, and delicate specimens of Asplenium flabellifolium, as well as both prothallia and sporophytes of Anogramme leptophylla. The situations adopted by this fern are found then to possess plenty of earth, which is quite moist, the surrounding and over-hanging rock surfaces also being quite damp. The plant is admirably sheltered, and does not have to stand the drying influences of wind, or long continued sunlight, or heat radiating from the rock.

Thus it is obvious that this damp, shaded habitat differs as widely as possible from the dry exposed habitats of Ch. sieberi, N. distans and P. rutaefolius. A. leptophylla corresponding shows the characters of a mesophyte in contrast with the xerophytic characters of the other ferns.

An important point to notice however is this : while the sporophyte of A. leptophylla is purely mesophytic in character, there are in the whole life history of the plant, including both sporophyte and gametophyte stages, certain features pointing towards an adaptation to somewhat xerophytic conditions.

c. Sporophyte : With regard to the sporophyte, its mesophytic features, or lack of xerophytic features may be pointed out briefly :

I Morphologically, the whole plant is fine and delicate, with very slender petioles, and thin smooth pale-green, almost transparent leaves.

II Anatomically, the plant possesses a petiole with a large-celled epidermis. The cells have a very thin sclerenchymatous layer on the outside only ; the cortical cells are very large and thin-walled ; the endodermal cells are not thickened ; in the leaf, there is no thickening of cuticle, or of

endodermal walls ; no development of palisade ; and only a relatively few layers of large thin-walled mesophyll cells.

It is very important to note a certain fact about this mesophytic sporophyte. It is an annual plant, living for only about 8 or 9 months of the year. It lives its whole life through during the damp Winter season, when there is always plenty of moisture seeking down from the rocks. The author observed the plant at various stages during late Autumn, Winter and early Spring. In Autumn (March), the leaves were very small and young and without spores. Later on the plant was seen to be further advanced, and in early spring (September), it was fully grown with sori on the backs of the pinnae. Most of the sporangia were unripe and green, but a few were turning brown. The necessity for completing this thesis in October prevented the extension of these observations into the Summer months. Field (1890) says that the fern dies as soon as the warm, dry Summer weather begins.

Wall (1918) also remarks on its " curious habit of appearing in the Autumn and Winter, fruiting in Spring and dying away during Summer ".

Thus this plant with its mesophytic character dies down and escapes the hot, dry months of the year, when conditions are much more xerophytic. During this time it carries on its existence in a resting stage as spores. Thus it is very well suited to the conditions under which it grows. The seasonal variations in these conditions may have induced this annual habit in the plant.

d. Gametophyte : With regard to the gametophyte, it will be found that it is of great interest and importance from the ecological view point. While the sporophyte is annual the gametophyte, as pointed out in an earlier chapter (B. part II) is " perennial ", or has the power if the archegonia are not fertilised of continuing its existence for several years by means of a tuber.

The green outgrowths die down, but the tuber perennates, and later under suitable conditions, sheds forth new green expanded portions.

Referring to the duration of life of the prothallia of the Pteridophyta Goebel (p.189) says " In the gametophyte of the Pteridophyta, the general feature is that it dies after producing an embryo. ----- and on page 214, it is as a rule absorbed by the developing embryo, and this is why it is not given time (so to speak) to grow into anything in the way of configuration. But adaptations of the prothallus are to be found. For example, in its relationship to water, there are to be found one or two rare adaptations. There are no special contrivances for holding water, and up till now special arrangements for the tiding over of a period of drought have been found only in two species of the genus Anogramme, these taking the form of the production of tubers. The prothallus in A. leptophylla is pre-eminently fitted to withstand a period of draught. "

This quotation makes clear the significance then of the gametophyte of A. Leptophylla. The author has already (11 B) described the tuber in full, pointing out its comparatively large size (up to 3 mm. in length) ; its numerous fine hair-roots ; also the large quantities of reserve foods in the way of starch and oil to be found in its cells. These capacities as an assimilating organ and as a storage organ, together with its power of long life constitute the prothallus of A. leptophylla a very important and valuable asset to the plant in its relation to its environment.

CONCLUSIONS.

In this thesis the four ferns under discussion have been studied with the main view of pointing out the nature of their relation to their environment. To this end, detailed morphological and anatomical descriptions were given first, with comparative accounts of "shade" forms. Full descriptions of the habitats of both typical and "shade" forms followed, with the object of pointing out the markedly xerophytic conditions under which the plants live. In the light of these facts regarding the environment, certain morphological and anatomical characters of the ferns were then given their significance, from the ecological point of view.

On the whole it is to be seen that the ferns possess characters enabling them to sustain life under a considerable variety of conditions. In situations of a pronounced xerophytic nature, the typical forms of Ch.sieberi, N.distans and P.rutasfolius thrive quite well, while in more mesophytic situations their shade forms hold their own. The fourth fern, A.leptophylla sustains life in a situation that varies from mesophytic in Winter to xerophytic in Summer.

In spite of various adverse circumstances, such as aridity of habitat, exposure to winds, danger of destruction by fire or by sheep etc, these ferns are still quite plentiful on the Port Hills. It is to be concluded therefore that their characteristics successfully fit them for life under exacting conditions.

On the whole, the study of this group of ferns brings into evidence the remarkable correlation between a plant and its environment; a correlation that exists in so wonderful a degree throughout the whole vegetable kingdom.

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EXPLANATION OF FIGURES.

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Fig. 18. N. distans.

- a. Back of Pinnule, showing scales.
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- d. Spores.

Fig. 19. N. distans.

- a. Surface view of lower epidermis.
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Fig. 20. Pleurosorus rutaefolius

- a. Typical plant (actual size)
 - i. Back of Pinna (enlarged)
- b. "Intermediate" leaves (actual size)
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Fig. 21. P. rutaefolius

Plant on rock at Heathcote Valley.

Fig. 22. P. rutaefolius

- a. Back of typical pinna, showing sori.
- b. Back of "shade" pinna, showing sori.
- c. Sporangium.
- d? Spores.

Fig. 23. P. rutaefolius

- a. Surface view of lower epidermis.
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Fig. 24. P. rutaefolius

- a. Longitudinal section of petiole.
- b. Fig. "a" shown larger.
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Fig. 25. Anogramme lentophylla.

- a. Young plant (actual size) - showing tuber e
- b. Young plant (enlarged) - showing tuber etc
- c. Older plant (actual size)
- d. Older pinnae (larger) showing venation.

Fig. 26. A. leptophylla

- a. Back of pinna showing sori.
- b. " " " (larger) showing sori.
- c. Young sporangium.
- d. Sporangium dehiscing.
- e. Spores.

Fig. 27. A. leptophylla

- a. Surface view of lower epidermis.
- b. Position of sorus (diagrammatic)

Fig. 28. A. leptophylla - Prothallus.

- a. Actual size.
- b. Enlarged showing "archegoniophore" etc. (side view)
- c. Side view of another prothallus.
- d. Top view of it.
- e. Archegonia.
- f. Portions of tuber crushed, showing -
i starch, ii oil.

Fig. 29. A. leptophylla - Prothallus

- a. Cell surface with antheridia.
- b. Antheridium (larger)

Fig. 30. C. sieberi - Rhizome.

- a. Diagrammatic sketch of transverse section
near growing point.
- b. Diagrammatic sketch of T.S. of older portion.
- c. Sclerenchyma.
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Fig. 31. C. sieberi (typical)

Transverse section of petiole -

- a. Diagrammatic sketch.
- b. Larger drawing.

Fig. 32. C. sieberi (typical)

T.S. of pinna -

- a. Diagrammatic sketch of whole T.S.
- b. Portion of T.S. (larger)

Fig. 33. C. sieberi ("shade")

T.S. of petiole -

- a. Diagrammatic sketch.
- b. Larger drawing.

Fig. 34. C. sieberi ("shade")

T.S. of pinna -

- a. Diagrammatic sketch of whole T.S.
- b. Portion of T.S. (larger)

Fig. 35. N. distans (typical)

T.S. of petiole -

- a. Diagrammatic sketch
- b. Larger drawing.

Fig. 36. N. distans (typical)

T.S. of pinna -

- a. Diagrammatic sketch of whole T.S.
- b. Portion of T.S. (larger)

Fig. 37. N. distans ("shade")

T.S. of petiole -

- a. Diagrammatic sketch.
- b. Larger drawing.

Fig. 38. N. distans ("shade")

T.S. of pinna -

a. Diagrammatic sketch of whole T.S.

b. Portion of T.S. (larger)

Fig. 39. P. rutaefolius (typical)

T.S. of petiole -

a. Diagrammatic sketch.

b. Larger drawing.

Fig. 40. P. rutaefolius (typical)

T.S. of pinna -

a. Diagrammatic sketch of whole T.S.

b. Portion of T.S. (larger)

Fig. 41. P. rutaefolius ("shade")

T.S. of pinna petiole -

a. Diagrammatic sketch. of whole T.S.

b. Larger drawing.

Fig. 42. P. rutaefolius ("shade")

T.S. of pinna -

a. Diagrammatic sketch of whole T.S.

b. Portion of T.S. (larger).

Fig. 43. Anogramme leptophylla

T.S. of petiole -

a. Diagrammatic sketch.

b. Larger drawing.

Fig. 44. A. leptophylla



T.S. of pinna -

a. Diagrammatic sketch of whole T.S.

b. Portion of T.S. (larger)

- Fig. 45. Large Rock Mass at Bowen's Gully.
- Fig. 46. Nearer view of part of rock mass in Fig. 45.
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- Fig. 51. N. distans (larger) at Heathcote Valley.

Abbreviations used in the Figures.

ann,		annulus
anth,	.....	antheridium
arch,	.....	archegonium
c,	.....	cuticle
c.s.,		cell-surface
cx,	.....	cortex
d,	.....	deposit
en,	.....	endodermis
ep,	.....	epidermis
ex,	.....	exodermis
g.c.,	.....	guard-cells
g.l.,	.....	ground-level
gr,	.....	groove
h,	.....	hairs
h.r.,	.....	hair-roots
hyp,	.....	hypodermis
m,	.....	mesophyll
pal,	.....	palisade
per,	.....	pericycle
ph,	.....	phloem
px,	.....	proto-xylem
rhd,	.....	rhizoid
rhm,	.....	rhizome
rt,	.....	root

sc,	.....	scale
sel,	.....	sclerenchyma
spm,	.....	sporangium
spp,	.....	spores
sr,	.....	sorus
st,	.....	stoma
stk,	.....	stalk
stm,	.....	stomium
t,	.....	tuber
v.b.,	.....	vascular bundle
v.t.,	.....	vascular tissue
w.l.,	.....	withered leaf.
xy,	.....	xylem
y.l.	.....	young leaf.

Note: After the author had concluded the foregoing thesis, Professor F.O. Bower's book, "The Ferns (Filicales)" Vol I (1923), came to hand. As far as time permitted, this was used to verify certain of the facts set forth in the thesis.

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