INTRODUCTION

The characteristic features of the vegetation of Australia

I. General Physiography

At present the animals and plants of Australia are isolated from the rest of the world, except by way of the Torres Straits to New Guinea and southeast Asia. Even here adverse climatic conditions restrict or make it impossible for migration. Over a long period this isolation has meant that even what was common to the floras of the southern Asiatic Archipelago and Australia has become restricted to small areas. This resulted in an ever increasing divergence. As a consequence, Australia is a true island continent, with its own peculiar flora and fauna.

As in southern Africa, Australia is largely an extensive plateau, although at a lower elevation. As in Africa too, the plateau increases gradually in height towards the east, culminating in a high ridge from which the land then drops steeply to a narrow coastal plain crossed by short rivers. On the west coast the plateau is only 300-500 m in height but there is usually an abrupt descent to the narrow coastal region. The plateau drops towards the center, and the major rivers flow into this depression. Fed from the high eastern margin of the plateau, these rivers run through low rainfall areas to the sea.

While the tropical northern region is characterized by a wet summer and dry winter, the actual amount of rain is determined by additional factors. On the mountainous east coast the rainfall is high, while it diminishes with surprising rapidity towards the interior. Thus in New South Wales, the yearly rainfall at the edge of the plateau and the adjacent coast often reaches over 100 cm. In Queensland, the effect of coastal elevation on rainfall is even more marked. The most highly developed rainforests on the continent occur where the eastern slopes of the ranges reach their summit in Bellenden-Ker (the wettest region in Australia with over 250 cm per year.). The decrease in rainfall from the coast towards the interior is also striking. Todd in 1879 showed that summer rains occurred as far south as 28°S along the north-east coast. However, by 16° 15’ S these summer rains were of little value. Rainfall is also very erratic by this latitude: in certain years heavy thunderstorms and floods extend over almost the whole of the interior. In others, the rain may extend only a few hundred kilometres inland so that the whole area south of the Tropic of Capricorn becomes subject to drought. We now know that this lack of reliability in the rainfall also applies to the north-west of Australia. The amount of reliable summer rain also diminishes from east to west with the fall in elevation of the plateau. Again, as one proceeds southwards along the west coast, summer rain gradually decreases, the minimum being recorded in the vicinity of the North-West Cape.

The winter rains are very similar in total. At the higher latitudes it is abundant as, for example, at South-west Cape [Cape Leeuwin], where the rainfall exceeds 100 cm per year. Again, in Tasmania, on the western slopes of its cloud-covered mountains, several localities receive over 250 cm of rain per year. In addition to this, the rainfall is spread over most months of the year so that the summer/ winter periodicity mentioned for other parts earlier, does not apply. The central region of the south coast, particularly the coastal region of the Bight, receives very little winter rain. Otherwise the coastal regions in general receive adequate rain. The interior, however, is subject to the same uncertainty of adequate rain as mentioned for the zone of summer rains. Notwithstanding the above, essentially rainless regions, such as those represented by the deserts of the northern hemisphere, or the western areas of southern Africa and South America, are almost completely lacking in Australia. The whole area of the central plateau is, nevertheless, subject to problems associated with its water supply. Periods when raging floods occur alternate with year-long droughts. This unpredictable curse seriously restricts agriculture which, to a great extent at the present time, provides the Australian States with their staple industry.

The temperature component acts in an equally extreme and unpredictable way. The first impression is that the mean temperature is not in general very high for the latitude. But the range of values reached in the interior is considerable. This is particularly true for the variation in daily temperature. This variation is due largely to the great heat exchange made possible by the clear skies of the interior. The maximum temperature for the year varies between 40°C and 48°C. To find comparable conditions elsewhere, one must refer to the hottest deserts of the old world, such as those of the Sudan, Arabia and the Punjab. At the same time, daily variations in temperature are among the largest on earth (particularly at these latitudes). An average daily variation of 20°C is common in central Australia.

II. Formations

The huge tableland of the Australian continent is, for the most part, covered with very mesomorphic or xeromorphic plant forms, with savanna with stiff-leaved and prickly shrubs, or with desert-adapted species. The greatest range of vegetation formations extends towards the interior from the northern and eastern edges of the plateau as broad zones, and from the south-west corner only as a narrow zone. These include savanna woodlands, low forests, and even rainforests. There are, however, extensive areas where this vegetationally well developed margin is lacking. For example, along the north-west coast and the shores of the Great [Australian] Bight in the south, the sparse vegetation characteristic of the interior extends unaltered to the coast.

1. TROPICAL RAINFOREST

Because of the unreliability of rainfall in the interior and its marked periodicity in most coastal regions, Australia would not appear to be a suitable region for the development of true rainforest. However, a few scattered areas do occur along the east coast where the greater elevation ameliorates the otherwise harsh climate of this part of the earth. In such areas a local reduction in periodicity associated with heavier rainfall in the drier half of the year occurs. At these places rainforests develop. Although they occur only as isolated patches in the Australian vegetation, they include many interesting forms. In spite of their relatively small extent and scattered occurrence, they are of great relevance to the genesis of the Australian flora.

With regard to the general floristic pattern, these rainforests are quite distinct. At least this is true in the tropics, and it probably applies also as far as about 30°S. Enclosed everywhere by eucalypt woodland, the rainforests remain unmixed, and show a purely Malaysian affinity. Both formations meet abruptly. They are sharply marked off from each other, and through the light-timbered eucalypt parkland one may suddenly see, towering up like an abrupt wall, the dark-foliaged trees of the rainforest.

In the true rainforest, rainfall is the controlling factor in the maintenance of these floristically rich formations, the level and movement of groundwater playing no direct role. Australia does not possess many such rainforest patches. Their total area is negligible. All lie close to the east coast. Coming down from Cape York Peninsular the first rainforest area is met to the north of Cape Tribulation (16°S). Here Mount Finnigan is thickly covered to its cloud-topped crest with rainforest. It is rich in epiphytes, the whole being “hopelessly tangled”, as Semon puts it. However, it is only south of Trinity Bay, where the mountains of Bellenden-Ker and Bartle Frere rise to over 1600 m that really imposing rainforest appears. This is the most extensive, the most beautiful and without doubt, the best example of Australian rainforest. It ends, however, on the other side of Rockingham Bay. Near Ingham (18° 30’S), where the elevation of the plateau decreases and the rainfall drops markedly, the rainforest almost disappears. It does, however, extend further south, although its occurrence is strictly limited and patchy. Not until one travels south of 25° on the Upper Burnett, and again to the north of Brisbane, does the rainforest again become apparent. It makes its final appearance in the Mount Lindsay region. The Richmond River area is extremely rich in “brushes” as the rainforests are called by

the settlers. The "Big Scrub" which extends from the upper reaches of this river to the Macpherson Range has been described in detail by A. Campbell (in Victorian Natural. XVII (1900) 84). We learn from this how completely the tropical character of the forest has been retained to this point. Further south, however, the characteristic elements become less and less evident. The rainfall appears no longer to be adequate to sustain rainforest. It retreats into the lowlands until finally its characteristic and peculiar features are largely lost. The savanna forest becomes dominant, and the remnants of the former rainforest are restricted to the shelter of gullies and depressions. It is only much further south in the moist and rugged mountain districts of Gippsland and in the temperate Tasmanian climate that something of a renewal of the rainforest occurs. It is, however, different in that the plants tolerant of higher temperatures have to a large extent been thinned out, while those characteristic of more temperate regions have increased. In short, we have a new type of temperate rainforest which is related only by certain genetic links with the tropical rainforests of the north.

The most extensive rainforest area extends as we have already indicated, over north-east Queensland, from Cooktown to Ingham, between 16° and 18° 30'S. Areas such as Daintree River, Mulgrave River, Cairns, Russell River and Rockingham Bay are among those most frequently mentioned in the literature as being representative of this 'scrub' region. The edge of the plateau rises to about 350 m. It is bounded on the east by the mountain systems of Bellenden-Ker, Bartle Frere and others. This area has the highest rainfall for the whole of Australia. Up to 500 cm has been recorded at Johnstone River, and it is possible that still higher figures may yet be recorded. The run-off feeds many streams which flow all the year round. Of these, the Barron River (and its impressive waterfall, situated where the river descends from the plateau to the lowlands) is probably the most famous.

Even in this favourable terrain the occurrence of rainforest is often confined to limited areas on mountain slopes, to low ground, river-banks and river gorges. Where it is best developed, however, it stretches almost uninterruptedly from the coast over mountain and valley for 50-60 km inland to the heights of the plateau.

The character of the forest on low-lying areas differs somewhat from that at higher altitudes. In the former the growth is much more lush. The damp humid depressions on the lower courses of the rivers and creeks favour the development of dense under-growth and lianes in the depths of the forest. The occurrence of numerous tall trees (on which plank-buttresses and cauliflory occur in great variety) are also a feature. These in particular are still imperfectly known and need further study. In the undergrowth, the slender stemmed palm *Archontophoenix Alexandrae is* of common occurrence. Among the lianes various species of *Calamus* (Palm.) are prominent, together with a climbing bamboo *(Bambusa Moreheadiana* Bailey*),* which as yet has not been found in flower. In areas where the vegetation is less dense *Pothos longipes* (Arac.) and species of *Piper* cover the trunks. The great leaf masses of *Epipremnum mirabile* (Arac.) are frequently seen. Species of *Musa (M. Banksii* and *M. Hillii),* and a tall *Elettaria* (*E. Scottiana* - Zingiber.) complete the true Malaysian aspect of the forest.

By contrast the rainforest at the higher altitudes (between 400-500 m) at the edge of the plateau shows many different features. On the whole, it is somewhat less dense, the undergrowth in particular being less well developed. It appears to have been modified to the so-called "open" type of rainforest which Kurz contrasted with the "closed" type in Pegu [Calcutta]. Members of the Scitamineae*,* climbing plants belonging to the Araceae*,* and *Bambusa Moreheadiana* occur only rarely. Climbing palms represented by *Calamus moti* and *C. australis* are, however, still present, although their stems fail to match the size and rate of growth of those specimens which were such a feature at lower altitudes. *Piper is* still common, but the most frequently occurring lianes belong to more cosmopolitan hardier types. Among these, many fine and graceful plants occur. *Clematis glycinoides, Jasminum Dallachii, Smilax australis* (Lil.)*, Tecoma australis* (Bignon.)*,* together with many members of the Vitaceae festoon trees, lightly linking them together or draping their tops. Among the epiphytes, ferns and orchids are quite strongly represented. *Asplenium Nidus*

and *Platycerium* are among the most common. We have more detailed knowledge of the trees of this upper forest than of those of the lower parts, due largely to the investigations of the younger Bailey. A beautiful tree, *Tarrietia argyrodendron* (Strecul.) is commonly present. It is easily recognized in the depths of the forest by its plank buttresses and by the silvery and shiny undersurface of the leaves. Among the most important elements of these virgin forests we may list the following: *Elaeocarpus grandis* (Elaeocarp.), several species of *Ficus*, *Flindersia* and *Cedrela* (Meliac.), many beautiful Proteaceous plants such as *Stenocarpus* and *Embothrium,* the huge *Agathis Palmerstonii* (Pinac.), a *Podocarpus* (*P. amarus*, which is also found in Java), together with several members of the Lauraceae and *Aleurites moluccana* (Euphorb.).

Many of the plants show promise of becoming valuable timber trees for Queensland. Even now, sawmills may be seen in operation, indicating that the excellent nature of the timber of these highland forests has been recognized. The timber here is considered to be of better quality than that of the lowlands. This is believed to be due to the moderate temperatures occurring in these regions and to the light but more or less continuous rainfall which favourably influences growth.

Unfortunately, I have only seen the southern rainforest between Wide Bay and Moreton Bay in the dry season. They are rich dense forests about 30 km from east to west and quite like those of the tropics, although the Aracacea and Scitamineae play a smaller part and only *Aplinia coerulea* (Zingib.) is still common. *Calamus* and chocking figs together with the large and small palms, still play an important part. However, these rainforests owe their particular character to the mixture of the Australian *Araucaria* (*A. Bidwillii* and *A. Cunninghamii*) whose unmistakable crests stand out above the richly tinted foliage of the dicotyledonous trees. The earth is ornamented with ground ferns, otherwise it is poorly clothed in plant growth. B. W. Spencer visited Mount Cooran in the same region during a better season of the year and described the epiphytic orchids as very stricking, especially *Cymbidium canaliculatum* which attracts attention by the size and abundence of the hanging yellowish brown flowers.[1] In the more southerly Richmond forest (cf. Campbell's aforementioned description, p. 4) the "roof-garden" is decorated also with *Dendrobium (D. speciosum* and *D. Hillii)*. Yet in these high latitude (ca. 27° S) epiphytes are found frequently on rocks, for example the western slopes of Mount Cooran are completely covered with *Asplenium Nidus* and *Platycerium*, and also a *Dendrobium* with delicate white flowers which stand out pleasingly from the red of *Kennedya rubicunda* (Legum.) (Spencer *loc cit.*).

The rainforest areas are separated by regions whose rainfall is insufficent for such formations, and yet there is enough water present in the damp valleys and basins to support communities of gallery forests made up of many rainforest elements. The various gradations of this development are well known in Africa and South America. In this part of Australia the absence of large rivers does not permit the development of gallery forests of any size, but there are all grades from the moderately sized to the last trace of the Malayan vegetation in the narrow hollows which are found so often in southern New South Wales. In eastern Queensland the bottom of the valleys are occupied by the dark rainforest whilst on the higher ground the eucalypt savanna predominates. Toward the south there is a diminution in the diversity and thickness of these formations. The two dissimilar palms *Archontophoenix Cunninghamii* and *Livistona australis*, with *Alsophila australis* (Cyatheac.) and the showy agave-like *Doryanthes excelsa* (Amaryll.) still decorate the short rocky valleys running toward the ocean in the Illawarra district (34° 30?S) and in similar local favourable sanctuaries. Finally the trees disappear completely and only shrubs and lianas remain as indications of the Malayan character. This development comes to a certain conclusion in the west at the edge of the New England plateau and in the south in the cooler parts of New South Wales where thickets of lianas are found (in the water channels of the *Eucalyptus* forests) just as in the warmer zones they indicate the last traces of rainforest. Thus, not far from Broken Bay, I saw a thick undergrowth consisting of *Panax cephalobotrys* (Araliac.), *Synoum glandulosum* (Meliac.), *Cissus Bau-*

1 Victorian Natural. IX 16.

diniana (Vit.), *Marsdenia flavescens* (Asclepiad.), *Discoria transvera* (Disocor.) completely filling a narrow moist gully, but the trees which cast light shadow were eucalypts and on the slopes there was only savanna woodland.

2. SUB-TROPICAL RAINFOREST

Further south in Australia climatic conditions change again, the winter rains becoming more regular and abundant. As a result, many of the taxa with Malaysian characters once again become important. Because of this, right down to the extreme southern part of the continent and even beyond to Tasmania (which biogeographically is part of Australia), the vegetation in sheltered places is sub-tropical in character. One may speak of it as subtropical rainforest. It is much poorer in species than the tropical rainforest, and because of the pervasive presence of species of *Eucalyptus* it has quite a different aspect. The flora of this region, particularly that of east Gippsland, has been studied by F. von Müller[1]. He describes the situation as follows:

> "Rather suddenly, tropical species such as *Nephelium* (Sapind.), *Acronychia* (Rut.), *Ficus, Passiflora, Tylophora* (Asclep.), *Marsdenia* (Asclep.) and *Livistona* (Palm.) appear to the east of Cape Otway."

He indicates how this south-eastern corner of Australia is shielded from the cold Antarctic winds (to which the Cape Otway district is exposed) by Tasmania with its high mountains, while it is warmed by the current from the Pacific. The possible effect of drying winds from the inland north-west are also minimized by the presence of buffering mountain ranges. A more detailed description of the vegetation of this climatically mild region has been given by W. B. Spencer and C. French (Victorian Natural. VI). Dense plant growths occur in the narrow valleys and depressions. The huge *Eucalyptus amygdalina* and *Eugenia Smithii* (Myrt.), together with the tall *Olearia argophylla, Pittosporum bicolor* (Pittospor.) and *Elaeocarpus cyaneus* (Elaeocarp.), make up the most important components of these woodlands. In addition, large specimens (over 30 m high) of the fine "Cabbage Palm", *Livistona australis*, are present even though this is the southern-most limit of the range of such palms in Australia. *Smilax australis* (Lil.) and *Clematis aristata* (Ranunc.) also occur while luxuriant growths cover the ground amid the tangle of fallen branches and rotting vegetation which make these forests so difficult to traverse. *Polypodium, Blechnum, Gleichenia, Pteridium* and *Asplenium* are represented, and also several species of *Hymenophyllum,* which cover the stems of the tree-ferns. These tree-ferns (of which *Dicksonia antarctica* and the large *Todea barbara* are the most common) are the pride of the Gippsland forests.

These forests also extend considerably further westward, although their sub-tropical nature rapidly deteriorates. Near Wilson's Promontory, for instance, one can still find tree-ferns present in each narrow valley, while an epiphytic member of the Gesneriaceae *(Fieldia australis)* still grows on their stems. In Tasmania we find the last of the epiphytic orchids *(Sarchochilus parviflorus)* attached to dead branches of *Aster argophyllus* (at almost 42°S). In the mountains of western Victoria, the tree-ferns *Dicksonia, Cyathea* and *Alsophila,* at present form the famous fern-tree gullies. It is only in the most southern corner of South Australia - the so-called "Garden of the Colony", in the Mount Gambier district (about 140°E) - where the climate is equable, misty and somewhat humid in contrast to that further west, that we find the last of the tree-ferns. *Todea,* however, still occurs a little further to the west in the gorges of the Mount Lofty ranges.

South of Gippsland we find a continuation of the sub-tropical rainforest in Tasmania but the lianes and the higher epiphytes have almost entirely disappeared. In their place for the first time we find cryptogamic growths strongly represented. The heavy rainfall and the uniformly moist conditions (particularly in the hilly regions), together with the

1 A lecture on the Flora of Australia. School of Mines and Industry. Ballarat 1882

ameliorating effects of the sea upon the temperature, encourage a richness of vegetation in many parts of the island which is rarely met with on the mainland. Here we see impressive stands of *Eucalyptus globulus* and underneath them the forest floor is thickly covered with ferns and mosses. Through the finely divided and transparent meshwork of the tree-ferns one may gaze up at the majestic crowns of the eucalypts whose dark green foliage forms such an effective contrast to the delicate undergrowth. A well developed cryptogamic flora is present. Filmy ferns adorn the tree-fern stems while mosses and liverworts, together with a great variety of delicate plants, grow in rank abundance. The picture is almost reminiscent of that presented by the damp mountain forests of New Zealand.

From the point of view of the flora, the sub-tropical rainforests of Australia cannot be regarded as impoverished derivatives of the tropical forests. Rather, they possess much that is peculiar to them as, for example, the fine "Sassafras" tree *(Atherosperma moschatum* Monim.). In addition to this, the presence of antarctic forms gives them a character of their own. In some ways they form a link with Alpine vegetation. Amongst them are species of *Nothofagus* and shrubby members of the Compositae. *Eucalyptus,* however, remains the dominant genus in these woodland. Consequently, there exists in the south a peculiar combination of the Malaysian rainforest and the Australian eucalypt forest. This contrasts with the north where the two formations are sharply separated. It appears advisable here to refer briefly to the genus *Eucalyptus* which dominates the Australian vegetation to an extent not achieved by any other genus in any other part of the world. The genus belongs to the Myrtaceae, arising from a branch which is typically represented in eastern Malaysia, although its exact place of origin is not known. At the present state of knowledge, *Eucalyptus* forms a natural genus whose character is not easily mistaken, and whose distribution is also in many ways similar to that of the marsupials. Like this group too, its members have developed almost entirely in Australia. They have become adapted to almost all possible conditions. Thus one meets them as tall trees in the forests of the moist coastal regions, as characteristic plants of the park-like savannas, and as gregarious constituents of the dense bush of the hot, dry interior. They occur as low gnarled bushes [mallees] on the windy hill-tops as well as on the desolate exposed sandplains of the interior. Although they show great variability in appearance, in overall growth, and in the colour and abundance of flowers, the most constant feature is the more or less vertical orientation of the leaves. The species also are all evergreen. It is because of this evergreen appearance that the Australian landscape appears so drab.

Due to this adaptability of the genus *Eucalyptus* all attempts so far to organize the species on a truly scientific basis have more or less failed. The mutual interchange between the environment and the specific elements of the flora is achieved in a novel manner, and no analogies exist elsewhere on earth. The genetic constitution of *Eucalyptus* is the ultimate cause of this. In no other part of the world can one demonstrate so clearly that in order to understand the situation the specific nature of the flora must be considered independently of plant geography.

3. SCLEROPHYLL FORESTS and WOODLAND

The temperate rainforests of the antarctic portions of South America are dominated by *Nothofagus* (Fagac.). The climate of the neighboring drier regions has caused it to adopt a regular leaf-fall. This has not occurred in the case of the genus *Eucalyptus.* In areas where the rainfall decreases, becoming moderate in amount, and shows increasing unreliability, we still find forests which are difficult to compare with anything of the kind elsewhere. These are forests in which the *Eucalyptus* trees are almost entirely dominant. Only a few other plants reach tree-like dimensions, as for example, *Casuarina* and some members of the family Proteaceae, in particular *Banksia.* The eucalypts tend to be closely spaced but the well-known vertical orientation of the leaves gives one an impression quite different from that given by other leafy woodland. The only analogy that one could make would perhaps be that with a thinly grown coniferous wood. The undergrowth is

important and interesting. It is a dense mixture of low shrubs and of bushes with hard evergreen foliage and often brightly coloured flowers. Herbaceous perennials are rare and annuals seldom common. Grasses are poorly developed, their place being taken by members of the Cyperaceae and Restionaceae. Ferns are few in number and of relatively little importance. The most common one would be *Pteridium aquilinum.* Tree-ferns are completely lacking.

This sclerophyllous formation shows its best development in the high rainfall area of south-west Australia between 30° and 35°S. The forests of *Eucalyptus marginata, E. diversicolor* and *E. redunca,* constitute the best example of this sclerophyll formation. It will be described in detail later. The rich undergrowth of these south-western forests forms an important component of the vegetation scene. The undergrowth extends beyond the boundaries of the forest area, changing gradually through xeromorphic modifications into the sandplain communities.

In south-eastern Australia *Eucalyptus* woodlands with hard-leaved undergrowth also occur. The formation is also found there in districts with a moderately high rainfall (50-l00 cm per year), but with a markedly dry period in summer.

In South Australia these conditions are only found east of Spencer's Gulf and there only in the southern portion of the mountain country. Even here sclerophyllous woodland is incompletely developed and, as Schombergk has already shown, it is broken up by savanna-like formations. Several species of *Eucalyptus* (e.g., *E. paniculata, E. viminalis* and *E. rostrata)* predominate and in the undergrowth we meet species of *Correa* (Rut.), *Grevillea* (Prot.), *Hakea* (Prot.), *Isopogon* (Prot.), *Exocarpos* (Santal.), *Acacia* (Legum.), *Banksia* (Prot.), *Cassia* (Legum.), *Calythrix* (Myrt.), *Pomaderris* (Rhamn.), *Leucopogon* (Epacr.), *Leptospermum* (Myrt.), *Daviesia* (Legum.), *Dillwynia* (Legum.), *Eutaxia* (Legum.), *Platylobium* (Legum.), and *Pultenaea* (Legum.). They comprise a series of genera which are representative of this formation in south-west Australia. The frequent occurrence of several species of *Xanthorrhoea,* which are common to the two areas, although they are not exclusively found there, is also important. The strongest development of these woodlands occurs in the deep valleys where the streams flow all the year round so that the plants remain fresh and green. It has already been mentioned that *Todea africana* (a most delicate fern) occurs there. Schomburgk has also given a list of other decorative ferns which inhabit these gullies. Violets *(Viola betonicifolia* and *V. hederacea)* may be found growing on the margins of the streams following good rains. The blue-flowered *Chamaescilla* and the white-flowered *Burchardia* (Lilac.) are present on the slopes while, higher up, *Pteridium* is often present.

It is not until we travel east of the dry Murray region in Victoria that we re-encounter this formation. It keeps essentially to the mountains, only descending to the lowlands as one passes eastwards and the rainfall increases. Finally, towards the north as we reach New South Wales and the winter rains cease, it is once again confined to the mountain areas. In all these regions it seems to develop well on sandstone soils. From the Grampians in the west of Victoria to the northerly parts of the Blue Mountains, it is on sandstone that the richest undergrowth in the *Eucalyptus* woodlands occurs. C. French (Victor. Natur. III (1886) p 147 and on) reports the following as playing a prominent part in the make-up of this undergrowth in the Grampians; members of the Epacridaceae, together with *Lhotskya* (Myrt.), *Conospermum* (Prot.), *Grevillea ilicifolia* and *G. dimorpha* (Prot.), *Correa,* and *Eriostemon* (Rut.) and *Hibbertia virgata* Dillen.). In favorable areas in the vicinity of Melbourne a similar type of vegetation is met with at lower elevations. The same applies also in eastern Victoria, Tasmania and the more southerly parts of New South Wales. Further north this formation, which is evidently dependent upon the winter rains, is confined to high ground and finally disappears altogether. It is well developed on the Blue Mountains on the edge of the tableland at about 200 m, where the undergrowth is particularly dense consisting of bushes from 1-2 m in height. Thickets of *Pteridium,* species of *Acacia,* members of the Proteaceae, *Pimelea* (Thymelaeac.), *Xantorrhoea* (Lil.), *Hibbertia* (Dillen.) and species of Epacridaceae occur. Grasses and herbs are, however, lacking. In certain places there is a marked resemblance to parts of the

Jarrah country of Western Australia. One may note that it is in just such places that the very definite occurrence on sandy soils of the representatives of the true Australian (autochthonous) flora becomes apparent. In New South Wales, the sandstones end in the Clyde and Braidwood district. It is here that one finds a large number of species which are at the southern limit of their distribution (see Maiden, in Proceed. Linn. Soc. New South Wales 2 ser. IV (Sydney 1890) 107-112).

With regard to the sclerophyll *Eucalyptus* forest, we may note that like rainforest it occupies only a small area but has a wide range across the continent, some 3000 km from Cape York to Tasmania and from the Swan River to the Blue Mountains.

4. SAVANNA WOODLAND

Savanna woodland occupies extensive parts of the marginal areas of the Australian tableland. While only weakly developed in the west, savanna woodlands are a major features of the eastern landscapes. In many cases they extend into coastal regions. In the southern part of Australia, the savanna woodland reaches its strongest development where soil conditions are favorable and the rainfall varies between 60 - 35 cm per year. Towards the north, however, in the regions of summer rainfall, it only persists where the rainfall is considerably higher.

In Western Australia, the savanna woodland appears to be confined to a comparatively small area. It may be present to some extent in the neighborhood of the Tropic where, unfortunately, little investigation has been made. In the south-west, however, it is only present along a very narrow zone. The dominant tree genera are, as usual, *Eucalyptus, Casuarina,* and *Acacia.* In the western savanna woodland *Eucalyptus loxophleba, E. occidentalis* and *Acacia acuminata* are particularly important.

Extensive areas of savanna woodland occur in the coastal areas of South Australia, and detailed descriptions of these have been published. Behr (in Linnaea XX), for instance, described it as meadow-like grassland. It is characterized by the presence of large eucalypt trees which are sparsely scattered throughout the area, producing a park-like effect. On poorer soils *Casuarina* occurs, its brownish-grey crowns contrasting strikingly with the green of the grass. As a rule they are rarely taller than 10 m and are dwarfed by the tall *Eucalyptus* trees. *Acacia* species, e.g. *A. retinodes* and *A. pycnantha,* are also found here. The latter rarely grows more than 2 m high, but it has a decidedly tree-like habit of growth and is easily recognised by its umbrella-like crown. It often forms small woody enclaves within the formation. It is an exact analogue of the western *Acacia acuminata.* Shrubby undergrowth is rare and in typical savanah woodland the only commonly occurring species is *Bursaria spinosa.* This is a privet-like member of the family Pittosporaceae which is widespread over almost the whole of Australia. On the other hand, there is a thicker growth of herbaceous plants and, although other herbs are very well represented, grasses predominate. In favourable localities, members of the Liliiflorae and two other bulbous plants are abundant, but the annual composites dominate the scene. A small number of introduced plants are present in addition to the foregoing. It is only in the grassy formations in Australia that large numbers of alien plants have established themselves. Most have come from Europe, but a few have been introduced from South Africa. Only one or two, however, have become widespread. Amongst these are *Medicago denticulata, Xanthium spinosum* and *Cryptostemma calendulacea* (Compos.), which many Australians mistakenly call the Dandelion). This is often extremely prevalent and gregarious on fallow land. In the cooler moister regions of the south-east *Rubus fruticosus* and *Ulex europaeus* occur. Wild roses of European origin are also found, particularly in Tasmania. In the tropical and sub-tropical regions the cactus *Opuntia* is present. These introduced plants, however, rarely pose any serious threat to the hardy native flora.

The strong development of undergrowth in savanna woodlands reflects, better than that of any other formation, the marked periodicity which prevails over wide areas of Australia. The first botanists in South Australia described in detail the different phases. Just before the beginning of the wet season everything appears dry and dead with the

exception of a few branches of *Eucalyptus* which may be in flower. Within a few days everything is changed by the rain. The annual grasses grow rapidly and form a fresh green carpet rather like that of a European meadow. The first flowers to appear are *Drosera Whittakeri* and *Oxalis corniculata.* They are the forerunners of the army of wildflowers which develop within a few weeks. They are followed by *Ranunculus lappaceus, Hypoxis glabella* (Amaryll.), *Stackhousia* (Stackhousia.) and many others, until the end of August when the number diminishes. Flowers of orchids and lilies next appear in great profusion. Each week brings new forms. The bright red *Kennedya prostrata* (Legum.) and the gay colours of *Swainsona* (Legum.) are splendid decorative features. Finally the sward "becomes a rich meadow ground in which related species develop in great variety'. These form 'as with us the last act of the beautiful drama" (Behr *loc. cit.* 550). "The ground which only a short time ago was rich and green, then comes to resemble a ripe but very thinly sown cornfield and the number of plants in flower diminishes daily. This continues until finally the only vegetation left appears restricted to the unusual species found in dried up creeks and small streams. The onset of this dry period is somewhat variable. However, it never sets in before the end of November and sometimes rather later, usually by the beginning of February" (Behr in Linnaea XX 551). However, by then the undergrowth appears completely dried up, with the exception of the almost succulent *Lobelia gibbosa.* At this time also many eucalypts develop their flowers. "*Acacia retinodes* also bursts into blossom at this time, while the bright-red flower tassels of *Loranthus* hang from the eucalypts, casuarinas, and acacias".

In Victoria, New South Wales and Queensland, the savanna woodlands occur in a broad zone often several kilometres wide, running parallel to the coast. It has been described for New South Wales under the name of "Argyle vegetation" by Lhotsky (in Hookers London Journ. of Bot. II (1843) 135). This is a most important region from the point of view of agriculture and in many places the native vegetation has been largely cleared. When it does remain in its natural condition, the same picture is presented again and again. It shows the uniformly and sparsely scattered eucalypts together with the mixture of species of *Casuarina* and *Acacia* with their mistletoe parasite *Loranthus.* The frequent presence of umbrella-like tree crowns and the ground covered with sparse underbrush is also a feature. According to the time of year, the grasses and herbs may appear fresh and green, or dried up and brown. Depending also upon the nature of the season they may be well developed and tall or sparse and depauperate. Through the blooming and fading of the flowers, and the colour play of the composites at the close of the favourable season, the overall impression given by savanna woodland with its characteristic plants is the same from west to east and from south to north.

The number of species of *Eucalyptus* which are found in the forests of the east is very high. Many of them are fine trees valuable for timber. They vary greatly in height, in growth form, in mode of branching, and in type of bark, as well as showing considerable differences in their flowers and fruit. Their habitats are sometimes extensive, sometimes very localized. In some places they are sharply segregated, in other areas their habitats adjoin and overlap with broad transition zones. The early colonists described them as gums, stringybarks, ironbarks, boxes and bloodwoods. But these terms are somewhat vague and are of little use to the taxonomic botanist. Even an experienced taxonomist finds it difficult to master the genus *Eucalyptus.* Only a few species can be easily recognised from a distance by some striking character as, for example, the delicate-leaved *E. crebra* in New South Wales, *E. melliodora* with its bright yellow bark, and similarly *E. platyphylla* which with its white trunks is first encountered near the tropics. It re-occurs on dry sandy country in the tropical parts of Queensland often as the dominant tree. In addition to the eucalypts, species of *Tristania* (*T. conferta* and *T. suaveolens*) are present. They are closely related to *Eucalyptus,* and this is clearly indicated by their appearance. For the physiognomist, they have much the same significance as the true *Eucalyptus* species.

In dry areas this *Eucalyptus* forest is only enriched to any marked extent by the

presence of the coniferous genus *Frenela* [*Callitris*][1]. This cupressoid, which from a distance resembles a poorly developed pine tree, forms an important element of the savanna woodland both in Queensland and New South Wales. From the interior of New South Wales southwards to Victoria a very broad zone of vegetation is present which is actually characterized by the mixture of *Eucalyptus* species and *Frenela* (*F. verrucosa* and *F. calcarata*).

The transition from savanna woodland to other formations is similar everywhere.

What is of particular interest, however, is its strong development in places where adequate water is available. Behr has already aptly described the use made of shallow valleys and creeks in the savanna woodlands. Majestic eucalypts with trunks over 1 m in diameter have their roots in the damp earth. A border of imposing shrubs accompanies them, e.g. *Viminaria* (Legum.), *Leptospermum* (Myrt.), *Melaleuca* (Myrt.) and *Myoporum* (Myporo), just as willows accompany the poplar and the ash tree. At the bottom of valleys, woody plants are naturally lacking, but when the surface water disappears, the ground becomes covered with a soft green carpet consisting of numerous herbs. They belong mostly to cosmopolitan genera, but many of the species are strictly Australian. This green band, shaded by tall trees on the banks, remains fresh long into the dry season when everything on the slopes above is withered and bleached to the colour of dry straw.

On the other hand, the gradual deterioration of the *Eucalyptus*-enriched savanna woodland is a feature which, at least in eastern Australia, also presents something typical. Jung (Petermanns Geogr. Mitt. XXIII (1877) 352) described how it takes place on the west slopes of the Flinders Range (South Australia). Where the rivers emerge from the hills: "Their beds widen out between the banks to a width of 2-300 feet the banks being covered with trees and shrubs. Towards Lake Torrens the vegetation becomes sparser with acacias gradually replacing the eucalypts, while sand instead of gravel appears in the river beds; these channels branch and finally the stream bed disappears altogether." The vigorous growth of vegetation along the stream bed and the thick layer of gravel and stone which fills the bed is quite characteristic of the creeks of the Mount Lofty and Flinders Range area. "Only where the eucalyptus vegetation peters out do we find that the stony nature of the district also disappears. Then stunted species of *Casuarina* make their appearance, followed by species of *Acacia*, and both finally make way for salsolaceous plants."

In the north-east, in Queensland, savanna woodland presents a striking feature in the extremely sharp boundary with the rainforest. Attention has already been drawn to this fact already. Its appearance is completely different from that of the rainforest. *Eucalyptus* species (together with *Tristania* or *Syncarpia*) form well-defined stands of tall trees. Only a few other woody plants are of any consequence, e.g. the delicately branched casuarinas (*C. Cunninghamiana* in particular), some *Acacia* species and *Banksia integrifolia*. The ground is richly covered with grasses and *Pteridium* also plays an important role. Shrubby undergrowth is very sparse, while the unmistakeable forms of *Cycas* are characteristic figures in the landscape. Some lianes and epiphytes have invaded the formation in the forest area where most rainfall occurs. They festoon the rough surface of *Cycas* in particular. Of the ferns, *Drynaria quercifolia* (even some with quite large stems) is present here and also mosses and orchids, e.g. *Oberonia palmicola*. Eucalypt trunks on the contrary support few guests. Occasionally in the region of the Barron River, I did see slender shoots of *Vitis trifolia* growing on their bark; but this was the only liane in these woodlands.

5. RIPARIAN WOODLANDS

It has already been mentioned that, near the east coast, a part of the riparian woodland is represented by complexes of the more resistant elements of the true rainforest. Beyond these areas and in the region of the pure savanna woodland one finds communities of river-banks which are in many ways characteristic. F. von Müller, while

1 see Maiden, The Forests of New South Wales. Agricult. Gazette of N. S. Wales 1901

on Gregory's expedition, found the following species to be common along the northern rivers: *Terminalia chuncoa* (Combret.), *Jambosa eucalyptoides* (Myrt.), *Morinda Leichhardtii* (Rub.), *Inga moniliferum* (Legum.), *Agati* (Legum.), *Polygonum Cunninghamii* (Polygon.), *Pandanus, Melaleuca* and *Eucalyptus rostrata.* These trees shade grassy valley slopes with an undergrowth consisting of a mixture of savanna and pan-tropical types. As the rainfall diminishes towards the south and west there is a gradual impoverishment of these riparian woodlands. The palm *Livistona alfredi* extends westwards to 117°E longitude. *Pandanus* does not seem to go beyond 125°E longitude. Finally, only a very small group remains. However, *Eucalyptus rostrata* and *Melaleuca leucadendron* continue to survive in the driest regions and adorn the creek banks with their fine crowns. *E. rostrata,* however, extends also beyond the tropics and in fact reaches the south coast. No other single species of the tropical riparian forests and woodlands extends that far.

6. COASTAL WOODLANDS and SCRUBS

Mangroves which occur along the tropical coast of Australia are somewhat depauperate relatives of the Malaysian forms, and neither floristically nor biologically have they developed any special features of their own. Its most resistant and extensive element is *Avicennia officinalis.* This Mangrove appears to occur around practically the whole coast of Australia, although here and there it is rare. In Tasmania for instance, it does not occur at all.

Immediately behind the mangrove swamps in many of the drier regions, one encounters the inland communities. On the north-east coast, however, a special coastal woodland formation can be distinguished. Also on the southern coast, dune and marsh communities are present.

The north-eastern and north-western coastal woodland occurs characteristically in the region of plentiful summer rain, and consequently extends from the Kimberley region eastward as far as Moreton Bay. *Melaleuca leucadendron,* unmistakable with its tall stem and its white bark splitting off in flakes, plays the most important role in this region. In the cool season of the year the scent of its greenish-white flowers fills the air. Further inland, *Tristania* (Myrt.) and species of *Acacia* become common and almost all are imposing trees. Most species of *Acacia* here possess remarkable broad phyllodes. In moist places in the tropics *Wormia alata* (Dillen.) is an important element, as is also *Clerodendron* (Verben.), and a number of leguminous lianes. The whole scene is characterized more by the strong development of these few forms rather than by the presence of a large number of different species. *Pandanus,* palms and *Cycas* become more abundant as one moves further away from the coast. *Alpinia coerulea* (Zingib.), *Amorphophallus* (Arac.) and *Tacca* (Tacc.) fill the shady places. *Pothos* (Arac.) climbs on their stems and great tufts of *Drynaria* (Polypod.) hang down. On the lakes, the water is covered by *Nymphaea gigantea* and *Nelumbium speciosum.* In short, a large number of those species which are of wide distribution in the world's vegetation are present. As one passes further into the interior the number of the above species gradually diminishes. This process continues until we reach the transition zone to the real savanna or to the sharp line where the rainforest suddenly begins. It may be noted, however, that projecting arms of the latter extend along the water-courses deep into the strand woodland.

In the southern coastal commuities, the presence of tall trees is the exception rather than the rule. However, *Eucalyptus gomphocephala,* an imposing tree which occurs in south-western Australia, between the Swan River and Cape Naturaliste, grows in abundance near the coast. Some species of *Melaleuca* (called paperbarks because of their white bark which sheds in flakes) occur as trees of gnarled form. It may be noted that they also appear in moist places in the interior. But the bulk of the coastal vegetation of the temperate parts of Australia consists of shrubs. According to their taxonomic character, they always bear a distinct relationship to the grasslands of the interior. As a result we get the remarkable fact that in south-western Australia the coastal bush differs sharply from the communities immediately bounding it on the interior, and appears as a

border of strange forms. Phyllode-bearing species of *Acacia* are present everywhere as an important genus, while *Alyxia buxifolia* (Apocyn.), *Myoporum* spp. (Myopo.), *Pittosporum phillyreifolium* (Pittspor.), *Fusanus acuminatus* (Santal.), and *Leucopogon australis* (Epacrid.) play a more or less important role. Where the sand becomes looser the number of shrubs diminishes considerably and herb-like dune plants such as *Apium* (Umbell.), *Mesembryanthemum* (Aizoac.), *Spinifex* (Gram.), *Lepidosperma* (Cyper.) and other related plants, together with several species of *Atriplex, Rhagodia* (Chenopod.) and *Zygophyllum,* appear. In addition, certain local elements, most of which may be regarded as extensions of the inland vegetation, occur. The flora of the muddy ground is more uniform in the south than the psammophilous dune vegetation. The most important elements of the scanty plant growth are *Salicornia, Atriplex, Chenopodium, Rhagodia* and *Apium.*

7. SAVANNA

Towards the interior the savanna woodland gradually changes to savanna over wide areas of Australia. By degrees the trees are found occurring further and further apart; they also show a decrease in height and vigour. This decline is particularly true of the eucalypts. The acacias compete more and more strongly with them until finally the savanna formation - the real "grassland" of Australian authors - develops its characteristic form.

It was most fortunate that Schomburgk described the scenery of this interesting formation in the east. The grassland, according to him, forms the principal part of South Australia. It consists of endless undulating plains (stretching from the coast towards the north and east). The coastal area, once covered by savanna woodland, is today the granary of the country, while the grassy plains of the interior constitute the pastoral areas. Their extent seems immeasurable and they finally blend with the horizon, becoming like the deserts, monotonous and lonely. In the deep interior there are only a few fertile regions of moderate extent. For the rest, bare sandstone tops and dune-like sandhills alternate with gravelly and arid plains. Only where the salty soil is covered with scattered wind-polished stones does a very sparse vegetation, consisting of succulent members of the family Chenopodiaceae *(Kochia, Atriplex* and *Salicornia),* together with hardy grass tufts, manage to survive. Usually, however, one sees on the grassy plains low shrubs and small strongly branched trees. These may be solitary or arranged in clumps which stand out like islands emerging from the sea. They consist chiefly of *Casuarina* spp. (e.g. *C. stricta, C. glauca, C. distyla),* eucalypts *(E. odorata, E. drumosa, E. virgata)* and *Acacia pycnantha.*

According to R. Schomburgk, "The grassland, in fact the whole appearance of the plains, bears a striking resemblance to the savannas of British Guiana. Naturally there are great floristic differences between the two, but these savannas usually present the same undulating ground, the scattered much branched trees, the oases, and the rivers lined with a green belt. The grasses and herbs which cover the areas during the dry season show the same sunburnt yellow character. With the onset of the rainy season, there is the same magical re-appearance of the green colour."

In Western Australia, Schomburgk's descriptions would apply only in a few cases, specifically to a few districts near the tropics. Elsewhere, the western half of the continent presents only the most depauperate picture. Because of the unreliability of the rainfall (15-25 cm per year.), it resembles desert rather than savanna. Species of *Acacia,* with their stiff, narrow oblong phyllodes and greyish-green colours, tend to dominate this area. We may mention, for example, *Acacia aneura* (called 'Mulga' by the early settlers). The grass growth, however, is scanty. The everlastings persist all the year round and over wide areas the salt-bush, with its glaucous or grey coloured fleshy stems, is the dominant vegetation form.

The situation in the eastern half of the continent is quite different. Here, in normal years, the summer rains extend far into the south, creating those broad grassland zones which play such an important part in the cattle industry. These grasslands develop

gradually from savanna woodland. On the other hand, they also change very gradually into almost grassless deserts as the rainfall diminishes.

Well towards the south, in the high plains at the foot of the Australian Alps, a savanna-like vegetation is present which is known locally as the "Mineroo-vegetation". In winter the plants are covered here and there by snow, but by November they have become green and form fine herbland until April.

The savannas in the region of the Darling, insofar as this river belongs to New South Wales, are, according to Maiden[1], characterized by "Low-growing species of *Eucalyptus, Casuarina, Acacia,* useful pasture shrubs and saltbush". These are in effect the same features as are present in South Australia. Further north the savannas extend to the coast at the Gulf of Carpentaria. They show a great diversity of form, but always retain the same fundamental characteristics. In fact, as Warburg states, it is the only formation of Australia which extends unaltered beyond the Torres Straits to New Guinea. Here, in the Fly River Basin, it becomes widespread.

The number of individual grass species which occur in these savannas is not as yet definitely known. Bailey mentions that on the "Downs" in the interior of Queensland the number of grass species is high and that for the most part they have high nutrient value. Species which are particularly highly regarded by the cattle farmers include *Andropogon sericeus* (Blue grass), *Astrebla pectinata* (Mitchell grass), and several species of *Panicum, Danthonia* and *Sporobolus.*

Because of the lack of reliability of summer rainfall in this part of the world, an unfavorable physiological peculiarity has been impressed upon the savannas of almost the whole of Australia. A rapid progression through the developmental processes occurs. This is in marked contrast to the savannas of Guiana and, more particularly, to the pampas of the Argentine. In Australia, where in one year a tall grass field waves, concealing horse and rider, in another year a poor growth occurs, the grasses being scarcely a foot high. This lack of reliability in one of the most vital climatic components, resulting as it does in long and frequently recurring droughts, has made the settlement and development of Australia exceedingly difficult and dangerous.

8. SHRUBLANDS

Over much of Australia, open grass plains are absent, their place being taken by shrublands which are very strongly developed. These constitute the so-called Australian "scrub". The scrub is the most characteristic form of vegetation in this part of the world, just as the savanna is in Africa. A large number of different types are to be found which we may list as follows:

a. Mallee scrub

On the southern margin of the tableland a quite dense assemblage of shrubby eucalypts is present. It appears to consist of a mixture of several *Eucalyptus* species with an admixture of other genera. These communities are characterized by the presence of strongly branched shrubs with dull green leaves and a general impression of barrenness. Called 'mallee scrub' by the early settlers, this formation extends from the Stirling Range in the west to the Murray River in the east. It comprises landscapes of depressing aridity which are often termed 'desert' in the literature and on the maps. But they are, in fact, deserts of a most peculiar character. The mallee scrub of South Australia has often been described, and the accounts of Schomburgk and Behr are generally known. These descriptions, for the most part, also apply to Western Australia. The scrub is an 'ocean of shrubs' extending further than the eye can reach and scarcely penetrable. Landmarks are lacking except where the harsh outline of some rugged hill rises above the dreary mass. In spite of the first impression of monotonous uniformity, however, the bush presents quite a diverse structure when more closely examined.

In one place the formation will be an almost pure and unmixed stand, in another

1 The Forests of New South Wales. Agricult. Gaz. of N. S. Wales 1901

a mixture of the most different elements; in some one finds shrubs all about the same height, while in other parts some members actually reach the dimensions of tall trees.

Pure stands of Eucalyptus communities are frequently encountered in the Murray Basin area. Here, *E. dumosa, E. uncinata, E. bicolor* and *E. incrassata* participate in the formation of a closely interwoven bush. This is the extensive shrub-labyrinth whose appearance Schomburgk termed "oppressively" uniform. 'The relatively low and similar height of the plants and the dull blue colour of the foliage form a picture which from a distance looks like the surface of the sea, extending to the horizon.' Frequently, however, the mallee scrub is found to be richer in species. Together with *Eucalyptus* species, one may find *Casuarina, Melaleuca* (Myrt.), *Exocarpos* (Santal.), *Dodonaea* (Sapind.) and *Frenela* (Pinac.) present in the formation, as well as an abundance of smaller bushes representing many different Australian genera. These are for the most part similar in form and appearance, yet specifically different according to the locality and type of soil. The genera represented are richer in species than those of the savanna formation and the whole is dominated by xeromorphic species. Behr describes how: "heath-like or vertically oriented leaves are crowded in a moss-like interlacing kind of growth into rounded shrubs. Alternatively, they sparsely cover the bareness of the long shoots which project from the forbidding scraggy shrubs. The dominant colour of this foliage is a dull blue green. However, in this respect nature allows some variety. *Rhagodia* (Chenopod.), for instance, bears whitish foliage, while other shrubs have brownish red leaves. Strangest of all because it appears so incongruous among such surroundings is the bright green of *Cassia* (Legum.) and of *Santalum*. Compound leaves are rare but, apart from that, one finds the greatest variation in shape, from ovate through lanceolate to spiny leaves. One notes also that leaf arrangement varies from the closest degree of crowding through all possible gradations to leafless branches. At the same time it is apparent that plants which belong to very different families are present. However, they are so alike in habit that it is only when in flower or fruit that one can make reliable determinations."

It is on the boundaries of the mallee scrub area that the richest developments of the formation occur. Such a favorable zone is present in the Southwest Province where it is particularly broad. At 129°E, the "giant mallees" rise to heights of 15-18 m, but as one proceeds further west, such tall forms become more and more common until in the Coolgardie Goldfields area, 122°E, they appear in woodland-like communities. A detailed description of these is given in a later section of this work. Under such circumstances, transitions to savanna woodland occur.

Over the whole extent of the mallee scrub area the undergrowth is more or less similar in nature. Some strongly xeromorphic grasses *(Stipa, Neurachne* and *Anthistiria)* grow in scattered tufts on the infertile soil. Herbs appear more plentifully only when the winter rains have been more than adequate, then everlastings, brighten the otherwise drab picture. Very important, in particular, are the mealy-white or almost metallic-looking succulent members of the Chenopodiaceae, which are resistant to the dryness and heat.

From the point of view of seasonal development, the scrub outwardly presents a very different picture from the grassland. This feature is clearly described by Behr who points out the small degree of change which takes place in the scrub with the advent of the dry season: "Little can fade where little sprouts, and each month sees the same dense, desert-like assemblage of rigid, sapless and mostly similar appearing species. Nevertheless, in the somewhat moister areas, flowers are rarely completely absent. With more abundant rain, herbs and some grasses develop, although they soon disappear. The flowering period of the shrubs and trees is, however, of longer duration than on the grassland, and it continues, although with diminished vigor, right up to the beginning of the next rainy season. It almost appears as if the flora of this region was quite independent of all climatic conditions. It has something demoniac about it. Undeterred by the hostile outer world it produces its own floral decoration." Up to the present these areas have largely been left undisturbed by man. The scrub "offers little resistance to the set-

tler but gives him at the same time little hope."[1]

Corresponding formations are sometimes present in the regions of tropical summer rainfall, although their components differ considerably in their taxonomic character from their southern counterparts. In his paper on the botany of the Gregory expedition to North Australia, F. von Müller gives an imposing list of plants which form the vegetation of these "sandstone tables" occurring to the west of the Gulf of Carpentaria. The list shows the presence of a peculiar mixture of tropical elements with many that we must consider as typically Australian. Thus, with species of *Terminalia* (Combert.), *Psoralea* (Legum.), *Strychnos* (Logan.), *Spathodea* (Bignon.) and *Bauhinia* (Legum.), there occur small eucalypts with brightly coloured flowers, and also species of *Boronia* (Rut.), *Jacksonia* (Legum.), *Verticordia* (Myrt.), *Goodenia* (Gooden.), *Persoonia* (Prot.), and *Grevillea* (Prot.). This is a very important flora, and further biological studies of it are urgently needed. That there are many points of agreement with the mallee types of the south can scarcely be doubted. It is also interesting that they seem to be similarly conditioned insofar as that in both places we have evidence of a sandy substratum.

b. Sublittoral sclerophyll shrubland

In the moister regions characterized by regular and plentiful winter rains, the mallee scrub as such comes to an end. To a certain extent it passes into other formations. Either the eucalypts become so dominant that *Eucalyptus* woodland with shrubby undergrowth is developed or eucalypts play a very small part and thick shrubby growths are formed which can be compared with the "Maquis" of the Mediterranean, or better still, with the stiff leaved scrub of the Cape. This formation shows its best development in the coastal regions of south-west Australia, between the Murchison River and Esperance Bay. It is rich in species and adds considerably to the number of species in the flora of Western Australia. The formation consists chiefly of shrubs of all heights down to heath-like dwarf bushes. In the rainy season a few perennial herbs and bulbous plants (Liliaceae, Orchidaceae and *Drosera)* together with some annuals also occur. These, however, are not nearly as numerous or important as the similar forms in the Cape or Mediterranean countries.

The south-eastern part of Australia also possesses such shrub-associations. The same preference for sandy soil is shown in both the mountainous areas and the coastal woodlands. They have frequently been described from the region around Sydney. The old name of Botany Bay actually refers to the particular richness in flowers and form of the plants in this area. The Sydney region, in fact, provides a particularly good example of the formation in eastern Australia. Topp (in Victor. Natur. V. 63), in a short but interesting article, has shown how, in terms of its floral biology, it appears more important than the corresponding sections further south, i.e. the Melbourne area. Near Sydney, according to this author, the red epacrids occur more frequently than the white and in particular the long-tubed species are more dominant. The same thing applies in the family Rutaceae. "While (in southern Victoria) only white or greenish yellow *Correa* spp. occur, red and blue species are common near Sydney." Members of the Proteaceae show much the same picture: the grevilleas of New South Wales are more brightly coloured than the more southern species, while the attractive *Lambertia formosa* (Prot.), with its long red tubular flowers, does not extend south to Victoria at all.

c. Sand heaths

It has already been shown that the undergrowth of the sclerophyllous *Eucalyptus* forest or woodland is taxonomically and biologically equivalent to the above formation and in a modified form is continued by it. This applies to the sand heaths of the whole of southern Australia, They are either directly connected with the undergrowth of the woodlands or originate through reduction of the sublittoral shrublands.

These heaths of the infertile sandy country (termed 'sandplains' by the early settlers who detested them) were first described in South Australia, and quite naturally as a sub-

1 Jung in Peterm. Mitt. XXIII (1877) 353.

division of the mallee scrub. “The plants in these regions,” says Behr, “‘while growing to less than the height of a man and differing very little in habit from those of other scrub regions, nevertheless always provided me with new species.” This brief characterization is apt and it holds good also for the south-west of Australia. The sand heaths occupy areas on the surface of the gently undulating tableland leveled by erosion. They often show a very clear line of demarcation from savanna woodlands and grass steppes which occupy the loamy soil of depressions in the same region. The deep-seated differences between the taxonomy and biology of these two Australian types of vegetation are, as a consequence, strikingly brought out. The remarkable duality of the whole plant world of the Australian winter rain area is clearly highlighted. The differences between them were perceived by the earliest South Australian botanists when they compared grassland and scrub areas.

d. Mulga scrub

Shrubby associations, which are closely bound genetically with the savanna woodlands, cover wide areas of the interior of Australia. In the west they occur slightly north of 30°S, while in the east they are found further south. *Eucalyptus* tends to take a back seat here, whilst species of *Acacia* dominate the scene. The early settlers referred to these *Acacia* communities as the “Mulga scrub”. We have already discussed its essential peculiarities and have also seen how, as conditions worsen in low rainfall areas, the Mulga scrub shows a gradual transition to desert-like stunted forms.

e. Brigalow scrub

The northern half of Australia shows many peculiarities in its shrub communities, and although the descriptions of explorers are somewhat incomplete, some features are now clear.

The Brigalow scrub must be regarded as a characteristic formation. It extends from the eastern edge of the plateau in Queensland to the region of the Victoria River in northern Australia and is bounded towards the interior by deserts. It is a formation of shrubs or small trees often closely mixed and of the most diverse relationship. *Eucalyptus* species are present, but although impressive in size, they play an inconspicuous role. By contrast, species of *Acacia* are of considerable importance. Amongst these, *Acacia harpophylla,* with its bluish-green leaves, is common, giving a remarkable pale and gloomy colour to the landscape. The Brigalow trees are, for the most part, gnarled and irregularly branched. The foliage of all the members of the community show xeromorphic modifications. Low undergrowth remains sparse, and grasses are almost completely lacking. Massive dead tree trunks and decaying wood cover the ground in abundance. Altogether the impression given by the Brigalow is bleak and depressing.

In addition to the above, the most important constituents are *Alphitonia excelsa* (Rhamn.), *Flindersia maculosa* (Rut.), *Eremophila longifolia* and *E. Mitchellii* (Myopo.), *Atalaya hemiglauca* (Sapind.), several *Capparis* species, *Heterodendrum oleifolium* (Sapind.), *Cassia* (Legum.), *Ehretia saligna* (Borrag.), *Bauhinia* (Legum.), *Carissa ovata* (Apocyn.) and *Delabechea rupestris* (Stercul.). Among the dense shrubs one may also see again the bottle-like trunks of *Brachychiton rupestris* and others. In the undergrowth, pan-tropical genera such as *Sida* (Malv.), *Polymeria* (Convol.), *Evolvulus* (Convol.) and *Vittadinia* (Compos.) are the main representatives.

Tenison Woods (Proc. Linn. Soc. N.S. Wales VII (1882-83) 579) concludes his description of this community in tropical Australia as follows: “By the term “Brigalow scrub” one understand a scrub composed almost purely of *Acacia harpophylla*, or of thickets of mixed character in which particular trees and shrubs are present in varying proportions.”

The Brigalow scrub is a pre-eminently xeromorphic woody assemblage. More xeromorphic than the savanna woodland, it bears the same relationship to it as the savanna woodland in its turn bears to the rainforest. The Goondiwindi district, for example, in

southern Queensland is described as follows in the Official Year Book for 1901 (p. 164): "The whole district is covered with woody growth; from open forests (i.e. savanna woodland) - usually on river banks and creeks - down to thick scrubs which are situated away from the watercourses. These are Brigalow scrubs of *Acacia harpophylla, Casuarina, Geijera* (Rut.), etc. They are usually found on the watersheds, but long tongues project into the forest land and often reach as far as the watercourses in this way. At the same time there are also clear open places in this scrub where it is replaced by forest".

9. DESERTS

Because of their links with less arid areas through a series of plants showing decreasing xeromorphy, Australian deserts do not show any effects of isolation on the vegetation. In consequence, there are no features of special interest. What is found in these deserts is a depauperate residuum of the vegetation of the surrounding areas. The definition of the desert, according to Australian explorers, is quite comprehensive. Large expanses where surface water is lacking are classed as desert, although covered to a certain extent by sparse vegetation or sometimes even by true woodland. As students of plant geography we cannot agree with this conception of a desert. Only regions where the rainfall is very small - less than 20 cm per year - show such a sparseness of vegetation that we can speak of them as deserts. Even here, however, the frequently emphasized unreliability of the weather does not always permit a rigid definition.

Actually, there are no really extensive areas in Australia which are completely lacking in vegetation. The edaphically peculiar salt pans are the largest. The vegetation may become very scanty, but it is still characterized by a certain diversity. In particular, its nature varies with differences in soil character. On loamy soils, succulent-leaved members of the Chenopodiaceae are most typical. In fact, near salt depressions, such as around Lake Torrens for example, they constitute the dominant vegetation. On the other hand, they are sometimes also present in the drier savanna country and are not completely lacking from the mallee scrub. Stiff-leaved woody or shrubby species of *Acacia* are also usually present with the salt-bush. The genus *Acacia* is the most important woody one of the loam deserts.

Sandy deserts are even more barren than loam deserts. Large sand-dune areas in the interior are in fact often completely barren of vegetation of any kind. As a rule, however, sandy desert country is scantily covered by dark crowned species of *Frenela* [*Callitris*], and by the leafless branch networks of species of *Casuarina* and *Exocarpos.* Poorly developed specimens of *Eucalyptus,* stunted forms of *Fusanus* [*Santalum*], and the peculiar cones of *Codonocarpus cotinifolius* (Phytolacc.). In their vicinity, one almost always finds the true sign of the Australian desert - the so-called "spinifex". This term is applied to clumps of the most stiff and highly xeromorphic members of the Graminaceae. In fact, they do not belong to the genus *Spinifex* at all, but are species of *Triodia*. The presence of these close bands and mats of pale-coloured spiny-foliaged grasses characterize the most dreary widespread stretches of the interior of Australia. Thus, for example, referring to the region 25°S and 122°E, Forrest (in his Journal of 1874) remarks: "The view from here stretches away to the horizon, but as far as the eye can see from NW to SW nothing is visible but an ocean of spinifex. There is no sign of water or of any other change in the character of the country." The main centre of the true spinifex desert (see map) lies in the low rainfall area between 120° and 130°E. The distribution of spinifex is, of course, much more extensive than this and in fact in the west it covers almost the whole width of the continent.

In the basin of the Finke River System, which occurs almost in the heart of the Australian desert region, the mountains create more favorable conditions. A broad oasis occurs where the heavier summer rains have led to the development of a kind of savanna with

grassland and attractive everlastings. In the river valleys even tree growth may occur. *Eucalyptus rostrata* attains a height of 30 m, and one may see specimens of *Grevillea striata* (Prot.) over 20 m high. *Frenela verrucosa* (Pinac.) covers the slopes of the gorge-like valleys. At the point where the Finke River breaks through the Krichauff Range, one finds *Livistona Mariae* (Palm.) growing in the river bed [Palm Valley]. It represents a very isolated outlier of the palm regions. The dark leaves of the 20 m tall fan palm contrasts effectively with the bright green of the eucalypts.

Schematic Explanation of the Vegetation map of Australia

Vegetation types on the map naturally represented only the approximate circumscription the patterning.

Name	Upper storey	Lower storey	Ground layer
Tropical rainforest	Mixed trees, many species	Many shrubs	No grass
Temperate rainforest	Eucalypts dominant, few other trees	Even more shrubs	Some grass, many ferns
Sclerophyll forest / woodland	Eucalypts dominant, few other trees	Many small shrubs	No grass
Savanna forest / woodland	*Eucalyptus* or *Acacia* dominant	Few or no shrubs	Much grass
Savanna	Few low trees or shrubs		Much grass
Mulga Scrub	Few low trees or shrubs (*Acacia* dominant)		Little grass
Brigalow, mallee scrub or sand heath	Many low trees or shrubs (*Acacia* or *Eucalyptus* dominant)		No grass
Desert	Scattered shrubs, *Acacia* or *Casuarina* dominant		*Triodia*, otherwise no grass

III. Regions

Variations in distribution of the vegetation according to altitude is restricted to eastern Australia. On even the highest peaks in south-western Australia (Stirling Range, 1100 m), the shrub growth present is only very slightly modified by elevation. Because of the higher humidity of the summits, however, the vegetation is thicker and there are some differences in species composition from that at lower levels.

The same holds true for the more northerly situated mountains of the south-eastern part of the continent, e.g. the Blue Mountains, where a characteristic shrub community forms the undergrowth at higher elevations.

By contrast, a distinct change in vegetation with elevation occurs in tropical Australia on the Bellenden-Ker Mountains in north-eastern Queensland.[1]

BELLENDEN-KER RANGE

At a height of about l000 m the luxuriant rainforest of the lowlands begins to show a decrease in vigour and gradually becomes somewhat depauperate. At this point, groups of low palms (e.g. *Bacularia Palmeriana* and *Calyptrocalyx australasicus)* and tree ferns *(Alsophila Rebeccae)* begin to appear. However, it is only at a short distance below the summit, at an elevation of about 1500 m, that a distinct change becomes apparent in the vegetation. *Dracophyllum Sayeri* (Epacrid.) now appears, 1.5-4 m in height, with wide horizontal, somewhat tortuous branches and reflexed leaves. It is the dominant feature of the stunted thickets which cover the rocks up to the summit at 1625 m. These thick-

1 The first account concerning this region was given by Sayer. More details on the flora and fauna of the Bellenden-Ker Range are found in the Report of the Government Scientific Expedition to Bellenden-Ker Range upon the Flora and Fauna of that Part of the Colony by Meston, Brisbane 1889. The botanist E. M. Bailey took part in this expedition and made a fine collection of plants (*loc. cit.* 30-80). In company with Dr Pritzel, I visited the range in June 1902.

ets consist of robust shrubs 1.5-3 m high, with darkgreen leathery leaves. They include *Orites fragrans* (Prot.), *Drimys* (Magnol.), *Hibbertia scandens* (Dill.), an upright, intricately branched form, *Myrtus metrosideros* (Myrt.), *Leptospermum wooroonooran* Bailey (Myrt.), *Rhododendron Lochae* F.v.M. (Eric.), *Trochocarpa laurina* (Epacrid.), *Halfordia* (Rut.), and *Alyxia ruscifolia* (Apocyn.).

The densely branched network of shrubs is even more closely knitted together by the tangled mass of mosses and lichens which live on the bark. In this moist atmosphere they grow so well that at first one overlooks the abundance of epiphytic ferns and small orchids *(Dendrobium, Oberonia, Liparis* and *Bulbophyllum).*

This unusual community on these isolated mountain tops, with its mixture of Malaysian, Melanesian and Australian species, bears a striking resemblance to the flora at high elevations in the Malay Peninsula from Java to New Guinea. Thus the flora of this part of Queensland retains its Malaysian features even on the highest peaks.

SOUTHEASTERN MOUNTAINS

The effect of elevation on distribution of the vegetation is more pronounced in the higher ranges of south-eastern Australia. These high ranges unite Tasmania geologically with the continent. On the mainland they stretch from Mount William to the southern border of N.S.W. In these regions, as temperature falls with elevation, it results in a gradual phasing out of the subtropical elements of the flora. Many Australian groups also become rare or disappear altogether. The effect occurs because the winter is too severe and the summer not warm enough. During winter, heavy snowfalls frequently occur in the higher parts of the woodland region and we may see the unusual spectacle of evergreen foliage contrasting with the glistening white of snow. The fronds of the tree-ferns bend down under the mass of snow, while the delicate pinnate leaves of the acacias are concealed beneath it. The twigs of *Eucalyptus* may even break under its weight.

The limit of tree growth and the start of the subalpine or alpine regions[1] occurs at 1950 m on Mount Kosciusko, at about 1600 m in southern Victoria and at 1100 m in southern Tasmania. Elevations above this are treeless, even though the growing season may last five months (November to March).

An indication that the limit of tree growth is being approached, particularly in Tasmania, is given by the occurrence of dense stands of woody composites (e.g. *Senecio centropappus* F.v.M.) 3-4 m high. At the same elevation, an undergrowth of dwarf eucalypts marks the limit of tree growth. In Tasmania this is represented by *Eucalyptus Gunnii* [*E. verncosa*], in Victoria by *E. Gunnii* [misdetermined = *E. glaucescens*] and *E. coriacea* [*E. pauciflora*], and on Mount Kosciusko by *E. coriacea* only. The plants eventually become so crowded together that they form an almost impenetrable thicket with a dense uniform canopy. It is interesting to note that even here the genus *Eucalyptus* maintains its dominant role in Australian vegetation. This contrasts with the situation in antarctic South America where *Nothofagus* is dominant.

In the alpine region of the continent, ericoid or xeromorphic-leaved bushes are usually common. Species belong mainly to the families Proteaceae, Myrtaceae, Compositae and Epacridaceae. They are characterized by low stunted stems, dense arrangement of branches, thick foliage and abundant flowers. They usually form very open stands which tend to shelter behind rock outcrops and are often interspersed with large areas where only perennial herbs are present. Many of them, such as the fine-leaved *Leptospermum* (Myrt.) or the silky *Pimelea* (Thymel.), grow close to the rocks. In this environment the *Pimelea* strongly resembles *Daphne striata* of the Tyrol Alps. As well as members of these genera, others include *Grevillea* (Prot.), *Orites* (Prot.), *Leptospermum* (Myrt.), *Kunzea* (Myrt.), *Richea* (Epacr.), *Epacris* (Epacr.) and *Leucopogon* (Epacr.). In addition, many low shrubs mostly belonging to typical Australian genera, e.g. *Hibbertia* (Dillen.), *Bossiaea* (Legum.), *Pultenaea* (Legum.), *Eriostemon* (Rut.), *Boronia* (Rut.), *Pimelea* (Thymel.), *Prostanthera* (Lab.), *Stackhousia* (Stackhous.) and *Gaultheria* (Eric.) occur here. By contrast,

1 The best on mountain flora is J.H. Maidens Second Contribution toward a Flora of Mount Kosciusko. Departm. of Agricult. Sydney, Misc. Public. n. 331 (1899).

the part played by *Acacia* in the mountain environment is not significant. On Mount Kosciusko, Maiden was unable to find any above the 1600 m contour.

In the gaps between the bushes many different herbaceous species occur. These are largely confined to mountainous areas. The imposing *Ranunculus anemoneus* with large white crowns and *R. Gunnianus* with deep yellow flowers, grow in depressions fed by melting snow, while *Caltha introloba* (Ranunc.) covers moist areas with a glistening green sward. Other examples of alpine plants are the mat-forming *Veronica densiflora,* the imposing composite *Celmisia longifolia* (Compos.) and *Euphrasia Brownii* (Scrophul.). This species of *Euphrasia* reminds one of *Pedicularis.*

Maiden's (*loc. cit.* 20) paper dealing with the Mount Kosciusko area gives a short account of the overall effect produced by these mat-forming species: "Naturally the green of the grasses provides the basic colour but numerous white patches of *Epacris* sp. and *Phebalium ovatifolium* (Rut.) occur, together with the yellow-flowered *Oxylobium alpestre* (Legum.). Scattered through the grassy areas are the yellow-flowered *Ranunculus anemoneus*, a violet-flowered *Brachycome* (Compos.), with the massed white clumps of *Olearia stellulata* (Compos.) and *Celmisia longifolia* (Compos.). Interspersed between these is the charming *Aciphylla glacialis* (Umbell.). Finally, growing as small, dense, cushions, we may note the elegant *Stackhousia pulvinaris* (Stackhous.)*, Raoulia catipes* (Compos.), *Epilobium confertifolium* (Oenother.) and many others."

As we move further south in Australia, the mountain flora rapidly becomes more abundant. Mount William in the Grampians is an isolated western outpost of the Australian Alps. In spite of its height of 1166 m, only *Celmisia longifolia* and two or three other species of alpine or subalpine plants, apart from the endemics *Eucalyptus alpina* and *Pultenaea rosea,* grow there. On the Australian Alps proper, the number of species present increases considerably and on Mount Kosciusko (2227 m high), 105 species have been collected above the tree line. But here, as well as on other mountains of the continent, the number of endemic species is very small. F. von Müller, the first botanist to investigate these wilderness areas 50 years ago [ca. 1850], could only find 15 species which were peculiar to the continent. Tasmania, however, posseses a large number of endemic alpine species and this island is the true home of the Australian mountain flora. Although its alpine flora surpasses that of the mainland, its lowland flora is, however, more closely related to and dependent upon the mainland flora. F. von Müller estimated that of the 130 endemic vascular plants of Tasmania, 80 were alpine. It is noteworthy that almost all the endemic genera are alpine. Some of them, such as *Bellendena* (Prot.)*,* whose charming white inflorescences are to be seen everywhere on the slopes of Mount Wellington, play a prominent part in the physiognomy of the Tasmanian Alpine flora. More important still are the low conifers which form the most remarkable feature of the Australian high mountain flora. They belong to the genera *Pherosphaera* [*Microstrobus*]*, Microcachrys* and *Arthrotaxis.* The distribution of these essentially endemic plants is very restricted. With few exceptions, they only occur in the moist mountains of western Tasmania. They are common there, however, and in places often gregarious. This at least is the view of Tenison Wood, who states that on some mountains there are impenetrable thickets of *Arthrotaxis cupressoides.* Species of *Pherosphaera* and *Microcachrys,* on the other hand, have a somewhat scattered distribution, more like that of the family Epacridaceae, with which they are often found associated.

The subdivisions of the alpine vegetation of Australia are most clearly seen in Tasmania. Rock outcrops and boulders appear to form the substrate. The communities are never closed; bare ground being always present between the scattered shrubs, perennial herbs and moss cushions. Also many streams and drainage channels are present. Moss moors form in the shallow depressions or on the flat summits of these rain-swept, cloud topped mountains. These are the only moss moors in Australia. They rarely form closed communities over large areas, but instead usually consist of a number of small areas interrupted by debris or rock outcrops.

Species of *Sphagnum* are an essential feature of this flora. They are not, in my opinion, as dominant as those of analogous moors in the northern hemisphere. They

also show some ecological differences from the northern hemisphere species. They do not occur as cover plants over wide areas but form small mats, rarely covering more than a few square metres. Cushion or turf-forming plants frequently occur interspersed with these mats. There are also many places where other plants act as turf-formers. Among these are some species of *Carex. Schizaea fistulosa* also occurs here and there, but the most important is *Gleichenia alpina.* This pygmy species was discovered by R. Brown on Mount Wellington where in waterlogged areas it forms extensive closed stands. In contrast to the pale *Sphagnum,* this moor plant is dark and glossy in appearance. Its stalks are dark grey and the frond is covered with reddish-brown scales.

Among the flowering plants of the Tasmanian moor, the monocotyledons appear to be the most important. It is interesting to note, however, that it is not the representatives of the families Cyperaceae and Juncaceae which are dominant but rather those of the families Restionaceae and Centrolepidaceae. In the Cyperaceae, *Oreobolus pumilio* is noteworthy because it forms a transition between the cushion and mat plants of the moor.

These plants have an important part to play in the Austral-Tasmanian Sphagnetum, just as they do in New Zealand and the Chilean moor regions. Members of the families Compositae (*Abrotanella, Pterygopappus*) and Stylidiaceae are (*Phyllachne*, *Donatia)* also prominent. Some members of the Compositae are so similar in appearance that one may easily be mistaken for the other, e.g. *Abrotanella* and *Pterygopappus* [while both cushion plants it is unlikely that they would be mistaken]. *Phyllachne* and *Donatia* also show an extraordinary resemblance. Together with *Azorella* and *Silene acaulis,* all these plants are grouped together as cushion plants.

As well as the species of *Sphagnum,* the gregarious members of the Restionaceae and the cushion plants, a very unusual species, *Astelia alpina,* is found. Its occurrence here is remarkable as otherwise the genus is almost absent from Australia. It occurs in New Caledonia and New Zealand with a fairly large number of species which are mainly epiphytic in their growth habit. But *Astelia alpina is* a true moor plant which often dominates extensive areas. Its leaves are dull olive green and their sheathing bases are covered underneath with long white silky hairs. In the Australian Alps this species is found occurring at the margins of the permanent snow cover.

Distributed almost at random among the moss cushions we find *Caltha introloba* (Ranunc.) and *Drosera Arcturi.* These two species, which floristically resemble many other species on these moors, are of great importance.

Physiognomically, only the shrubs give character to the moors. Members of the Epacridaceae are particularly important. In this respect they resemble the Ericaceae of Europe. One often sees them in the middle of a group of plants surrounded by *Sphagnum* which forms hummocks around the central shrubs. Among the conifers, *Pherosphaera, Podocarpus* and *Microcachrys* must also be mentioned. *Microcachrys is* the most unusual of these with its horizontally growing main stem and prostrate branches. As a rule, a thick mat of dark-coloured needles forms over the boggy ground or the boulder-strewn waterlogged hummocks.

The floral biology of the Australian alpine flora is similar to that of New Zealand. Pale-coloured flowers predominate. According to Maiden out of 75 species which occur at the summit of Mount Kosciosko, 36 are white-flowered, 13 yellow and 13 either green or indeterminate. Blue- and red-flowered species are rare.

IV. Floristics

1. ELEMENTS OF THE AUSTRALIAN FLORA

Analysis of the Australian flora, the foundations for which were laid by Sir J. Hooker and F. v. Müller, shows that it consists of three main elements, to be termed the Antarctic, Malaysian and Australian.

a. Antarctic element

Of the three floral elements, the Antarctic is the most limited in distribution. It is restricted to the south-east corner of the country, and even here it is only well developed in the mountain regions. In such areas, however, it is a major component, particularly in the alpine areas, and provides the link between the Australian mountain flora and the alpine vegetation of New Zealand. Its general geographical characteristics have already been discussed by Hooker (1859) and referred to by later plant geographers, especially Engler (in Versuch d. Entwickelungsgeschichte II 95-103), who analysed this element in considerable detail.

One point which emerges from the discussions is the difficulty of formulating a concise definition of the term 'Antarctic'. It has been extended incorrectly to include groups which belong to the southern hemisphere but are not Antarctic.

The following Australian genera may be regarded as typically Antarctic: *Oreobolus* (Cyper.), *Astelia* (Lil.), *Libertia* (Irid.), *Nothofagus* (Fagac.), *Colobanthus* (Caryophyll.), *Caltha* (Ranun.), *Drosera* § Psychophila , *Aristotelia* (Elaeocarp.), *Azorella* (Umbell.), *Oreomyrrhis* (Umbell.), *Drapetes* (Thymel.), *Geum* § Sieversia (Ros.), *Ourisia* (Scrophul.), *Euphrasia* (Scrophul.), *Gentiana, Forstera* (Stylid.), *Donatia* (Stylid.), *Phyllachne* (Stylid.), and *Abrotanella* (Compos.). Some have been mentioned earlier as moor plants. *Nothofagus* requires closer analysis. In Tasmania, the evergreen *Nothofagus Cunninghamii* frequently occurs up to subalpine levels in the mountains. In Victoria, it only occurs near the sources of the Yarra, Latrobe and Goulbourn rivers and on Bawbaw. Here it descends to the tree-fern gullies. This species has not been found further north than Victoria. About 8° further north, however, in New South Wales, another species, *Nothofagus Moorei,* occurs. An impressive stand of this species may be seen on the ranges at the edges of the plateau where the Bellingen and MacLeay Rivers arise.

The Antarctic components of the flora appear to be essentially confined to the mountains of south-east Australia. However, it would be incorrect to include all the mountain plants as Antarctic, as many are not essentially Australian. Species of *Veronica, Anemone crassifolia,* and *Alchemilla* are members of families with distant but unknown origins.

b. Malaysian element

The Malaysian element – refered to by many authors as "Indian" - covers greater areas of the Australian flora than the Antarctic element. It is also taxonomically more diverse and shows greater versatility in its adaptations.

The greatest number of species appears to occur in the rainforests of north-eastern Australia. The floristic character of the Australian rainforest is without doubt predominantly Malaysian. Naturally, very close links occur with Papua. How far the agreement extends is not at present known, since the floras of Queensland and New Guinea have not been sufficiently studied. It is quite possible that Warburg's statement: "The forests of Queensland are not a remnant and still less a replica of those of New Guinea; in spite of its relative poorness in species it possesses a very large number of endemics" may prove to be substantially correct.

Engler (Entwickelungsgesch. II 45) provided an interesting list which confirmed the high degree of endemism of the Malaysian groups in northern and eastern Australia. For example, endemism of the palms in northern Australia is 66%, and in eastern Australia, 76%. In the Annonaceae, the respective levels are 100% and 92%, in the Sapindaceae 40% and 72%. In eastern Australia 75% of the Passifloraceae are endemic.

In addition, a large number of Australian forest genera are not present in New Guinea[1]. Nevertheless, despite the quite specific differences listed by Warburg, the high degree of agreement between the two forest floras is perhaps not fully appreciated. He does state, however, that Malaysian species are not 'quite so sporadic' in the rainforests of Queensland. Many species are common to the two floras, e.g. *Aleurites moluccana* (Euphorb.), *Cananga odorata* (Anon.), *Elaeagnus latifolia* (Elaeagn.) and *Podocarpus amarus* (Taxac.). Others, however, are slightly modified under Queensland conditions. Their overall character, however, remains essentially Malaysian. There is also the possibility that really isolated Queensland taxa, such as *Blepharocarya* (Anacard.) or *Davidsonia* (Cunon.), may yet be found in New Guinea, just as *Eupomatia* (Anon.) has now been found there.

The close relationship which exists between the Malaysian, Papua and eastern Australian rainforests indicates that these floras have a common origin. However, this does not imply that there has been a recent migration of the rainforest flora from the north. On the contrary, I consider this to be quite out of the question. The rainforest flora of eastern Australia is very old. Its distribution indicates that it represents only the remnants of a widespread past. It is important to note that each segment possesses its own characteristic array of taxa. The northern, and most extensive, part not only has the largest number but also, as might be expected, the most striking of these taxa. Even in the small districts north of Moreton Bay, species characteristic of the area are present. In the larger forest complex extending from the Macpherson Range to the Richmond River, endemic genera include *Piptocalyx* (Monim.), *Daphnandra* (Monim.), *Doryphora* (Monim.) and *Hicksbeachia* (Prot.).

The smaller southern rainforest complexes bear the same relationship to the main northern centres as Natal does to the tropical African forest regions. One must not, however, limit their characteristics by assuming that the tropical families have, as it were, delivered a variety of adaptive capabilities to the species of the sub-tropical regions. These latter, in fact, show little ecological or floristic difference. It is the typical diversity of form of the tropical rainforest species which confers the characteristic endemism on these outlier species of the higher latitudes. As well as the rainforest types, northern Australia possesses numerous mesophytic to xeromorphic species which in the widest sense are Malaysian components. This includes not only the species found in the river-bank forests, but also many components of the savanna and shrublands. The Brigalow scrub abounds in them. A strong development of these xeromorphically-modified components is also found in the drier regions towards the western coast and further south beyond the tropics. The proportion of endemics here is less than in the eastern woodlands. Nevertheless, it is still strong enough to show that northern Australia has not received its flora second-hand and unaltered from its ancestors, but has diversified into new forms.

Taking into account the great variety in the flora of the Malaysian area, it is not surprising that on Australian soil this Malaysian element again lacks complete homogeneity. Further investigation of components of the flora shows that they fall into two sub-groups, one widely distributed in the south-east Asian vegetation, the other largely restricted to Papua, Melanesia and perhaps New Zealand.

The first of these - which we may call the Malaysian section - is represented in Australia by a large number of families. These include: Aracaceae, Taccaceae, Scitamineae, Orchidaceae, Piperaceae, Moraceae, Urticaceae, Nymphaceae, Aristolochaceae, Annonaceae, Lauraceae, Myristicaceae, Menispermaceae, Capparaceae, Nepenthaceae, many Leguminosae, Connariaceae, Rutaceae, Simaroubaceae, Euphorbiaceae, Meliaceae, Malpighiaceae, Flacourtiaceae, Ochnaceae, Dilleniaceae, Guttiferae, Vitaceae, Combretaceae, Ericaceae, Myrsinaceae, Sapotaceae., Styracaceae, Ebenaceae, Contorae, Rubiaceae, Sambucaceae and Cucurbitaceae. The relatively small number of endemics in this section is of interest. Among the 37 families listed above, there are only about 30 endemic genera. The total number of endemic species, however, is quite considerable.

1 Warburg lists about 33 such endemic genera but this number could probably be doubled. One must take into account, however, the fact that most of these are known from Australian sources and that material from Malaysia with which it could be compared may not yet be available.

The main area where these Malaysian species occur is in the moister, low-lying country, although they also occur to a slighter extent in the drier areas.

The second subgroup, which is more limited geographically in its distribution, is known as the Melanesian section. The fact that much of New Guinea remains unexplored makes it difficult to accurately describe its nature and extent. However, it has already been shown that it is of considerable importance, not only in indicating links between Australia, New Caledonia, New Zealand and South America, but also in relation to the plant geography of Australia. The following groups may be considered representative of the Melanesian section: *Araucaria,* part of the Palmae, *Balanops*, Proteaceae - Grevilleoideae, Monimiaceae, Saxifragaceae, Cunoniaceae, *Pittosporum,* Sapindaceae - Cupanieae, Violaceae and Bignoniaceae.

Typical geographical distributions of this section may be illustrated using the family Monimiaceae[1]. As shown in the following table, 9 genera of the family occur in Australia, but their distribution in the other more eastern regions listed is quite limited.

	Papua-Asia	Australia	New Caledonia	Fiji and Polynesia	New Zealand
Hedycarya	—	1	2	2	1
Levieria	3	1	—	—	—
Piptocalyx		* 1	—	vw	—
Tetrasynandra	vw	*3	—	–	—
Wilkiea	vw	*2	—	—	–
Palmeria	1	2	—	—	—
Daphnandra	—	2	vw	—	—
Atherosperma	—	2	—	—	—
Doryphora	—	*1	—	—	—

The links with Papua and the other island areas are also found in other groups of the Melanesian section, although to a varying degree. Furthermore, links with South America are often evident. These links are, however, mostly more tenuous in families other than the Monimiaceae.

With regard to the degree of endemism, there is a very significant difference between the Melanesian and the Malaysian sections. In the 11 families and genera listed as Melanesian there are no less than 35 endemic genera and the species of these are almost all endemic. The number endemic genera on a family basis is thus over three times greater in the Melanesian than in the Malaysian section.

As a generalisation, the Melanesian species are distributed mainly in the sub-tropical regions and tend not to be present in the drier districts. They are often present in the southern outposts of the rainforest. In the north they tend to occur in the higher parts of the ranges towards the edge of the plateau, although they are not entirely lacking from the low-lying country.

The Melanesian section appears to be the older component of the flora. Its existence in Australia probably extends back to the time when the land mass extended eastward from the present continent between the parallels of 15° and 30°S latitude.

The assumption that such land masses existed in those latitudes is supported by various authors who have provided indirect evidence from data on distribution of plants and land animals. The only question which remains unanswered is the extent and shape of the old mainland. The extent of its former boundary is indicated by the location of the present-day islands. There is some evidence favouring the idea that two large peninsulas extended southwards from Papua into higher latitudes, one connecting with eastern Australia and the other with Melanesia. Without doubt, the configuration of these old land

1 J. Perkins and E. Gilg, Monimiaceae. In “Pflanzenrich” IV. 101 (1901)

complexes underwent many changes but their influence reached as far as Samoa and New Zealand. It provided the nucleus of the Melanesian section of the Australian flora.

c. Australian element

The Australian element includes the majority of plant species in Australia. Its components are either restricted to Australia with no close relatives outside the continent, or they possess a few wandering representatives which are closely connected with the main stock in Australia. While a clear boundary for this element is not yet possible, the following taxa comprise the most important of the Australian components of the flora. There are a few more groups of secondary importance.

Cyperac. –Rhynchosporeae
Cyperac. –Gahnieae
Centrolepidaceae
Restonaceae
Lilliaceae – Johnsonieae
Lilliaceae –Dasypogoneae
Lilliaceae –Lomandreae
Lilliaceae –Calectasieae
Lilliaceae –Anguillarieae pr. p.
Lilliaceae –Anthericineae

Amaryllidaceae –Haemodoreae
Amaryllidaceae –Conostylideae
Iridaceae –Patersonia
Philydraceae
Orchidaceae –Thelymitrinae
Orchidaceae –Diuridinae
Orchidaceae –Pterostylidinae
Orchidaceae –Caladeniinae

Casuarinaceae

E *Santalaceae*
Proteaceae
E *Amarantaceae-Achyranthinae* pr. p.
E *Chenopodiaceae – Camphoros meae* pr. p.
E *Phytolaccaceae*
Lauraceae –Cassytheae
Droseraceae –Drosera Sub. -gen *Ergaleium*
Pittosporaceae
Leguminosae –Podalyrieae
Leguminosae -Genisteae
Leguminosae –Acacia
Rutaceae –Boronieae
Polygalaceae –Comesperma
Tremandraceae
Euphorbiaceae –Stenolobeae
E *Sapindaceae –Dodonaea*
Stackhousiaceae
Rhamnaceae –Rhamneae

Sterculiaceae – Bütterieae
Sterculiaceae –Lasiopetaleae
Myrtaceae –Chamaelaucieae
Myrtaceae –Leptospermeae
Halorrhagaceae
Thymelaeaceae –Pimele
Umbelliferae -Hydrocotyleae
Epacridaceae
Loganiaceae

E *Verbenac. -Lachnostachydinae*
E *Verbenac. -Chloanthinae*

Labitae -Prostantheroideae
E *Myoporaceae*
Goodinaceae
Stylidiaceae
Rubiaceae -Opercularia
Compositae -Asterinae
E *Compositae -Gnaphaliinae*
E *Compositae –Angianthinae*

The Australian element comprises about 300 endemic genera at present. It shows little affinity with the Antarctic element but a more marked relationship with the Malaysian element. Since this Australian element is strongly developed in Western Australia, we leave a more detailed account to a later section of this book.

The distribution of the Australian element in Australia is tied to the physical geography of the country. The contrast between the western and eastern parts of Australia pointed out by Hooker (Introduct. Essay) is due essentially to the absence of the Antarctic element and the almost complete absence of the Malaysian element in south-western Australia. A second and more important feature relates to the remarkable division of the Australian element into two groups. This duality was first noted and stressed by Tate who developed the terminology used below. He pointed out that one part of the Australian element was restricted to the more coastal areas, being strongly developed in the true winter rain regions of south-western Australia, and called it the “Autochthonous flora”. The other part showed its best development in the inland or more central parts of the continent which were either summer rainfall areas or showed a general unreliability in rainfall. Tate called this the “Eremaean flora”. The more important components of this second category are indicated in the table by the letter **E**. In addition, there are a few groups which are quite uniformly distributed over the whole of Australia, especially the important genus *Acacia.*

The area of the Autochthonous section is divisible into two widely-separated regions. The south-western area, because of its large number of species, is the best developed. This rich area occurs between the coast and a line drawn between Shark Bay and Cape Arid. The high degree of endemism which characterizes south-western Australia has been known since Robert Brown’s time, but it has almost always been overrated. When, for example, Hooker (*loc. cit.* p. 28) states that the difference between south-eastern and south-western Australia is greater than that between Australia and the rest of the earth, he is going too far. His conclusions are based on incorrect deductions from inadequate

data. A close investigation of the difference between the two sides of the continent shows that the families characteristic of the west show little difference from those of the east. In fact, apart from the Conostylideae, there are no differences even at the tribe level. It may further be noted, as emphasized by Engler, that the endemic genera of eastern Australia are recruited from 48 families, while those of the western area come from only 33 families. Many show just as strong a development in south-eastern Australia as in south-western Australia. Others show a much stronger degree of endemism in the south-western than in the south-eastern area. This varies from twice the number of species in some families to about 4 times the number in the Stylidiaceae and up to 10 times the number in the Chamaelaucieae (Myrt.) and Proteaceae. All this indicates that progressive endemism has established itself particularly effectively in the south-west. This is the reason for the higher number of species here as compared with south-eastern Australia, as Hooker so clearly demonstrated. It is this high level of endemism which is responsible for the species richness of Western Australia which has made its flora so world famous. Several factors have interacted in bringing about this richness in species - the absence of the Antarctic and Malaysian elements and the varied and at the same time intergrading of its climatic zones which would tend to favour the formation of complex adaptations. Hooker has already pointed out the great interest in this area and we will examine the matter in more detail in the final section of this work.

The Eremaean section forms a broad area in the centre of Australia, where the landscapes are very similar. As a consequence of this, eremaean forms tend to show considerable uniformity. From the boundaries of the narrow Southwest Province to the Darling and Murray Rivers, the same flora predominates. Its eastern and western boundaries come into contact with the Autochthonous element, but the two sections show very little mixing. What mixing does occur is less evident in Western Australia than in the east. On the other hand, a relatively broad zone exists in the west where the two sections show segregation due to the operation of edaphic factors. The Autochthonous component predominates on sandy soils, while the Eremaean element favours the clay-loam soils. While the Autochthonous flora rarely intermixes with other elements, the Eremaean tolerates the presence in its communities of quite a large number of xeromorphic species of Malaysian origin, e.g. members of the family Malvaceae, and species of *Cassia* and *Solanum.* As a result, the Malaysian and Eremaean elements are often found closely intermingled, particularly in the northern parts.

2. REGIONAL DISTRIBUTION OF THE AUSTRALIAN FLORA

From the point of view of biogeography, the plant formations and floral elements of Australia cannot be divided into just eastern and western halves. On the other hand, divisions may be carried to excess, as done by Drude, who defined 11 vegetation regions. This appears to me to obscure the main divisions.

I consider three provinces of very unequal extent as representing the primary divisions of the Australian flora, namely: the Eastern Australian, the Eremaean, and the Southwest Australian Provinces.

a. Eastern Australia

Eastern Australia is the most clearly defined province of the three. It contains most formations and all the floral elements are represented. The Malaysian flora present shows great ecological diversity. The Australian element is well represented but its polymorphic potential is only really shown in some families. Finally, the Antarctic element only occurs in this province where it is restricted almost entirely to the mountains of the south-east.

The following subdivisions of the Eastern Australian Province may be distinguished-northern Australia in the restricted sense, Queensland and the South-East.

1. In northern Australia, the Malaysian element is present with xeromorphic types often predominating. The Australian element shows its strongest development in the genus *Acacia* and several representatives of the Eremaean Province are also present. On

the other hand, the Autochthonian element is rather poorly developed. The Antarctic element is absent.

Northern Australia is the land of the savanna woodland. This formation is open and rarely shows rank growth. The river valleys with heavy permeable soils, however, are occupied by rich forests where *Pandanus* and palms grow. In Arnhem Land, Tate estimated that the flora of the lowlands comprised about 1,221 species with 64% endemic, while the tableland only possessed 614 with about 80% endemic. Dense rainforests are not present in this area and the region is therefore richer in pan-tropical forms than in true tropical groups.

2. In Queensland, there is a great contrast between the vegetation of the coast and the interior. On the coast, the mesophytic forms of the Malaysian element occur sporadically but nevertheless are of considerable importance. The Melanesian species also are conspicuous. In the interior, the xeromorphic forms of this element predominate, but many eremaean types also play a part. Among the Autochthonian flora, only a few genera, such as *Eucalyptus,* show a reasonable degree of development. The Antarctic element is absent. The savanna woodland also covers wide areas here. The inland development of this formation differs markedly from the infertile Brigalow scrub and from the open savannas - the undulating "Downs", where the summer rains produce excellent pastures on fertile soils. The plateau rises markedly to the east. In the coastal ranges with high rainfall, true tropical rainforests develop. The rainforests are dependent to a large extent on the presence of a favourable environment, and so in some areas savanna woodland is in close competition with it.

3. The line of separation of the South-eastern subprovince from the Queensland subprovince lies at about at 30°S latitude. From there it extends to the extreme south, including Tasmania. This botanical district is easily distinguished from the two northern subdivisions by the reduction in number of the Malaysian species which is apparent in both the coastal and inland areas. This is balanced by a comparable rise in the Australian element. The Antarctic element is present in the mountains, being most strongly represented at the higher elevations. Tate originally coined the term "Euronotic element" for the south-eastern flora. While this name may have some local application, it is of little use in considering wider relationships.

In the drier zones of the South-eastern subprovince, attractive *Eucalyptus* woodlands of varying character develop. The undergrowth is either grassy or shrubby. In moister habitats (Gippsland, Tasmania), the undergrowth may be interspersed with tropical climbers as well as showing a strong development of ferns. These areas belong to the subtropical rainforest zone. The high mountains on the mainland and in Tasmania do not show typical mat-growths but carry a mixed collection of alpine pasture and high moor species.

b. Eremaean

The Eremaean shows a remarkable degree of uniformity. That strange assortment of Australian plants which we know as the Eremaean element is predominant in this large area. However, many Malaysian species are also present. In the marginal areas of the southern half, isolated outliers of the Autochthonian element occur and these break down the uniform character of the vegetation to some extent. In addition, isolated occurrences of Autochthonian species occur far inland on the mountains of central Australia, e.g. *Actinotus Schwarzii* (Umbell.) on the Macdonnel Range.

Edaphic factors are responsible for the most important variations in the vegetation of this very extensive area. The inland parts consist of vast sandy deserts with scant vegetation. Here, *Triodia* (Gramin.) and scattered specimens of *Casuarina, Fusanus* [*Santalum*](Sant.) and *Frenola* [*Callitris*](Pinac.) give the general tone. On loamy soil, *Acacia* shrubs predominate. Members of the Myoporaceae and succulent representatives of the Chenopodiaceae also occur, together with perennial herbs and annuals, according to the incidence of rain. Finally, in the more southern part of the Eremaean Province, where winter rains predominate, the dry land is covered by mallee scrub for hundreds

of kilometres. A more detailed description of the western Eremaean Province, which also applies to the eastern part, will be found in Part IV of this work.

c. Southwest Australia

Southwest Australia is by far the smallest of the three provinces. At the same time, it is the most sharply delimited. No representatives of either the Malaysian or the Antarctic elements are present, but numerous groups of the Australian branch of the flora have reached a high degree of development. It is the home of the Autochtonian flora. Large areas are completely dominated by it, and it can compete on more-or-less equal terms with the eremaean species. A more detailed examination of these topics forms the subject matter of the following chapters.