

ART. XXV.—*An Ecological Study of some New Zealand Sand-dune Plants.*

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#### A. INTRODUCTION.

THE work of Warming (1895) and of Schimper (1898) gave an impetus to the study of plant-ecology, and led to the publication of a considerable amount of literature on the subject, and ecology is now recognized as an important branch of botanical science. Previous to the year 1909 there has not been much published regarding the ecology of New Zealand sand-dune plants, the subject treated of in this paper. Various papers, mostly floristic, in the "Transactions of the New Zealand Institute" have dealt with or referred to the sand-dunes or littoral districts of various parts of New Zealand, and lists of species, generally incomplete, have been there included. For example,—

J. B. Armstrong, in "A Short Sketch of the Flora of the Province of Canterbury, with Catalogue of Species" (Trans. N.Z. Inst., vol. 12, p. 325), mentions some of the dominant plants of the littoral district of Canterbury Province, and in his list of species (grouped in families) he gives the locality in which the plants are found.

J. Buchanan, in his "List of Plants found on Miramar Peninsula, Wellington Harbour" (Trans. N.Z. Inst., vol. 1, p. 349), gives a list of some eighty-two species (belonging to fifty-two genera) of plants of swamp, sand-dune, and seaside botanical regions, which plants, he says, "having here an estuarine relation, may be grouped as one; spreading, as many of the species do, over the whole district, it would be difficult to separate them on the experience of this locality alone."

J. Buchanan and T. Kirk give a "List of Plants in Northern District of the Province of Auckland" (Trans. N.Z. Inst., vol. 2, p. 239). The plants are not grouped according to their environment, but the locality of each species is given.

H. Carse, in his articles "On the Flora of Mangonui County" (Trans. N.Z. Inst., vol. 43, p. 194) and "On the Flora of the Mauku District" (vol. 34, p. 362), gives lists of plants, and includes a short description of plants of sandhills, mentions some of the chief plants, and gives a catalogue of the flowering-plants and ferns of the districts studied, the plants being grouped in their families, and the environment of each species being mentioned.

T. Kirk, in his article "On the Botany of the Thames Goldfield" (Trans. N.Z. Inst., vol. 2, p. 89), mentions about thirty-six species of plants of the

littoral district of the field observed ; in "Notes on the Botany of certain Places in the Waikato District" (Trans. N.Z. Inst., vol. 3, p. 142) and "On Flora of Isthmus of Auckland and the Takapuna District" he mentions a few coastal plants.

D. Petrie, in an article entitled "A Visit to Stewart Island, with Notes on its Flora" (Trans. N.Z. Inst., vol. 13, p. 323), gives a description of the various localities, with plants found there, and a list of plants grouped in families, not according to environment. D. Petrie also gives a "List of the Flowering-plants indigenous to Otago, with Indications of their Distribution and Range in Altitude" (Trans. N.Z. Inst., vol. 28, p. 540), and in this list shore-plants are included.

W. Townson, "On the Vegetation of the Westport District," includes in his description of the district a list of plants (grouped in families), with a brief description of their environment (Trans. N.Z. Inst., vol. 29, p. 380).

W. T. L. Travers, in his "Remarks on the Sand-dunes of the West Coast of the Provincial District of Wellington" (Trans. N.Z. Inst., vol. 14, p. 89), gives a list of the principal plants found on the sand-dunes of New Zealand.

L. Cockayne has several articles published in the "Transactions of the New Zealand Institute," in which dune-ecology received for the first time some attention ; but his "Report on the Sand-dunes of New Zealand," published in 1909, gives the first comprehensive account of the sand-dune plants of New Zealand. In 1911 an enlarged edition of this work appeared, giving an account of the geology, botany, and reclamation of the dune areas of New Zealand. Cockayne has given a general description of the sand-dune flora of New Zealand, including a list of the species, in families, with the distribution and growth-form of each, and grouping the dominant species in plant associations according to their origin and relationships. Such a general description, though comprehensive, is not intended to be exhaustive or detailed, and no attention is paid to plant-anatomy.

Any one species living in any plant association or region has its own special conditions, apart from those of the habitat in general, and may not show the characteristics of a typical denizen of that plant association. Indeed, its anatomy may reveal characters quite unsuited to the general habitat : for instance, although a sand-dune flora is typically xerophytic certain species perhaps will not show xerophytic characters. Each individual species must therefore be examined in detail, to show how far its habit and structure correspond with, or differ from, those typical of the vegetation in which it is found.

The present paper, then, is intended to supplement Cockayne's account of the botany of New Zealand dune-plants, and to give such attention to individual species as is required to extend our knowledge of the life requirements of certain plants mentioned or described in the above report.

## B. FIELD OF OBSERVATION.

### *Description of Aspect and Plant Covering of the Dunes observed.*

The sand-dunes selected for examination are those of the seashore at New Brighton, Canterbury, and form a portion of that large area of sand which extends from the Sumner Estuary to the Waimakariri River.

Extending along the greater part of the beach is a ridge of sand—the foredune—fixed to a great extent naturally, and in part artificially, by the native pingao (*Scirpus frondosus*) and the introduced marram-grass (*Ammophila arenaria*).

Inland from the foredune are—(1) unstable dunes; (2) dune-hollows; and (3) sand-plains.

For purposes of description, the beach may be divided into two portions—(1) the south beach, extending from the New Brighton pier to the Sumner Estuary; (2) the north beach, reaching north from the pier towards the River Waimakariri.

The south portion is fronted all along by a prominent foredune, inland to which is a small extent of dune. Farther inland still are found stable sand-plains. At the extreme end, near the estuary, are found moist sand-hollows.

At the north end of the beach there is an artificial foredune for some distance from the pier; farther north there is no foredune. Here the dunes extend farther inland than those of the southern beach; the gently undulating dune-land nearest the shore has little plant covering, the pingao (*Scirpus frondosus*) being here, as usual on the active dune, the dominant species. Farther inland the dunes are higher and the hollows deeper; and after rainfall there are numerous lakes, some of which dry up, but others appear stagnant, and have a rich vegetation.

*List of Indigenous Species found on the Sand-dunes, New Brighton*

[N. refers to northern beach, S. to southern.]

Species, Family, &c.	Habitat.
FILICES.	
<i>Pteridium esculentum</i> (Forst. f.) Cockayne (common bracken fern)	Heath, plain. S.
GRAMINEAE.	
<i>Calamagrostis Billardieri</i> (R. Br.) Steud. ..	Active dune, sand-hollow. N.
<i>Arundo conspicua</i> Forst. f. (toetoe) ..	Stable dunes or shrub dunes. N. and S.
<i>Poa caespitosa</i> Forst. f. (tussock-grass) ..	Dunes, active or semi-stable. N. and S.
<i>Festuca littoralis</i> Labill. (tussock-grass) ..	Active dunes. N. and S.
CYPERACEAE.	
<i>Scirpus nodosus</i> (R. Br.) Rottb. ..	Dunes, plain, hollows. N. and S.
— <i>frondosus</i> Banks & Sol. (pingao) ..	Foredune, active dune. N. and S.
<i>Schoenus concinnus</i> (Hook. f.) Cheesem. ..	Sand-hollow.
<i>Carex pumila</i> Thunb. ..	Moist sand-hollow. N. and S.
RESTIONACEAE.	
<i>Leptocarpus simplex</i> A. Rich. ..	Plains, hollows, swampy places. N. and S.
JUNCACEAE.	
<i>Juncus maritimus</i> Lam. var. <i>australiensis</i> Buch.	Moist hollow, wet places. N. and S.
LILIACEAE.	
<i>Phormium tenax</i> Forst. (N.Z. flax) ..	Shrub dune only. N.
RANUNCULACEAE.	
<i>Ranunculus acaulis</i> Banks & Sol. ..	Sand-hollow. S.
ROSACEAE.	
<i>Acaena novae-zealandiae</i> T. Kirk (pipiri) ..	Stable plains. N. and S.
<i>Potentilla anserina</i> L. var. <i>anserinoides</i> (Raoul) T. Kirk	Stable plains. N. and S.
LEGUMINOSAE.	
<i>Carmichaelia subulata</i> T. Kirk (native broom)	Shrub dune.

*List of Indigenous Species found on the Sand-dunes, New Brighton—continued.*

Species, Family, &c.	Habitat.
LINACEAE.	
<i>Linum monogynum</i> Forst. f. (white flax) ..	Active dunes. N. and S.
RHAMNACEAE.	
<i>Discaria toumatou</i> Raoul (wild-irishman) ..	Active dunes, sand-plains. N. and S.
VIOLACEAE.	
<i>Viola Cunninghamii</i> Hook. f. (N.Z. violet) ..	Dunes. S.
THYMELAEACEAE.	
<i>Pimelea arenaria</i> A. Cunn. ..	Active dune. S.
MYRTACEAE.	
<i>Leptospermum scoparium</i> Forst. (manuka) ..	Shrub dune, plain; wet places. N. and S.
ONAGRACEAE.	
<i>Epilobium Billardierianum</i> Ser. ..	Moist sand-hollows. N.
— <i>nerterioides</i> A. Cunn. ..	Moist sand-hollows. N. and S.
HALORRHAGACEAE.	
<i>Gunnera arenaria</i> Cheesem. ..	Moist hollow. N.
UMBELLIFERAE.	
<i>Hydrocotyle tripartita</i> R. Br. ..	Moist hollow. N.
<i>Apium prostratum</i> Labill. ..	Sand-hollow. N.
<i>Crantzia lineata</i> Nutt. ..	Moist hollow. N.
PRIMULACEAE.	
<i>Samolus repens</i> (Forst.) Pers. var. <i>procumbens</i> R. Knuth	Moist hollow. N.
CONVOLVULACEAE.	
<i>Calystegia Soldanella</i> (L.) R. Br. (shore convolvulus)	Active dunes. N. and S.
SCROPHULARINACEAE.	
<i>Mazus pumilo</i> R. Br. ..	Moist hollow. N.
MYOPORACEAE.	
<i>Myoporum laetum</i> Forst. f. (ngaio) ..	Only one tree was found, on the active dunes south. This is one of the rare occurrences of the species on the active dune referred to by Cockayne in his report, 1911, p. 40.
RUBIACEAE.	
<i>Coprosma acerosa</i> A. Cunn. ..	Active dunes, shrub dunes. N. and S.
GOODENIACEAE.	
<i>Selliera radicans</i> Cav. ..	Moist hollows. N. and S.
COMPOSITAE.	
<i>Gnaphalium luteo-album</i> L. ..	Shrub dunes and sand-hollows. N. and S.
<i>Cassima fulvida</i> Hook. f. ..	Active dunes, shrub dunes, heath. N. and S.
<i>Cotula droica</i> Hook. f. ..	Moist hollow. N. and S.
<i>Senecio lautus</i> Forst. f. var. <i>a</i> ..	Active dunes. N. and S.
<i>Sonchus littoralis</i> (T. Kirk) Cockayne ..	Active dunes. N. and S.

Many introduced plants are found, especially in the stable sand-plain. The tree-lupin (*Lupinus arboreus* Sims) covers extensive patches on dune and plain.

Of the forty or so indigenous species found in the field examined, seventeen were selected for anatomical observation, namely,—

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| <p>(a.) GRAMINEAE.</p> <ol style="list-style-type: none"> <li>1. <i>Calamagrostis Billardieri</i>.</li> <li>2. <i>Arundo conspicua</i>.</li> <li>3. <i>Poa caespitosa</i>.</li> <li>4. <i>Festuca littoralis</i>.</li> </ol> <p>(b.) CYPERACEAE.</p> <ol style="list-style-type: none"> <li>5. <i>Scirpus nodosus</i>.</li> <li>6. — <i>frondosus</i>.</li> <li>7. <i>Carex pumila</i>.</li> </ol> <p>(c.) RESTIONACEAE.</p> <ol style="list-style-type: none"> <li>8. <i>Leptocarpus simplex</i>.</li> </ol> <p>(d.) THYMELAEACEAE.</p> <ol style="list-style-type: none"> <li>9. <i>Pimelea arenaria</i>.</li> </ol> <p>(e.) MYRTACEAE.</p> <ol style="list-style-type: none"> <li>10. <i>Leptospermum scoparium</i>.</li> </ol> | <p>(f.) ONAGRACEAE.</p> <ol style="list-style-type: none"> <li>11. <i>Epilobium Billardierianum</i>.</li> <li>12. — <i>nerterioides</i>.</li> </ol> <p>(g.) HALORRHAGACEAE.</p> <ol style="list-style-type: none"> <li>13. <i>Gunnera arenaria</i>.</li> </ol> <p>(h.) UMBELLIFERAE.</p> <ol style="list-style-type: none"> <li>14. <i>Crantzia lineata</i>.</li> </ol> <p>(i.) CONVOLVULACEAE.</p> <ol style="list-style-type: none"> <li>15. <i>Calystegia Soldanella</i>.</li> </ol> <p>(j.) RUBIACEAE.</p> <ol style="list-style-type: none"> <li>16. <i>Coprosma acerosa</i>.</li> </ol> <p>(k.) COMPOSITAE.</p> <ol style="list-style-type: none"> <li>17. <i>Cassinia fulvida</i>.</li> </ol> |
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### C. ECOLOGICAL CONDITIONS OF THE DUNE-PLANTS.

Full details as to New Zealand dune conditions are not necessary here, since they are treated of at length by Cockayne ("Report on the Dune Areas," p. 19 *et seq.*).

Some of the more important factors, however, governing the form, &c., of the dune-plants are as follows:—

#### 1. Edaphic.

- (a.) Moderately fine quartz sand.
- (b.) Moisture available at all times except for first 5 in. of surface of hills.
- (c.) Hollows much wetter than hills, owing to proximity to water-table, so that water may lie in pools on the surface for considerable periods, especially in winter.
- (d.) Layer of humus in many places, at some yards deep in the hills, but forming an upper thin soil in some of the hollows.
- (e.) Lack of nutritive salts.

#### 2. Climatic.

- (a.) Prevalent winds at New Brighton: (1) East, from sea; (2) north-west, hot and dry; (3) south-west, cold and often bringing rain.
- (b.) Effect of wind: (1) Blows sand, thus plants are liable to be buried, and liable to mechanical damage from drifting sand; (2) cools soil, and causes rapid evaporation; (3) transpiration accelerated.
- (c.) Insolation strong.

(d.) Heating of surface sand intense at times, but substratum where moist quite cool at few inches below surface.

(e.) Frosts are comparatively severe from June to August,  $-10^{\circ}$  C. having been frequently recorded; shallow-rooting plants would therefore be subject to lack of water.

When considering the structure of the dune-plants it must not be forgotten that the hills and hollows, as shown in the above table, offer different conditions, the hills demanding not only a more xerophytic structure than do the hollows, but a tolerance of blown sand on the part of the plants.

In connection with the amount of salt in the sand of the dunes, it must be noted that T. H. Kearney, in "Are Plants of Sea-beaches and Dunes True Halophytes?" finds that the sea-beach sand contains a very small quantity indeed of salt; therefore the sand-dune plants of the seashore are not halophytic.

#### D. PLANT DESCRIPTIONS.

##### 1. *Calamagrostis Billardieri*.

###### (a.) *Habitat.*

Found in both active dunes and sand-hollows at the northern portion of the beach.

###### (b.) *General Form.*

A tufted grass, growing in green patches longer than broad, about 8 in. to over 1 ft high.

Leaves shorter than the culms, about  $\frac{1}{4}$  in. broad, striate, flat, dorsal surface ridged and furrowed, bright green, sheathing, spreading semi-vertically, tapering to a point.

Rhizome slender, creeping, with many roots.

###### (c.) *Leaf-anatomy.*

*Epidermis*: Dorsal—In transverse section, large round cells on the ridges, five or six very large bulliform cells at the bottom of the furrows; stomata with subsidiary cells, sunken air-spaces beneath. Ventral—In transverse section, large cells, those beneath the mestome bundles projecting, thus forming an irregular surface; in surface view, long cells alternating with short cells, which sometimes appear as papillae; cell-walls thick, not undulating.

*Chlorenchyma*: Bands, butterfly-shaped in transverse section, alternate with mestome bundles; cells of irregular shape, rounded or polygonal, with small intercellular spaces.

*Stereome* in small subepidermal patches above and beneath the mestome bundles.

*Fibro-vascular bundles* of ordinary monocotyledon structure, xylem with two large pitted vessels and smaller elements, and a patch of phloem; the bundle surrounded by a sheath with thickened inner walls, and a parenchyma sheath sometimes colourless, sometimes containing chlorophyll-grains. Above and below the bundles there are often small groups of colourless parenchyma cells, adjoining the stereome, and probably functioning as water-storage cells. The bundles, together with the stereome and water-parenchyma, separate the bands of chlorenchyma.

*(d.) Conclusion.*

Contrary to what might be expected from the fact that this plant frequently grows in an exposed position on the active dunes, leaf-anatomy shows structure far from xerophytic. There is a small amount of stereome and of water-parenchyma, the epidermal walls are thick, but otherwise the leaf is mesophytic. It is flat and green and thin, and the frequent stomata are not well protected.

*Calamagrostis* also grows in dune-hollows, where xerophytic characters are not so necessary, owing to the greater amount of moisture and protection from winds.

2. *Arundo conspicua*.*(a.) Habitat.*

Rarely occurs on the southern portion of the New Brighton beach—*i.e.*, between the pier and the Sumner Estuary; more common on the north beach, towards Belfast, where it is found some distance inland, where the dunes are comparatively stable. Elsewhere a denizen of both swamp and heath; therefore a plant of very different stations, though a swamp may be xerophytic.

*(b.) Growth-form.*

A very conspicuous grass, tall, often reaching a height of as much as 11 ft.; forms large dense tussocks; inflorescences characteristic.

*Leaves* long, relatively narrow, coriaceous, flat or involute, veins plainly seen, ridged and furrowed.

*Inflorescence* a showy panicle, yellowish-white, silky, 1–2 ft. long, thickly branched, spikelets very numerous.

*Rhizome* stout; can grow upwards to some extent as buried.

*(c.) Leaf-anatomy.*

*Epidermis*: On exposed surface, a cuticle; regular rectangular cells, elongated in direction of the leaf-axis, alternating with small cells; cell-walls thick, wavy; a few stomata. On inrolled surface, cells elongated, cell-walls thin, stomata numerous in the furrows, subsidiary cells present, epidermal cells commonly rounded, and with outer walls much thickened.

*Chlorenchyma* in bands alternating with vascular bundles, reaching to both surfaces of the leaf; water-parenchyma in the midst of each chlorenchyma band. Cells more or less polygonal; air-spaces beneath stomata.

*Stereome* present in subepidermal patches, sometimes extending from the surface to the vascular bundles. The stereome immediately beneath the epidermis consists of much smaller cells than that adjacent to the bundles.

*Fibro-vascular bundles*, together with stereome, separate bands of chlorenchyma; of typical monocotyledon structure; sheath with thickened inner walls, surrounded by parenchyma sheath.

*(d.) Conclusion.*

*Arundo conspicua* shows marked xerophytic characters—*viz.*, inrolled leaf, stomata in furrows and mostly on protected side of the leaf, water-parenchyma, and stereome. The growth-form, the tussock, also is xerophytic. Its tall habit in all positions obviously exposes it to the full force of the wind. On the other hand, its tussock form shelters the inner leaves, and combats transpiration.

### 3. *Poa caespitosa*.

#### (a.) *Habitat.*

Found on active dunes, often just inland to the foredune; also at times in dune-hollows. Confined to the dune area.

#### (b.) *Growth-form.*

A grass forming close yellowish-green tussocks,  $1\frac{1}{2}$ –3 ft. high. Very like *Festuca littoralis* in external appearance, but can be distinguished by the inflorescence and less rigid leaves.

*Leaves* narrow, so strongly involute as to be nearly terete, smooth, pale green or yellowish, ending in fine sharp points.

*Inflorescence* a panicle, fine, lax; stalks slender; branches few, in distinct clusters.

#### (c.) *Leaf-anatomy.*

Leaf-margins meeting above midrib. From the small opening between the margins to the midrib extends a narrow fissure, with a furrow on each side of the midrib, reaching more than half-way to the dorsal surface of the leaf.

*Epidermis*: Exposed surface—elongated rectangular cells alternating with smaller cells; walls thick, undulating; no stomata; thick cuticle. Inrolled surface—cell-walls thinner than on exposed surface, elongated in surface view; stomata frequent between the bands of subepidermal stereome, regularly arranged with stomatal clefts parallel with leaf-axis; subsidiary cells present. Stomata sunk beneath the surface. Epidermal cells rounded, and with outer wall much thickened; many epidermal cells smaller than the ordinary ones, and prolonged into simple hairs with thick walls, forming a fairly close covering to the inrolled surface of the leaf.

*Chlorenchyma* arranged in bands, alternating with fibro-vascular bundles and stereome. Cells relatively small, polygonal, close-packed, undifferentiated, thick-walled; air-spaces beneath stomata; the chlorenchyma bands reach the inrolled surface, but are usually separated from the exposed epidermis by stereome.

*Stereome* well developed, in thick bands above and below the vascular bundles, extending to both surfaces; stereome extends all along the exposed epidermis.

*Fibro-vascular bundles* arranged regularly, alternating with chlorenchyma bands, of typical monocotyledon structure; two large pitted vessels, a few smaller spiral or annular vessels, and a lysigenous cavity; sheath of colourless parenchyma enclosing mestome sheath with thickened inner walls.

#### (d.) *Conclusion.*

*Poa caespitosa* shows the following xerophytic characters: Tussock form, involute leaf, protected surface hairy; stomata on protected surface only, and sunken; homogeneous chlorenchyma of thick-walled polygonal cells, and well-developed stereome.

It is interesting to note the extra wall-thickening of the chlorenchyma as compared with that of the apparently more xerophytic *Festuca littoralis*. *Poa caespitosa* is a characteristic plant of tussock-steppe, and not a special dune-plant.



4. *Festuca littoralis*.(a.) *Habitat*.

Found commonly all along the dunes, sometimes on the foredune among *Scirpus frondosus*, and rarely, even on the shore, in front of the foredune, where, so far as New Brighton is concerned, the only other vegetation is the introduced succulent cruciferous plant *Cakile maritima*.

(b.) *Growth-form*.

Forms close-growing yellowish-green tussocks, usually 2–3 ft. high, and measuring about 5 in. through at the base; several small tussocks commonly grow together, so that the whole clump measures more than 1 ft. through at the base. Very like *Poa caespitosa*, but can easily be distinguished by the inflorescence.

*Roots* many, long, spreading, covered with rootlets.

*Leaves* narrow, strongly involute, appearing almost cylindrical, ending in a point, smooth, shining, pale green or yellowish.

*Inflorescence* a panicle, long, dense, narrow, spike-like, with broad spikelets.

(c.) *Leaf-anatomy*.

Leaf-margins almost meeting above the midrib, and hence only one surface exposed. From the slight opening between the margins to the midrib extends a narrow fissure, with lateral furrows between the veins, reaching two-thirds of the way to the exposed surface of the leaf. The ridges above the vascular bundles between these furrows are broad and rounded.

*Epidermis*: Inrolled surface—cell-walls undulate, cells elongated, many cells smaller but extended into straight or curved spreading unicellular hairs which line the main cavity and lateral furrows with a dense cross-work; stomata numerous in the furrows, clefts in direction of leaf-axis, subsidiary cells present. Exposed surface—long rectangular cells alternating with short cells; cell-walls more undulating than on the other surface; no stomata; waned cuticle.

*Hypodermis* present beneath epidermis of exposed surface, consisting of one or two layers of small thick-walled cells, merging gradually into the thick-walled colourless parenchyma which surrounds the mestome bundles, separates the chlorenchyma from the exposed surface, and extends right along the ridges from one surface of the leaf to the other.

*Chlorenchyma*: Relatively small patches lining the ends of the furrows in horse-shoe form, and in bands lying at the sides of the ridges; cells small, irregularly polygonal, thin-walled.

*Mestome bundles* of typical monocotyledon structure, with parenchyma sheath, and mestome sheath with inner walls much thickened; one bundle in the middle of each ridge.

(d.) *Conclusion*.

The presence of the following characters shows that *Festuca littoralis* is strongly xerophytic: Tussock growth-form, leaf strongly involute, inner surface furrowed, with hairs, stomata in furrows, strong reduction of chlorenchyma and development of colourless thick-walled parenchyma, which may be considered a water-tissue.

Two points of difference from *Poa caespitosa* are interesting—namely, absence of stereome, which is compensated for by the thick walls of the colourless parenchyma; and thinner walls of chlorenchyma.

5. *Scirpus nodosus*.

(a.) *Habitat.*

Found in active dunes, commonly in manuka heath or sand-plain, also in sand-hollows, at both ends of the beach. Also occurs on coastal rocks and inland in heath river-bed, and occasionally steppe.

(b.) *Growth-form.*

Close, stiff, tussocks of rush-form,  $1\frac{1}{2}$ –3 ft. high, of numerous stems. Can be easily recognized by the inflorescence. Rhizome stout, woody.

*Stems* erect, stiff, slightly flattened,  $\frac{1}{8}$ – $\frac{1}{4}$  in. in diameter, dull green, functioning as leaves.

*Roots* long; root-hairs all along, rather long and sparse.

*Leaves* absent, except for reddish sheathing scales at the base of the stems.

*Inflorescence* characteristic; a head of spikelets towards the end of the stem, head brown, solitary, globose,  $\frac{1}{4}$ – $\frac{2}{3}$  in. in diameter, spikelets numerous, crowded together; head appears lateral, owing to the presence of a rigid bract, about 1 in. long, continuous with the stem.

(c.) *Anatomy.*

Stem a slightly flattened solid cylinder, consisting of epidermis, chlorenchyma, and stereome, fibro-vascular bundles, and central pith.

*Epidermis*: Cells above stereome bands rectangular, not much elongated, cell-walls thick, those parallel with stem-axis undulate; cells above chlorenchyma rather irregular; cell-walls not undulate; frequent stomata arranged parallel with axis, subsidiary cells present, thick cuticle; stomata slightly sunken.

*Chlorenchyma* in a continuous cylinder beneath the epidermis, interrupted on its outer side by bands of stereome; all palisade tissue, several cells deep, cells small and compact; a relatively large air-space beneath the stomata.

*Stereome* in thick bands, regularly arranged beneath the epidermis, all round the stem, forming ridges; stereome bands somewhat pear-shaped in transverse section; peculiar processes from the stereome, probably thickenings of cell-wall, are occasionally seen in the epidermis.

*Fibro-vascular bundles*: Structure typical of monocotyledons, with sheath of thick-walled cells and patch of thick-walled cells at the base of the bundle; bundles arranged in two or more rings, the outer ring of small bundles, the inner bundles larger and more well developed.

The centre of the stem consists of pith of large polygonal cells.

(d.) *Conclusion.*

Stem-structure is typically xerophytic, with thick cuticle, thick-walled epidermal cells, compact palisade, and stereome. The absence of leaves and the photosynthesizing stems are markedly xerophytic characters.

In connection with *Scirpus nodosus* a few words must be said about the tussock form. Cowles\* says, "The leaves of most grasses and sedges grow so close together that the assumption of a position transverse to incident light is mechanically impossible. . . . Leaf verticality or parallelism to the incident light results obviously in minimum lighting for any individual

\* "Text-book of Botany," vol. 2, Ecology, p. 544.

leaf, but there is maximum lighting for the vegetation as a whole, since the more vertical the leaves the more numerous may they be in any given space, and yet have sufficient light to live." And on page 666, on the subject of plants such as the rushes (*Juncus* and *Scirpus*), "It has been suggested that their exposure to intense light, reflected as well as direct, makes verticality almost as advantageous as in xerophytic habitats. It is much more likely that in rushes, as in swamp-grasses and in flags, verticality is advantageous because it permits a maximum display to light where growth is intense. Whatever may be the causes or advantages, it certainly is striking that leafless stems with a relative maximum of stem synthesis occur in such opposite habitats as deserts and swamps, and that the vertical habit which means minimum light-exposure and maximum protection for the desert individual means maximum light-exposure for the mass of vegetation in the swamp."

In the case of the various sand-dune species which exhibit the tussock form—e.g., *Scirpus nodosus*, *Festuca littoralis*—it seems that because (1) the tussocks are commonly not closely packed together, and (2) the habitat is xerophytic, the advantage of the tussock form is one of protection against light-exposure and excessive transpiration. At the same time, with such a plant of *Leptocarpus simplex*, which grows in habitats varying from the dune to the swamp, it may be that the advantage of the tussock form and vertical leafless stem may be minimum light-exposure and maximum protection for the individual growing on dry sand, or maximum light-exposure for the mass of vegetation in the swamp.

## 6. *Scirpus frondosus*.

### (a.) *Habitat.*

*Scirpus frondosus* is the most common of all plants on the sand-dunes at New Brighton. It covers both natural and artificial foredune, sharing its position on the artificial dune with the introduced marram-grass (*Ammophila arenaria*). Towards the Sumner end of the beach *Scirpus frondosus* reigns in almost undisputed sway on the foredune, the only other plant growing there being *Festuca littoralis*, with the introduced *Cakile maritima* on the shore close by. At the extreme end of the New Brighton beach, by the Sumner Estuary, opposite the Shag Rock, *Scirpus frondosus* is extremely common, giving to the dunes a very picturesque appearance by its orange-red colouring.

### (b.) *Growth-form.*

A sedge, with leaves thickly arranged resembling tussocks, propagated enormously by means of its long thick rhizome; green, brownish, or orange in colour, giving a characteristic orange-brown colour to the vegetation.

*Rhizome* thick, stout, sometimes an inch in diameter, woody, fibrous (therefore hard to cut or break), long, creeping, often many yards in length covered with old brown leaf-sheaths; at frequent intervals giving rise to stems with tufts of numerous leaves.

*Leaves* numerous, closely packed, spreading, harsh, stiff, flexible, coriaceous,  $1\frac{1}{2}$ –2 ft. long,  $\frac{1}{4}$ – $\frac{1}{2}$  in. broad, narrowing to long trigonous points; upper surface concave, under convex; margins have small sharp teeth, and there are one or two rows of teeth on the convex under-surface. Young leaves green with orange or brown colouring towards the tips, bases yellow or yellowish-green, older leaves often orange or orange-red for the greater part of their length. Leaf at base broadens out into a sheath, brown, membranous, 3–4 in. long, about  $1\frac{1}{2}$ –2 in. broad at extreme base.

*Inflorescence* 4–9 in. long, clusters of spikelets spirally arranged around the upper part of the stem, each cluster subtended by a linear bract like the leaves, bracts about 2 ft. long,  $\frac{1}{3}$  in. broad, expanding at base around the spikelets to about  $\frac{1}{2}$ – $\frac{3}{4}$  in. across. Spikelets densely crowded, brown or reddish-brown.

(c.) *Leaf-anatomy.*

*Epidermis*: Cell-walls thick; some four or five rows of cells above each band of stereome, elongated, and with undulate cell-walls. About four rows of cells alternating with the stereome, cell-walls not so undulate, more irregular, and with stomata; stomata sunken, arranged parallel with leaf-axis; cuticle thick, orange-coloured commonly.

*Chlorenchyma*: A band extending from vascular bundles to epidermis, except where interrupted by stereome. Continuous except for the presence in the middle of the concave side of the leaf of large colourless polygonal cells just beneath the epidermis and continuous with the central parenchymatous tissue. Outer layers of chlorenchyma consist of palisade cells, compact. Towards the vascular bundles the chlorenchyma cells are more rounded or polygonal, with intercellular spaces, thus forming a tissue like spongy parenchyma; air-spaces beneath stomata.

*Stereome* strongly developed—(1) subepidermal, in bands regularly arranged parallel to leaf-axis, and alternating with groups of palisade cells; (2) with vascular bundles. In adult plant, stereome forms thick cords in the central colourless parenchyma, adjacent to the bundles; also a well-developed sheath around each bundle. In the portion of this sheath nearest the chlorenchyma plainly appear passage-strands, radiating from the central cavity of the cells. As in *Scirpus nodosus*, peculiar processes appear from the stereome into the epidermis.

*Fibro-vascular bundles* are arranged in one or two rings just internal to the chlorenchyma, with thick-walled sheaths enclosed in colourless parenchyma sheath. The stereome groups are developed adjacent to the vascular bundles towards the convex surface, not to those on the concave.

The chief points in which the adult plant differs from the seedling are the development of stereome tissue, and the increased compactness of the chlorenchyma.

(d.) *Conclusion.*

*Scirpus frondosus*, with its characteristics—tufted growth-form, rigid arched leaf, thick cuticle, sunken stomata, compact chlorenchyma cells, and strong development of stereome—is a typical xerophyte. Also, the well-developed rhizomes, with their ability to strike upwards and root, save the plant from being buried by wind-blown sand, and give to it its strong sand-binding propensity. Thus *Scirpus frondosus* is, by both habit and structure, well adapted to its environment.

7. *Carex pumila*.

(a.) *Habitat.*

Found in moist sand hollows or plains commonly in northern portion of the New Brighton beach. The plant acts as a minor sand-binder when a hollow is invaded by sand.

(b.) *Growth-form.*

A small sedge, 1 ft. or less in height, with leaves arching over towards the ground.

*Rhizome* long, creeping, giving rise at intervals to new plants.

*Leaves* sheathing at the base, sheaths completely surrounding the stem; about  $\frac{1}{8}$  in. broad, grooved, glaucous-green, coriaceous, upper surface concave, leaf bending over towards the ground and tapering to a point, midrib prominent in adult leaf.

(c.) *Leaf-anatomy.*

*Epidermis*: On concave surface epidermis consists of large bulliform cells; in the seedling the cells in the middle of this surface extend fully a quarter of the way into the leaf. Convex surface—oblong cells with thick cell-walls, those parallel to the leaf-axis being undulate; stomata frequent, parallel to leaf-axis; level with surface; cuticle present.

*Chlorenchyma*: In the seedling, slightly differentiated, with palisade cells towards the outside and polygonal cells in the interior; water-storage tissue in the chlorenchyma cells, beginning to appear between mestome bundles. In the adult there are two or three layers of palisade cells on the surface, about two on the concave surface; inner cells irregular, polygonal, with intercellular spaces. Large water-storage tracts alternate with the bundles, sometimes there being only one layer of chlorenchyma around the parenchyma sheath.

*Stereome* occurs adjacent to the vascular bundles or subepidermal in origin.

*Fibro-vascular bundles* in a single row through the leaf, surrounded by a mestome sheath and a parenchymatous sheath, some cells containing chloroplasts, others quite colourless.

(d.) *Conclusion.*

*Carex pumila*, as far as anatomy goes, is xerophytic; for instance, cuticle, chlorenchyma differentiated with palisade tissue on both sides of leaf, well-developed water-storage tissue, large epidermal cells on the concave surface which can contract when dry and thus enable the leaf to protect itself against transpiration by arching. The tufted growth-form is also xerophytic. All this is contrary to what might be expected from the fact that the plant grows in moist hollows.

8. *Leptocarpus simplex.*

(a.) *Habitat.*

Found commonly in moist hollows, sand-plains, and marshy places. At the south end of the beach it grows chiefly on the sand-plain among the manuka (*Leptospermum scoparium*), and in the north portion it is common in wet places and in pools. Besides growing in dune areas, it is the most characteristic plant of salt swamp; but it also occurs under mesophytic conditions inland, as on the gravel shores of Lakes Te Anau and Manapouri.

(b.) *Growth-form.*

A rush-like plant which forms dense tussocks of a dull-green or brownish-yellow colour, to which a characteristic mottled appearance is given by the numerous small blackish scales clasping the stem at intervals of about 3 in.

*Rhizome* stout, woody, creeping, covered with brown scales.

*Stems* erect, stiff, wiry, terete, rush-like, slender, diameter less than  $\frac{1}{8}$  in; 1-3 ft. long.

*Leaves* reduced to scales.

(c.) *Anatomy.*

Stem a solid cylinder, consisting of epidermis, chlorenchyma and stereome, fibro-vascular bundles, and pith.

*Epidermis* : Cuticle very thick ; stomata numerous, above the bands of chlorenchyma, sunken, subsidiary cells present.

*Chlorenchyma* : A ring of bands alternating with stereome ; about two to three layers of palisade cells, bands about six cells wide.

*Stereome* well developed ; thin bands between chlorenchyma bands, joining into a thick cylinder internal to the chlorenchyma.

*Fibro-vascular bundles* occur in three rings. The outer ring consists of very small bundles in the inner ends of the narrow stereome bands between the groups of chlorenchyma. The second ring is embedded in the stereome cylinder, and the third ring of larger vascular bundles in the pith, with patches of stereome adjoining the bundles and connected with the stereome cylinder. In transverse sections stained with haematoxylin and safranin, the phloem and smaller xylem elements are apparent, but the larger xylem vessels appear the same as the surrounding pith.

*Pericycle* apparent, consisting of a discontinuous ring of cells between the chlorenchyma and the stereome cylinder, and interrupted at the stereome bands. Internal to the stereome is a cylinder of thick-walled polygonal cells, separated by a ring of cells resembling stereome from an inner mass of large thin-walled polygonal cells in the centre of the stem.

(d.) *Conclusion.*

*Leptocarpus simplex* shows the following xerophytic characters : Tussock form (this has already been discussed in connection with *Scirpus nodosus*), reduction of leaves, and stems taking on the function of photosynthesis ; very thick cuticle, sunken stomata ; compact palisade cells, stereome strongly developed.

The plant, therefore, seems fitted for any xerophytic position, and yet, on the dunes, it grows in moist hollows. Its xerophytic characters are therefore much more in harmony with its halophytic habitat than with its position in the sand-hollow.

9. *Pimelea arenaria.*

(a.) *Habitat.*

Only two shrubs of *Pimelea arenaria* were found, though it is common in New Zealand dune areas generally ; these were at the extreme south end of the beach, near the Summer Estuary. They grew on the active dune, in exposed position, among *Scirpus frondosus*.

(b.) *Growth-form.*

A leafy, much-branched, spreading, and rather procumbent shrub. The lower part of the stem is low-growing, the upper part erect and thickly leaved, with corymbose branching. Leaves at top of branches closely pressed together, overlapping one another, with under-surface outwards, covered with shiny white hairs.

*Stems* woody, flexible, dark brown, lower part leafless, upper twigs leafy for about 4 in. from top, tufts of hairs in axils of branches, and upper twigs hairy.

*Leaves* opposite, decussate, sessile or with short knob-like petioles closely appressed to the stem; each pair of leaves about  $\frac{1}{4}$ – $\frac{3}{8}$  in. apart; leaves standing out from the stem at an angle of  $30^\circ$  usually, but varying to  $80^\circ$ ;  $\frac{1}{3}$ – $\frac{3}{8}$  in. long,  $\frac{1}{4}$ – $\frac{1}{3}$  in. broad; some lower leaves bend downwards at the tip, many are flat, others slightly hollow on upper surface; ovate in shape, varying from elliptic-oblong to almost orbicular, ending in a blunt point; thick, coriaceous, only a mid-vein apparent, upper surface smooth or with few hairs, under-surface thickly covered with silky white appressed hairs.

*Flowers* in heads at the top of the branches, at the very tip or in the axil of a topmost branch. Flowers sessile, white; perianth cylindrical with spreading limbs, covered with silky hairs; four perianth leaves; stamens two, seated upon the perianth, opposite the two outer lobes; ovary superior; one carpel, one ovule; stigma capitate, style brownish-red. Fruit a berry, white, fleshy.

(c.) *Leaf-anatomy.*

*Epidermis*: Dorsal surface—cells irregular, thick-walled; stomata frequent, irregularly disposed, sunken; thick cuticle. Beneath the upper epidermis is a layer of very large colourless cells, probably for water-storage. Ventral surface—cell-walls thick, cells somewhat polygonal in shape, stomata numerous, clefts pointing in all directions, sunken cuticle present; numerous long hairs, unicellular, thick-walled, secreting rather sticky fluid.

*Chlorenchyma* only slightly differentiated; cells rounded, upper layers not definitely palisadic, rather loosely arranged; lower cells loose, forming sort of spongy mesophyll; air-spaces on both surfaces beneath stomata. Patches of water-storage cells alternating with vascular bundles.

(d.) *Conclusion.*

*Pimelea arenaria* is always a plant of semi-stable dunes, and its growth-form, with small leaves growing close together, and the whole plant procumbent and close-growing, is typically xerophytic. The leaf is xerophytic in certain anatomical characters—*e.g.*, in having thick cuticle, thick-walled epidermis, sunken stomata, water-storage cells, under-surface protected by hairs—yet mesophytic in other respects, especially in the important point of chlorenchyma structure.

10. *Leptospermum scoparium.*

(a.) *Habitat.*

Very common on stable dune, and especially upon heath plains; it forms close brown patches of varying size, interspersed among *Cassinia fulvida*, *Discaria toumatou*, *Carmichaelia subulata*, *Leptocarpus simplex*, and *Scirpus nodosus*. On the fixed plains towards the southern end of the beach the manuka is rather more stunted in height, and forms large patches, sometimes near patches of the bracken fern (*Pteridium esculentum*). At the northern end the manuka is commonly found in the vicinity of standing water. Besides occurring on dunes, *L. scoparium* is the dominant heath plant of New Zealand. It occurs also in swamps, bogs, and on rocks

(b.) *Growth-form.*

A stunted or erect brownish shrub, varying in size and shape, with spreading, leafy branches; from  $1\frac{1}{2}$  ft. to 3 ft. high, sometimes forming considerable colonies.

*Stems* woody, brown, much branched.

*Leaves* about  $\frac{1}{2}$  in. long,  $\frac{1}{10}$ – $\frac{1}{8}$  in. broad, varying in shape, lanceolate or ovate, ending in a sharp point, sessile, rigid, thick, underside convex with midrib apparent, otherwise leaf apparently veinless; dotted, usually spreading; brown in colour.

*Flowers*: Solitary, sessile, in axil of group of leaves or at end of branch; usually  $\frac{1}{3}$ – $\frac{1}{2}$  in. diameter. Calyx-tube brown, top-shaped, ending in five small brownish-white membranous lobes. Petals white, spreading, with a small claw, almost orbicular,  $\frac{1}{8}$  in. or more in diameter, with brownish veins. Stamens numerous in a ring around the top of the perianth-tube. Ovary semi-inferior, usually with five carpels, multilocular, with numerous linear slightly curved seeds in each loculus. Stigma capitate, almost peltate. Fruit a capsule, brown, woody, persistent, with persistent calyx-tube forming a rim around it.

(c.) *Leaf-anatomy.*

*Epidermis*: Cells thick-walled, rounded, square, rectangular or polygonal in shape (surface view); above the glands there are two long cells surrounded by a ring of smaller cells. Cuticle thick on both surfaces. Upper surface, no stomata; on under-surface stomata numerous, irregularly arranged, prominent as regards epidermis, but sunk beneath the cuticle.

*Chlorenchyma* differentiated; two or more layers of palisade cells on upper surface, spongy mesophyll in the middle, and palisade cells on the underside; cells loosely arranged, with intercellular spaces, and air-spaces adjacent to stomata. Large glands containing aromatic oil, embedded in the chlorenchyma just beneath the epidermis on both sides of the leaf. Stereome in two patches, above and below each vascular bundle.

*Fibro-vascular bundles*: About three seen in transverse section in the chlorenchyma with stereome, and parenchyma sheath. In transverse section of the woody stem, the large polygonal pith cells in the centre contained round starch grains, some of the cells staining deeply, others scarcely at all.

(d.) *Conclusion.*

*Leptospermum scoparium* exhibits the following xerophytic characters: Small stiff leaves, relatively thick, thick cuticle on both surfaces, thick-walled epidermis, stomata only on under-surface, palisade tissue on both sides of the leaf, stereome developed in vascular bundles. With regard to its growth-form the following quotation from Cockayne\* is instructive: "*Leptospermum scoparium* Forst. (Myrtac.) may be a moderate-sized tree, a tall shrub, a dwarf plant 2–8 cm. tall which flowers and ripens seed, and an absolutely prostrate plant which forms a dense covering to the ground and puts forth adventitious roots, although the erect forms are exceeding difficult to artificially strike as cuttings." Its varied habitats are for the most part xerophytic, so that its leaf-anatomy, considered along with the variety of growth-forms, may in general be considered epharmonic.

11. *Epilobium Billardierianum.*

(a.) *Habitat.*

Found in moist sand-hollows.

(b.) *Growth-form.* Figs. 1 to 3.

A small herb with the lower part of the stem rather woody and low-growing, from which arise several stolons running along the ground and

\* Trans. N.Z. Inst., vol. 44, p. 14.



giving off rather long adventitious roots and leaves at short intervals. Stem reddish in parts, with tiny white hairs.

*Leaves* glabrous, bright green, sessile,  $\frac{3}{4}$ -1 in. long, in shape usually oblong-ovate or linear-oblong, tips obtuse usually, margins denticulate, pinnately veined, midrib prominent, leaves on erect stems decussate.

*Fruit* a capsule, about 2 in. long,  $\frac{1}{2}$ - $\frac{1}{3}$  in. wide; four carpels, each carpel forming a rounded ridge; numerous seeds, small and brown, surmounted by tuft of white silky hairs.

(c.) *Leaf-anatomy.*

*Epidermis*: On both surfaces walls thin, wavy, no cuticle; stomata frequent, prominent.

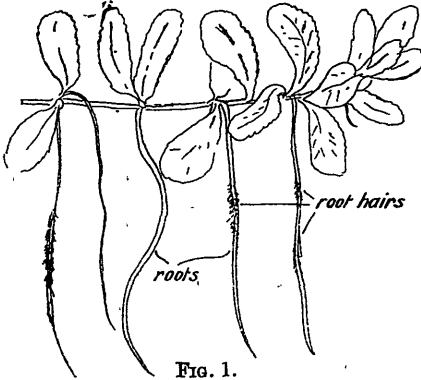


FIG. 1.

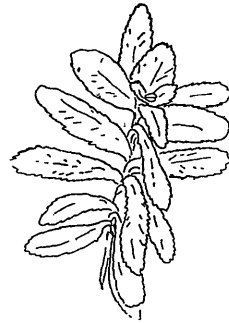


FIG. 2.

FIG. 1.—*Epilobium Billardierianum*: Growth-form with creeping stem.  
 FIG. 2.—*Epilobium Billardierianum*: Erect stem with decussate leaves.

*Chlorenchyma* differentiated; on upper surface large rounded cells, elongated like palisade cells; towards lower surface spongy mesophyll with large intercellular spaces; chloroplasts large and round; crystals (raphides) found commonly in the mesophyll.

*Fibro-vascular bundles*: Large vein in midrib surrounded by mass of colourless parenchyma; a few smaller bundles appear in transverse section in the mesophyll.

(d.) *Conclusion.*

This plant is evidently a strong mesophyte, from the following characters: Leaf delicate and green, no cuticle, prominent stomata, epidermal cell walls thin, structure of chlorenchyma, large intercellular spaces.

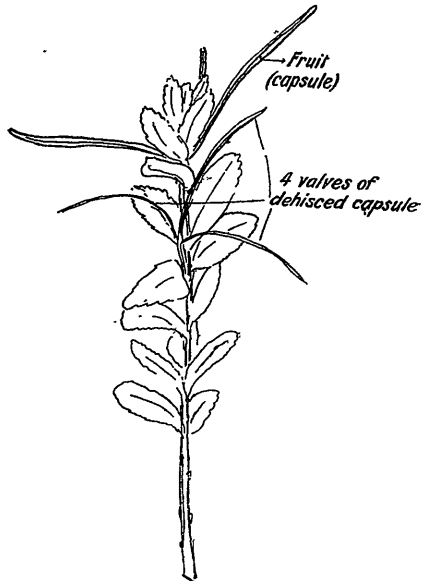


FIG. 3.—*Epilobium Billardierianum*: Flowering stem.

This plant grew well when pot-grown in the greenhouse, seeming to endure both moisture and dryness. Some shoots grew erect, others bent over the sides of the pot and took root in the sand beneath.

12. *Epilobium nerterioides*.

(a.) *Habitat.*

Very common in moist sand-hollows at both ends of the beach. On the south end it grew commonly with *Selliera radicans*, forming sparse carpets on the surface of the sand.

(b.) *Growth-form.*

A small creeping herb, with stem covered, and only the leaves visible above the sand in its natural habitat, forming a double row or small patch of leaves dotted more or less closely over the sand.

*Stem* long, creeping, often under sand, herbaceous, slender, giving rise at intervals of about  $\frac{1}{8}$ – $\frac{1}{4}$  in. to a pair of leaves and a rootlet or two.

*Leaves* opposite, with short petioles,  $\frac{1}{8}$ – $\frac{1}{4}$  in. long, the blade orbicular or orbicular-ovate, apex rounded, top bent slightly downwards, margins entire, green, glabrous, slightly fleshy.

*Capsule* four-lobed, about  $\frac{3}{4}$  in. long, on peduncle longer than the capsule.

(c.) *Leaf-anatomy.*

*Epidermis*: On both surfaces walls thin, wavy outline; stomata numerous, irregularly arranged, prominent; a few unicellular hairs occur, with granular contents; no cuticle.

*Chlorenchyma*: On upper surface very large palisade cells; on underside spongy mesophyll, with large intercellular spaces. In section parallel to surface chlorenchyma cells are circular, with large chlorophyll grains arranged round the walls; crystals (raphides) commonly found embedded in cells in the mesophyll.

*Fibro-vascular bundles* few and small, consisting of a few xylem vessels, spiral chiefly, and a small patch of phloem; bundles surrounded by a parenchyma sheath.

(d.) *Conclusion.*

Leaf-anatomy shows that this plant, like *Epilobium Billardierianum*, is a strong mesophyte, although its prostrate habit appears xerophytic. The plant is very variable in habit; when grown in ordinary dry sand in the greenhouse many shoots grew erect, and the leaves were longer and narrower and of a darker green. Sections taken of these leaves which grew up into the light showed that the cells are smaller and more numerous.

13. *Gunnera arenaria*.

(a.) *Habitat.*

Common in damp sand-hollows, towards north end of New Brighton beach; not found at south end.

(b.) *Growth-form.*

A small plant forming leafy patches or round mats often several feet in diameter. Conspicuous when in fruit.

*Rhizome* stout, with withered leaf-bases.

Leaves dull green, fleshy, with fleshy petioles; leaf 1-2 in. long, including the petioles, which are longer than the blade;  $\frac{1}{3}$ - $\frac{5}{12}$  in. broad; petioles sheathing at the base, and hairy; leaves broadly ovate, margins crenate; large veins prominent on under-surface.

Fruit conspicuous. Peduncles elongated, often 3 in. long or more, projecting above the foliage, with raceme of fleshy orange-coloured drupes, pendulous,  $\frac{1}{4}$ - $\frac{1}{2}$  in. long.

(c.) Anatomy. Fig. 4.

*Epidermis*: On both surfaces cells large, walls thin, outline wavy in surface view, no cuticle; stomata frequent, prominent, wide open, guard-cells containing numerous chloroplasts.

*Chlorenchyma* differentiated; on upper side two layers of palisade cells, the rest of the chlorenchyma consisting of large rounded cells; air-spaces beneath stomata. Embedded in the chlorenchyma were seen large round cells containing sphaerocrystals.

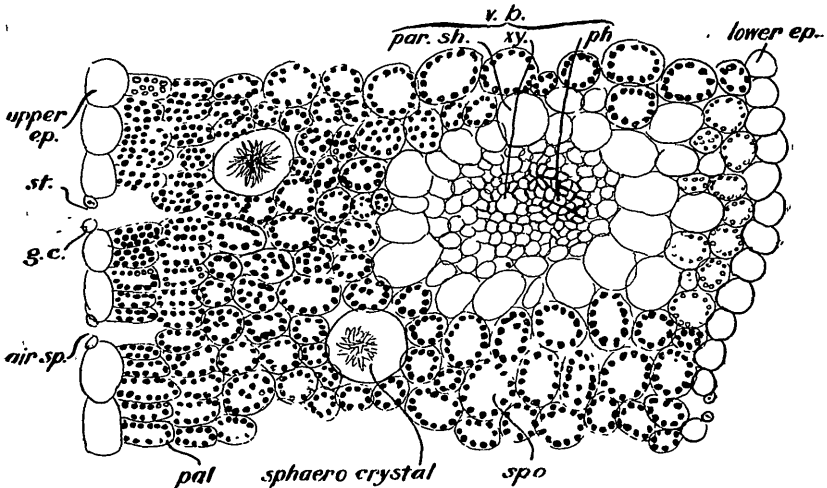


FIG. 4.—*Gunnera arenaria*: Part of T.S. of leaf.

*Fibro-vascular bundles*: Small patch of phloem towards underside, beneath a patch of xylem; bundle surrounded by sheath of large round colourless cells.

When the stem is cut through, two or three blackish specks on the cut ends can be seen by the naked eye. On microscopical examination these are seen to be caused by the presence in the outer cortex of colonies of *Nostoc*.

(d.) Conclusion.

The habit and the fleshy reduced stem of *Gunnera arenaria* are xerophytic; but the leaf, with its prominent wide-open stomata on both surfaces, large rounded chlorenchyma cells, large chloroplasts, and well-marked sponge parenchyma, is strongly mesophytic, in accordance with the moist habitat.

This plant, pot-grown in the greenhouse, thrives both when watered regularly and when kept dry.

14. *Crantzia lineata*.

(a.) *Habitat.*

Found in damp places towards north end of New Brighton beach, often carpeting the ground in company with *Selliera radicans* and *Epilobium*. Also found elsewhere on rock, in salt meadow, and in shallow water.

(b.) *Growth-form.*

A small plant forming mats of narrow erect green rush-like leaves.

*Rhizome* slender, creeping.

*Leaves* arising in tufts along the rhizome, narrow, linear, 1-3 in. long, hollow, cylindrical, slightly compressed, apex blunt, leaves appear jointed by reason of dark ring-like markings across the leaf at intervals of about  $\frac{1}{5}$ - $\frac{1}{4}$  in.

*Inflorescence* a simple umbel with about four pedicels  $\frac{1}{4}$ - $\frac{1}{2}$  in. long, surmounted by ovoid or oblong-globose fruit, with ridges and furrows; tiny bracts at base of umbel.

(c.) *Anatomy.* Fig. 5.

*Epidermis*: Cells irregular, elongated in direction of axis, walls thin, transverse walls often oblique; stomata prominent, not very frequent clefts usually parallel with axis; no cuticle.

*Chlorenchyma*: Large round cells, the outer layer slightly compressed like palisade cells, the inner cells circular in transverse section, longer than broad in section parallel to axis; chlorophyll grains large, round, numerous; air-spaces beneath stomata.

*Fibro-vascular bundles*: About three in each leaf, consisting of a mass of phloem towards the outside and a very few xylem vessels. Bundle surrounded by a colourless sheath of parenchyma, with a few smaller polygonal cells above the phloem, perhaps for water-storage.

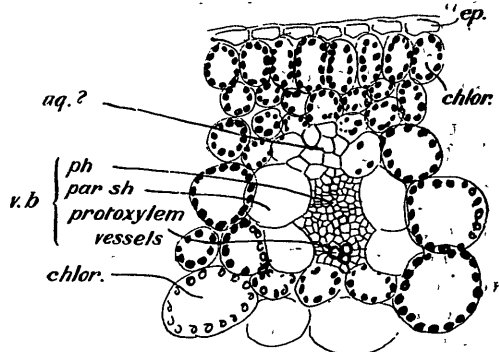


FIG. 5.—*Crantzia lineata*: Part of T.S. of leaf, showing vascular bundle.

(d.) *Conclusion.*

The so-called "leaves" of *Crantzia lineata* are probably phylloides. The rush form and leaf-reduction are xerophytic characters, but anatomy reveals mesophytic characters—e.g. prominent stomata, large rounded chlorenchyma cells with large chlorophyll grains, well-developed spongy tissue, and rudimentary vascular system.

This plant was grown in the greenhouse, and grew well when kept moist and when dry.

15. *Calystegia Soldanella*.

(a.) *Habitat.*

Common on active dunes, where, owing to its prostrate habit and long rhizomes, it binds together and renders stable the mounds of sand on which it grows.

(b.) *Growth-form.*

A prostrate creeping herb forming mats over the sand, with showy convolvulus flowers.

*Rhizome* long, creeping.

*Stems prostrate*, trailing, of varying thickness, cord-like, much branching.

*Leaves* many, on petioles 1-3 in. long, blade in breadth reaching 2 in., broader than long, reniform, basal sinus broad and shallow; leaves green, fleshy.

*Corolla* showy, pale lilac in colour.

*Seeds* blackish-brown, numerous.

(c.) *Leaf-anatomy.*

*Epidermis* much the same on both surfaces, formed of large polygonal cells; stomata numerous, clefts in all directions, on a level with surface, and placed within two cells similar to the guard-cells (these are the "biceller" referred to by Warming, "Halofyt-Studier," p. 33, under *Convolvulus Soldanella*, and p. 21 under *Ipomoea pes caprae*). On epidermis of both surfaces are glandular hairs, consisting of a ring of wedge-shaped cells. These glandular hairs are the "kirtelhaar" described by Warming. In the epidermal cells around them the cuticle is thicker than elsewhere, and the surface is wrinkled.

*Chlorenchyma* differentiated; about four upper layers of the palisadic type, rather loosely arranged. On the underside the cells are rounded and more loosely arranged, with large intercellular spaces; air-spaces beneath stomata.

Ramifying through the chlorenchyma are lacteal veins (the "maelkerorene" of Warming), usually near the vascular bundles. These ducts are surrounded with a layer of cells tangentially stretched, and their contents appear granular.

*Fibro-vascular bundles* numerous. The mid-vein is surrounded by a ring of five or six "maelkerorene," embedded in colourless parenchyma. Each vascular bundle consists of a mass of xylem and of phloem, with parenchyma, surrounded by a parenchyma sheath.

(d.) *Conclusion.*

The characters of the leaf are in part xerophytic—e.g., cuticle, lacteal veins, and water tissue near the veins; but, on the whole, the leaf is mesophytic, with its unprotected stomata on both sides of the leaf, and the structure of the chlorenchyma. It is therefore the habit of the plant rather than its structure which fits it for its position.

16. *Coprosma acerosa.*(a.) *Habitat.*

Found fairly frequently, in rounded masses, on the active dunes at both ends of New Brighton beach; often in company with *Cassinia fulvida*.

(b.) *Growth-form.*

A spreading, ragged, low-growing, matted shrub, with woody interlacing stems and clusters of small linear leaves. Forms wiry cushions or mats about 2 ft. high and several feet in diameter.

*Stems* flexible, and covered with brown bark; curving in all directions; branches at various angles, often at right angles.

Leaves often appear whorled, arising in opposite pairs, or clusters of two to four leaves, sometimes on small branches; dull green, linear, relatively thick, obtuse or subacute,  $\frac{1}{4}$ – $\frac{1}{2}$  in. long,  $\frac{1}{8}$ – $\frac{1}{6}$  in. wide, mid-vein apparent. Fruit a white fleshy drupe, about  $\frac{1}{4}$  in. long.

(c.) *Leaf-anatomy.* Fig. 6.

*Epidermis* of polygonal cells with rather thick walls and outline slightly wavy, cells seeming granular and to contain chloroplasts; stomata very frequent, enclosed in two epidermal cells, and rather prominent; a thin cuticle. Epidermis much the same on both surfaces.

*Chlorenchyma*: Layers of palisadic cells on both surfaces, rather loosely arranged, cells towards the middle much looser, with large intercellular

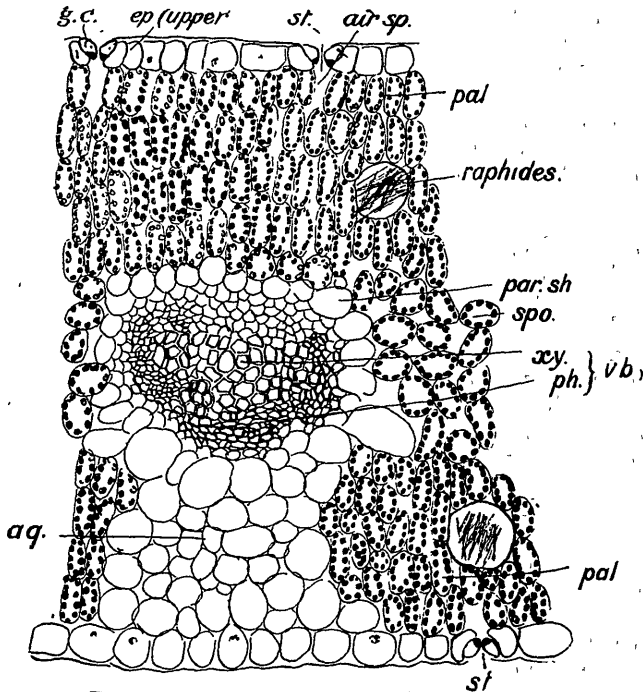


FIG. 6.—*Coprosma acerosa*: Part of T.S. of leaf.

spaces. Embedded in the chlorenchyma are several cells containing small raphides (found, when tested, to be crystals of calcium oxalate).

*Fibro-vascular bundles*: Five or six seen in transverse section, traversing the mesophyll; a mass of colourless parenchyma cells, probably for water-storage, adjacent to the mid-vein, on the ventral surface; bundles well developed, a mass of xylem and a considerable amount of phloem; each bundle surrounded by a parenchyma sheath.

(d.) *Conclusion.*

The almost isolateral leaf, strong development of palisade tissue, and presence of water tissue are xerophytic characters; otherwise the leaf is mesophytic. Here, again, as in *Calystegia Soldanella* and *Pimelea arenaria*, it seems that the habit of the plant rather than its structure fits it for its exposed position on the active dune.

17. *Cassinia fulvida*.(a.) *Habitat*.

Common on active dunes on both ends of New Brighton beach, where it is a characteristic heath plant.

(b.) *Growth-form*.

A heath-like, much-branched shrub, 3-4 ft. high, often straggling, of a characteristic tawny-yellow colour.

*Stems* at first sparingly branched, but much branched towards the top. Upper branches flexible, and covered with a golden-yellow tomentum of thickly matted hairs, giving rise at close intervals to shorter tomentose branches 2-3 in. long, almost erect, these branches being thickly clothed with leaves.

*Leaves* small, thick, green above, but under-surface covered with tomentum, midrib prominent and yellowish; small orange close-set petioles, making leaf appear sessile;  $\frac{1}{8}$ - $\frac{1}{3}$  in. long, oblong or linear-obovate, obtuse, alternate, entire.

*Inflorescence*: Numerous small white heads arranged in corymbs at the end of leafy branches. The plant often bears whitish leaf-like galls, which appear like inflorescences from a distance.

(c.) *Leaf-anatomy*. Fig. 7.

*Epidermis*: Upper surface covered with thick yellow waxy covering; cuticle rather thick, epidermal cells polygonal, with thick walls, a sparse covering of hairs running through the wax; no stomata. Under-surface: stomata numerous, prominent, arranged in all directions, guard-cells with numerous chloroplasts; epidermal cells irregular, no cuticle, a dense covering of thickly matted unicellular hairs that seem to exude oily drops.

*Chlorenchyma* differentiated. About four layers of fairly compact palisade cells on upper side, loose round cells forming a spongy mesophyll on lower side; air-spaces above stomata.

*Fibro-vascular bundles*: About five seen in transverse section; each consists of a mass of xylem above an equal mass of phloem, and is surrounded by a parenchyma sheath.

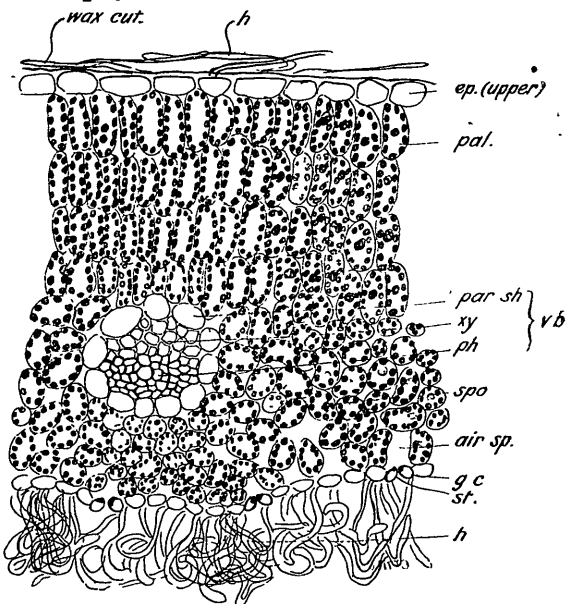


FIG. 7.—*Cassinia fulvida*: Part of T.S. of leaf.

(d.) *Conclusion*.

Leaf-anatomy reveals strong xerophytic characters—wax covering and cuticle on upper surface, dense hairs on under, thick-walled epidermal cells, stomata only on ventral surface, palisade tissue of several compact layers. The plant is therefore well fitted for its exposed position by the xerophytic character of both habit and structure.

E. TABLE OF LEAF-CHARACTERS, EXTERNAL AND ANATOMICAL.

	Growth-form				Leaf, Outward Appearance.							
	Tussock or Tufted	Stems reduced or creeping	Close-growing Shrubs.	Absent or Scaly.	Small.	Grass-like, Reed-like, or Linear.	Conduplicate or Involute.	Concave or Arched.	Bifacial.	Apparently Mesophyte.	Cylindrical.	
1. <i>Calamagrostis Billardieri</i> ..	x	..	..	..	..	x	..	..	x	..	..	
2. <i>Arundo conspicua</i> ..	x	..	..	..	..	x	..	..	x	..	..	
3. <i>Poa caespitosa</i> ..	x	..	..	..	..	x	..	..	x	..	..	
4. <i>Festuca littoralis</i> ..	x	..	..	..	..	x	..	..	x	..	..	
5. <i>Scirpus nodosus</i> ..	x	..	..	x	..	..	..	..	x	..	..	
6. — <i>frondosus</i> ..	x	..	..	..	..	x	..	..	x	..	..	
7. <i>Carex pumila</i> ..	x	..	..	..	..	x	..	..	x	..	..	
8. <i>Leptocarpus simplex</i> ..	x	..	..	x	..	..	..	..	x	..	..	
9. <i>Pimelea arenaria</i> ..	..	..	x	..	x	..	..	..	x	..	..	
10. <i>Leptospermum scoparium</i> ..	..	..	x	..	x	..	..	..	x	..	..	
11. <i>Epilobium Billardierianum</i> ..	..	..	..	..	..	..	..	..	x	..	..	
12. — <i>nerterioides</i> ..	..	x	..	..	x	..	..	..	x	..	..	
13. <i>Gunnera arenaria</i> ..	x	x	..	..	..	..	..	..	x	..	..	
14. <i>Crantzia lineata</i> ..	x	..	..	?	..	x	..	..	x	..	..	
15. <i>Calystegia Soldanella</i> ..	..	x	..	..	..	..	..	..	x	..	..	
16. <i>Coprosma acerosa</i> ..	..	..	x	..	x	..	..	..	x	..	..	
17. <i>Cassinia fulvida</i> ..	..	..	x	..	x	..	..	..	x	..	..	

	Epidermis.										Large Epidermal Cells in T.S.
	Cuticle		Wax Covering	Teeth.	Hairs	Cell-walls.					
	Present	Thick				Exposed Surface		Protected Surface		Wavy Outline.	
						Thick	Undulate	Thick.	Undulate.		
1. <i>Calamagrostis Billardieri</i> ..	x	..	..	..	..	x	..	x	..	..	x
2. <i>Arundo conspicua</i> ..	x	x	..	x	x	x	x	..	..	..	..
3. <i>Poa caespitosa</i> ..	x	x	..	..	x	x	x	..	..	..	..
4. <i>Festuca littoralis</i> ..	x	x	..	..	x	x	x	..	..	..	..
5. <i>Scirpus nodosus</i> ..	x	x	..	..	..	x	x	..	..	..	..
6. — <i>frondosus</i> ..	x	x	..	x	..	x	x	..	..	..	..
7. <i>Carex pumila</i> ..	x	..	..	..	..	x	x	x	x	x	x
8. <i>Leptocarpus simplex</i> ..	x	x	..	..	..	x	..	..	..	..	..
9. <i>Pimelea arenaria</i> ..	x	x	..	..	x	x	..	..	..	..	..
10. <i>Leptospermum scoparium</i> ..	x	x	..	..	..	..	..	x	..	..	..
11. <i>Epilobium Billardierianum</i> ..	..	..	..	..	..	..	..	..	..	..	..
12. — <i>nerterioides</i> ..	..	..	..	..	x	..	..	..	..	..	..
13. <i>Gunnera arenaria</i> ..	..	..	..	..	..	..	..	..	..	*	..
14. <i>Crantzia lineata</i> ..	..	..	..	..	..	..	..	..	..	..	..
15. <i>Calystegia Soldanella</i> ..	x	..	..	..	x	..	..	..	..	..	..
16. <i>Coprosma acerosa</i> ..	x	..	..	..	..	x	x	..	..	..	..
17. <i>Cassinia fulvida</i> ..	x	..	x	..	x	x	..	x	..	..	..

\* Slightly.



	Stomata								Hairs						
	On Both Sur- faces.	On One Sur- face only.	Prominent.	Level with Surface.	Sunken.	In Furrows.	Parallel to Leaf-axis.	Irregularly disposed.	Subsidiary Cells present	On Both Sur- faces.	On One Sur- face only.	Dense Cover- ing.	Unicellular or Simple.	Pitricellular.	Glandular
1. <i>Calamagrostis Billardieri</i>	x	..	..	..	x	x	x	..	x	..	..	..	..	..	..
2. <i>Arundo conspicua</i>	..	x	..	..	..	x	..	..	x	..	..	..	..	..	..
3. <i>Poa caespitosa</i>	..	x	..	..	..	x	x	..	x	..	..	..	x	..	..
4. <i>Festuca littoralis</i>	..	x	..	..	x	..	x	..	x	..	..	..	x	..	..
5. <i>Scirpus nodosus</i>	..	x	..	..	..	..	x	..	x	..	..	..	..	..	..
6. — <i>frondosus</i>	x	..	..	..	..	..	x	..	x	..	..	..	..	..	..
7. <i>Carex pumila</i>	..	x	..	..	x	..	x	..	x	..	..	..	..	..	..
8. <i>Leptocarpus simplex</i>	..	x	..	..	..	..	x	x	x	..	..	..	..	..	..
9. <i>Pimelea arenaria</i>	x	..	..	..	..	..	x	x	x	..	x	x	x	..	..
10. <i>Leptospermum scoparium</i>	..	x	..	..	..	..	x	x	x	..	..	..	..	..	+
11. <i>Epilobium Billardierianum</i>	x	..	x	..	..	..	..	x	..	..	..	..	..	..	..
12. — <i>nerterioides</i>	x	..	x	..	..	..	..	x	..	x	..	..	..	..	..
13. <i>Gunnera arenaria</i>	x	..	x	..	..	..	..	x	..	..	..	..	..	..	..
14. <i>Crantzia lineata</i>	..	..	x	..	..	..	x	..	..	..	..	..	..	..	..
15. <i>Calystegia Soldanella</i>	x	..	x	..	x	..	x	x	x	..	..	..	..	x	..
16. <i>Coprosma acerosa</i>	x	..	x	..	x	..	x	x	x	..	..	..	..	x	..
17. <i>Cassinia fulvida</i>	..	x	..	..	..	..	..	..	..	x	..	..	..	..	..

\* Slightly. † Glands. ‡ Or slightly.

	Chlorenchyma.															
	Homogeneous	Differentiated.	Two or more Layers.	On Two Sides of Leaf.	Compact.	Large Cells.	Well-marked Sponge Tissue	Intercellular Spaces present	Polygonal Con- nect Cells with no Space.	Cells large.	Polygonal	Cells rounded.	Chloroplasts large.	Cell-walls thick.	Water Tissue present	Crystals found
1. <i>Calamagrostis Billardieri</i>	x	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..
2. <i>Arundo conspicua</i>	x	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..
3. <i>Poa caespitosa</i>	x	..	..	..	..	..	..	..	x	..	x	..	..	..	..	..
4. <i>Festuca littoralis</i>	x	..	x	..	..	..	..	..	x	..	x	..	..	..	..	..
5. <i>Scirpus nodosus</i>	x	..	x	..	x	..	..	..	x	..	x	..	..	..	..	..
6. — <i>frondosus</i>	..	x	x	..	..	..	..	..	x	..	x	..	..	..	..	..
7. <i>Carex pumila</i>	..	x	x	..	x	..	..	..	x	..	x	..	..	..	..	..
8. <i>Leptocarpus simplex</i>	x	..	x	..	x	..	..	..	x	..	x	..	..	..	..	..
9. <i>Pimelea arenaria</i>	..	x	x	..	..	..	x	x	x	..	x	..	..	..	x	..
10. <i>Leptospermum scoparium</i>	..	x	x	x	..	..	x	x	x	..	x	..	..	..	..	..
11. <i>Epilobium Billardierianum</i>	..	x	x	..	..	x	x	x	..	x	..	x	x	..	x	x raphides
12. — <i>nerterioides</i>	..	x	x	..	..	x	x	x	..	x	..	x	x	..	..	x raphides
13. <i>Gunnera arenaria</i>	..	x	x	..	..	x	x	x	..	x	..	x	x	..	..	x sphaero- crystals.
14. <i>Crantzia lineata</i>	..	x	..	..	..	x	x	x	..	x	..	x	x	..	..	..
15. <i>Calystegia Soldanella</i>	..	x	x	..	..	x	x	x	..	x	..	x	x	..	..	..
16. <i>Coprosma acerosa</i>	..	x	x	x	..	..	x	x	..	x	..	x	x	x	x	x raphides
17. <i>Cassinia fulvida</i>	..	x	x	..	x	..	x	x	..	x	..	x	x	..	..	..

	Stereome.			Vascular Bundles.			
	Subepidermal.	In Leaf-margins.	Adjoining Vascular Bundles.	Well differentiated	Not well developed	With Mesotome Sheath.	With Parenchyma Sheath.
1. <i>Calamagrostis Billardieri</i>	..	x	..	x	..	x	x
2. <i>Arundo conspicua</i>	..	x	x	x	..	x	x
3. <i>Poa caespitosa</i>	..	x	x	x	..	x	x
4. <i>Festuca littoralis</i>	..	..	..	x	..	x	x
5. <i>Scirpus nodosus</i>	..	x	x	x	..	x	x
6. — <i>frondosus</i>	..	x	x	x	..	x	x
7. <i>Carex pumila</i>	..	x	..	x	..	x	x
8. <i>Leptocarpus simplex</i>	..	x	..	x	x	x	..
9. <i>Pimelea arenaria</i>	..	..	..	..	..	..	..
10. <i>Leptospermum scoparium</i>	..	..	x	x	..	..	x
11. <i>Epilobium Billardierianum</i>	..	..	..	..	x	..	x
12. — <i>nerterioides</i>	..	..	..	..	x	..	x
13. <i>Gunnera arenaria</i>	..	..	..	x	..	..	x
16. <i>Crantzia lineata</i>	..	..	..	..	x	..	x
15. <i>Calystegia Soldanella</i>	..	..	..	..	..	..	x
16. <i>Coprosma acerosa</i>	..	..	..	x	..	..	x
17. <i>Cassinia fulvida</i>	..	..	..	..	..	..	x

#### F. GENERAL CONCLUSIONS.

1. A good deal of anatomical structure appears which, in the case of the true dune-plants, is mesophytic and antagonistic to their well-being.

2. Certain species are strongly xerophytic in leaf-anatomy—e.g., *Scirpus frondosus*, *Scirpus nodosus*, *Cassinia fulvida*, *Leptocarpus simplex*.

3. In considering adaptation to environment, leaf-anatomy alone is not sufficient to decide, but it must be read in conjunction with the special growth-form of the species.

4. A strongly xerophytic growth-form may permit mesophytic leaf-anatomy—e.g., *Pimelea arenaria*, *Calystegia Soldanella*.

5. The plants of the moist hollows for the most part are strong mesophytes, as is natural in their environment; some, however, have xerophytic growth-forms.

6. Be all the above as it may, so far as the New Zealand dune-plants go that have been studied here, there seems to be anatomical structure quite out of harmony with the environment: the xerophytic structure of *Carex pumila*, which grows in moist hollows, may be here instanced.

7. The case of the three active-dune shrubs, *Coprosma acerosa*, *Pimelea arenaria*, and *Cassinia fulvida*, is of interest, since there is a gradual transition, so far as leaf-anatomy goes, from mesophytic to xerophytic, in the order given, and yet they all grow under exactly similar conditions. The three are of distinctly xerophytic habit, but it is certainly worthy of remark that the *Pimelea* and *Cassinia* not only have the advantage over the *Coprosma* in leaf-anatomy, but both have the leaves further protected by tomentum or dense hairs, one of the most efficient of xerophytic adaptations, and extensively common in the indigenous alpine xerophytes. It is not well to generalize from individual cases, but here the anatomical

structure may perhaps be considered rather as a family characteristic than an ecological adaptation.

8. Anatomy and study of growth-forms are by no means sufficient in themselves, but physiological experiments as to transpiration, &c., are demanded, and anatomical studies, although of much moment, are but suggestive, and prepare the way for future research.

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EXPLANATION OF LETTERING IN FIGURES.

<i>air sp.</i>	air-space.		<i>par. sh.</i>	parenchyma sheath.
<i>aq.</i>	aqueous tissue.		<i>ph.</i>	phloem.
<i>chlor.</i>	chlorenchyma.		<i>spo.</i>	spongy parenchyma.
<i>ep.</i>	epidermis.		<i>st.</i>	stoma.
<i>g.c.</i>	guard-cell.		<i>v.b.</i>	vascular bundle.
<i>h.</i>	hairs.		<i>xy.</i>	xylem.
<i>pal.</i>	palisade parenchyma.			