ART. LVII.—*Observations on some New Zealand Halophytes.*

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INTRODUCTORY.

DURING the last hundred years there has been published an ever-increasing volume of literature on the so-called halophytes—that is, plants occupying situations where there is a superabundance of salt in the soil. This special group of plants has been studied from all points of view—morphologically, anatomically, physiologically, and ecologically.

To some extent this order is chronological, for the first observers gave their attention to external characters only, anatomical characters being considered at a later date, while the ecological aspect has been the subject of more modern papers. The physiological section of the subject still opens up much field for research. At the very outset it is yet a debatable point whether halophytes are to be considered salt-loving or salt-enduring plants.

HISTORICAL.

According to Lesage (II, p. 6),* as early as 1804 an article on maritime plants appeared in "L'Encyclopedie," where it is noted that such plants are usually succulent, and have closely packed tissues (*tissu serré*). After this date, and until the publication of his own book, Lesage considers that the works of the following authors are the most noteworthy: Moquin-Tandon (1841), Willkomm (1852), Lecoq (1854), Duval-Jouve (1875), Vesque, and Prillieux; and among these he gives the first place to that of Duval-Jouve.

Before the appearance of Lesage's thesis, however, came the work of Constantin "La Flore du littoral." † M. Constantin notes more especially the external variations of maritime varieties, though he says that "It is very probable that anatomical study will reveal modifications even where the outward appearance would not lead one to suspect so."

The works which have been most consulted for the compilation of this paper, and more especially for the anatomical part of it, are those of Lesage (II) and Warming (V and VIII), though several shorter papers by American writers were found very useful for comparison (see bibliography, p. 574).

Of New Zealand authors, Cheeseman (XVII) has been found invaluable for identification of species. The New Zealand halophytes, however, have been very much neglected, for, with the exception of a recent paper of Dr. Cockayne's on "The Coastal Vegetation of the South Island of New Zealand" (XIX), there has been no special work on this part of the flora.

SCOPE OF THE PAPER.

In the present paper it is proposed to deal with certain typical halophytic formations in the neighbourhood of Christchurch, and to compare these with similar formations at Timaru.

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* The numbers refer to the bibliography, page 574.

† Jour. de Bot., 1re année, No. 3, p. 44, 1887.

The body of the paper consists of two parts: (1.) A general description of life-forms, and of variations of each species according to station. (2.) A short anatomical account of certain of the more characteristic plants of each formation. Attention also will be given to such general conclusions as may be drawn from observations of the plants and their habitats, and some comparison made between these and the results given by authorities on the subject.

Methods of Observation.

The methods employed may be divided, roughly, into two classes—(1) Field-work; (2) laboratory-work. Unfortunately, almost the whole of the field-work had to be done during the winter months—a serious drawback, more especially in the case of annuals. It is for this reason, most of all, that no mention has been made of the flowers of the different species, except in a few cases of flowering out of their usual season.

To supplement the field-work, plants of several of the species observed were planted, some in the open flower-beds, others in the greenhouse at Canterbury College, and these have been examined from time to time, and compared with specimens from their natural habitats.

Districts observed, and Plant Formations.

The Heathcote, on the banks of which most of the field-work has been done, is a small, sluggish stream that forms with the River Avon an estuary, invaded by every high tide, and left a barren expanse of mud at its ebb. Both streams are for a considerable distance affected by the tides, and so their banks and the immediate surroundings of the estuary are favourable situations for halophytic plants. Nowhere do they flourish better than in the little patch of ground in the last bend of the Heathcote, and in this comparatively small area there exist at least three different plant formations: (1) Salt-marsh formation; (2) salt-meadow formation; (3) brackish-water formation.

Of the first of these, the salt marsh, it is difficult to say which is the dominant species. Probably it would be better to say that there are really two dominant species, *Leptocarpus simplex* and *Juncus maritimus*. Looking over the expanse of rushes in the winter, one sees alternately dark and lighter patches, the former being composed of *L. simplex*, the latter of *J. maritimus*. The monotony of these acres of rushes is broken only by purplish-grey clumps and lines of *Plagianthus divaricatus*. These three species, then, are the sole occupants of the greater part of the salt marsh; but at its extreme edge there are a few of the typical species of the salt meadow. These plants must have been excluded from the salt marsh through their inability to cope with the rushes, and not through any unsuitability of edaphic conditions, for the few found there are particularly luxuriant.

In the salt meadow the vegetation is more varied, and is composed of a turf of close-growing plants with creeping stems. The mats of *Salicornia australis* and *Selliera radicans* form the most noteworthy feature of this formation.

Again, the salt meadows are traversed by channels, evidently dug for drainage purposes, and these, at high tide, are filled with water. Here *Plagianthus divaricatus* is the dominant species, though all the plants of the salt meadow, with the exception of *Atriplex patula*, and the addition of *Samolus repens*, root in the sides of the channels, or even in the very bottom.

It is perhaps worthy of note that in the channels, and also in the mud-flats, are innumerable holes of small land-crabs (*Heterograpsus crenulatus*, M. Edw.). Dr. Cockayne (XIX, p. 316) is of opinion that these "must assist materially in aerating the soil, and, to some measure, also in draining the ground."

For purposes of comparison, observations were made also along the banks of the Avon, near New Brighton. Here there are practically the same formations, though they are not in all cases made up of the same members as those at Heathcote. In the salt marshes, for some reason, *Leptocarpus simplex* is much more in evidence than *Juncus maritimus*. The salt meadows, however, are dotted with clumps of the latter rush. Again, out in the meadows are wide pools of brackish water, much less salt than that of the channels of Heathcote. Here there occur, in great numbers, plants (wholly submerged in winter) of *Mimulus repens* and *Cotula coronopifolia;* the latter also a vigorous denizen of the salt meadows.

Both New Brighton and Heathcote were visited from time to time—Heathcote from April to October, New Brighton from July to October; but during the month of June some small amount of work was able to be done at Timaru. Here there are a series of lagoons, separated from the sea only by a very narrow shingle-bank. The first point noticed was that here rushes and rush-like plants do not form a characteristic feature of the landscape. In the neighbourhood of the one lagoon which was comparatively easily approached, only one small tuft of *J. maritimus* was collected. This, perhaps, may be accounted for by the fact that there are no mud-flats, the soil being of a rather sandy nature. An even more striking fact is that, whereas at Heathcote all the halophytes grow side by side in the salt meadow, at Timaru comparatively large tracts round the edges of the lagoon are occupied solely by *Salicornia australis*. One small hollow stretching between two shingle-banks presented, in June, a very peculiar appearance, for it was divided longitudinally into two almost equal halves —one half thickly covered with withered mats of *S. australis*, the other with a bright-green turf of *Cotula coronopifolia*. On closer inspection, it was seen that in this matted growth of *Salicornia* there were innumerable seedlings of *Cotula*, which evidently could not find a foothold there while the *Salicornia* was in a flourishing condition. All the typical plants of the salt-meadow formation, except *Samolus repens* and *Spergularia media*, were found out in the grass at the edges of the neighbouring fields. Some, again, especially *Selliera radicans* and *Apium prostratum*, have established themselves among the rocks of a railway embankment, and here also, though nowhere else in the locality, are a few low grey bushes of *Plagianthus divaricatus*.

LIST OF SPECIES IN NATURAL ORDERS.

A. CYPERACEÆ.

1. *Scirpus americanus*, Pers.
2. *Scirpus lacustris*, Linn.
3. *Scirpus maritimus*, Linn.
4. *Carex litorosa*, Bail.

B. RESTIONACEÆ.

5. *Leptocarpus simplex*, A. Rich.

C. JUNCACEÆ.

6. *Juncus maritimus*, Lam.; var. *australiensis*, Buchen.

D. CHENOPODIACEÆ.

7. *Atriplex patula*, Linn.
8. *Salicornia australis*, Soland.

E. CARYOPHYLLACEÆ.

9. *Spergularia media*, Presl.

F. MALVACEÆ.

10. *Plagianthus divaricatus*, Forst.

G. UMBELLIFERÆ.

11. *Apium prostratum*, Lab.; var. *filiforme*.

H. PRIMULACEÆ.

12. *Samolus repens*, Pers.; var. *procumbens*, R. Knuth.

I. SCROPHULARIACEÆ.

13. *Mimulus repens*, R. Br.

J. GOODENIACEÆ.

14. *Selliera radicans*, Cav.

K. COMPOSITÆ.

15. *Cotula dioica*, Hook.
16. *Cotula coronopifolia*, Linn.

DESCRIPTION OF LIFE FORMS.

(*Abreviations*—H.C. = Heathcote; N.Br. = New Brighton; Tu. = Timaru.)

As the first four species in the above list occur plentifully only at New Brighton, and as this was not visited till July, only their withered leaves were collected; and, so, few particulars of the life forms could be given. It was thought better, however, to mention, at any rate, their station rather than leave them out altogether.

1. Scirpus americanus.

Station.—(1.) H.C.: Absent from all formations. (2.) N.Br.: In channels of brackish water in the salt marshes. (3.) Tu.: Unrepresented.

Life Form.—From the great profusion of dry, withered leaves, one would imagine that in the previous summer the channels must have been fairly choked with a dense growth of this plant. It grows from a perennial, long, black rhizome. The leaves are linear, concave and grooved, sheathing, and covered with short stiff hairs.

2. Scirpus lacustris.

Station.—(1.) H.C.: In the water at the edge of the river, commencing some distance up stream. (2.) N.Br.: As at H.C. (3.) Tu.: Unrepresented.

Life Form.—Of this, the stems only were found growing from a rhizome. According to Cheeseman, leaves are absent.

Stems short and cylindrical.

3. Scirpus maritimus.

Station.—N.Br. (only): In the channels with *S. americanus*, but extending further out into the marsh.

Life Form.—It was not distinguished with any certainty from *S. americanus*. The leaves appeared somewhat broader.

4. Carex litorosa.

Station.—(1.) H.C.: Very sparingly in the salt marshes at the border of the rushes. (2.) N.Br.: In rather greater numbers, but occupying same station as at H.C. (3.) Tu.: Not collected.

Life Form.—Compact tufts, with numerous fibrous roots.

Leaves long, narrow, grooved, the inner surface concave. They are produced into long thread-like points, which in the dead leaves collected were twisted into fantastic spirals.

5. Leptocarpus simplex.

Station.—(1.) H.C.: Associated with *Juncus maritimus* in the salt marshes. (2.) N.Br.: As noted previously, it is here the dominant species of the salt-marsh formation. (3.) Tu.: Absent from the vicinity of the lagoons.

Life Form.—A rush-like plant, growing from a stout creeping rhizome, covered thickly with brown scales.

Stems 30–150 cm. high, about 1 mm. in diameter, numerous, unbranched, cylindrical. They are extremely tough and wiry, with narrow internodes 4–10 cm. long.

Leaves reduced to the sheathing-scales, which clasp the stem closely. Each scale is composed of an outer membranous skin and an inner glassy, brown, thicker coat.

6. Juncus maritimus, var. australiensis.

Station.—(1.) H.C.: Salt marshes. (2.) N.Br.: Salt marshes, and also in scattered clumps over the salt meadows. (3.) Tu.: Though, according to Cheeseman, not found further south than Banks Peninsula, a few plants were collected in the neighbourhood of the lagoons.

Life Form.—A typical rush, growing from a short, stout, brownish rhizome, giving off stems 30–90 cm. high, numerous, rigid, dark-coloured, cylindrical, ending in sharp points. They are of greater diameter (up to 3 mm.) than the stems of *Leptocarpus simplex*, but hardly so wiry. They are marked longitudinally with narrow ridges and grooves. At the base of the stems are brown scales, the inner ones of which are produced into cylindrical pungent leaves of exactly the same appearance and structure as the stems. These leaves clasp the bases of the stems.

This variety, according to Cheeseman (XVII), "differs from the typical state of the species in the darker colour of the plant, in the smaller and more densely aggregated darker flowers, in the shorter capsule, and in the less evident tails to the seeds."

7. Atriplex patula.

Station.—(1.) H.C.: Isolated plants scattered all over the salt meadow, some even down to the edges of the mud-flats. (2.) N.Br.: As at H.C. (3.) Tu.: Out in the grass meadow, and also in prostrate clumps on the shingle-bank.

Life Form.—An annual herb, with main axis (30–60 cm. high) erect; but the branches crowded at its base are quite prostrate, and, as they may reach a length of 25 cm., the plant may occupy a considerable area. This is the case in the damper portions of the meadow; but in the higher stony parts the plant is exceedingly stunted, scarcely ever exceeding 10 cm. In striking contrast to this, specimens from the marshes may reach the height of 90 cm., while the branches are correspondingly longer, and the lower ones are ascending instead of being prostrate.

According to Cheeseman, the plant is green, but all those from the above stations exhibited a reddish appearance, owing to colour in both stem and leaves.

Stem and branches are deeply grooved, and tomentum occurs in the grooves.

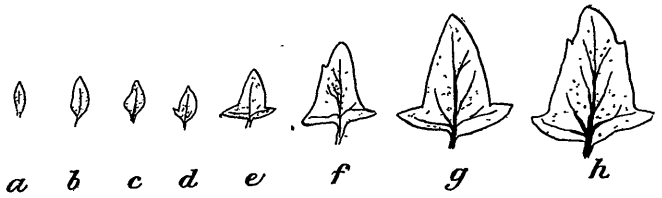

Fig. 1.—Variation in Leaves of Atriplex patula.

Leaves 1–4 cm. long, in a more or less vertical position, generally opposite; but the upper ones may be alternate, very variable in shape, the upper ones being almost linear or linear-lanceolate, the lower ones hastate, while there appear many transitions between these two types. They are shortly petiolate, exstipulate, and have acute apices and entire or sparingly toothed margins. Both upper and lower surfaces are covered with a mealy tomentum. In the dried parts of the meadow the leaves are smaller and very rarely hastate; sometimes they are almost sessile. In the marshes the leaves reach their greatest size, and have the typical hastate shape.

The main root is fairly stout, and has numerous secondary branches.

8. Salicornia australis.

Station.—(1.) H.C.: (*a.*) In the channels, sometimes almost completely submerged. (*b.*) Very abundant in the salt meadow, even in the driest parts, associated with the other typical plants of the meadow, though perhaps the dominant species. (*c.*) On the edge of the mud-flats, beneath the rushes. (2.) N.Br.: It occupies here much the same positions as at H.C., but occurs also completely submerged in the brackish waters of the pools at some distance from the river itself. (3.) Tu.: Crowding out almost all vegetation, except *Cotula coronopifolia*, for some acres round the lagoon and the stream which enters it.

Life Form.—A perennial semi-fruticose plant with numerous spreading succulent branches which may be quite prostrate, procumbent, ascending, or stiffly erect.

The branches are very succulent, though sometimes woody at the base. In winter most of them die down, leaving the dry, woody lower parts, which send out fresh succulent branches in the spring, or, indeed, in winter should a few mild days intervene. In the more sheltered situations the ordinary succulent branches are persistent throughout the whole year. In form they are jointed with internodes 1–2 cm. long, 2–3 mm. in thickness, and cylindrical, except at the joints, where they are slightly flattened, and produced into two short lobes, with membranous edges. Each pair of lobes is at right angles to the pair immediately above. The whole plant is perfectly glabrous.

Leaves are entirely absent.

Roots are short and very woody, and sometimes spread horizontally for a considerable distance.

Inflorescences were found in autumn and the early part of the winter at the ends of the branches. They are in the form of spikes, slightly thicker than the branches they terminate. The flowers are ambisporangiate, and sunk in the joints, which are here much shorter. Each flower has a fleshy perianth, a single rather conspicuous stamen, two styles, papillose stigmas, and one erect ovule.

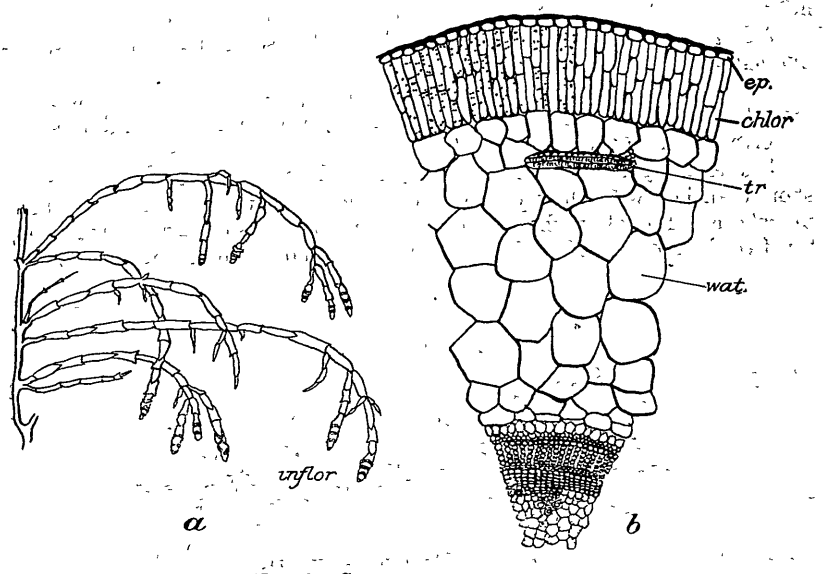

FIG. 2.—SALICORNIA AUSTRALIS.

a. Branches with terminal inflorescences, half natural size. *b*. T.S of succulent stem, × 38.

This species varies much according to station. When wholly or partially submerged it is paler green, much less rigid, and has larger internodes than the ordinary form of the salt meadow. It assumes very much the same appearance out in the marshes, though the branches are slightly more rigid. In the meadows it forms a dense, matted growth, with short branches stiffly erect. In one part, at Heathcote, where a narrow belt of meadow stretches right out to the river, *Salicornia* is found rooting on the upper edge of the bank, and hanging down almost to the surface of the

water. The branches in this place reach a length of 60 cm., and they may cover the banks very thickly, those nearest the bank being very hard and woody, the more superficial ones of the ordinary succulent type.

At Timaru *S. australis* forms a thick carpet almost without a break, and is recognisable at a considerable distance by its conspicuous reddish colour. This red colour is found also to some extent in the stem of *Salicornia* at H.C. and N.Br., but not so markedly as at Tu., for it appears only in a few scattered individuals. Probably this difference is due to a greater amount of salt in the soil in the vicinity of the Timaru lagoons, which, as it was shown above, are separated from the sea only by a very narrow bank of shingle, and are sometimes even invaded by it. With reference to this, Ganong (XI, 355) may be quoted. In his section on the *Salicornetum*, he says, "In general, its members are more stiffly upright, sparser, and redder the salter the place." Comparison of the life forms of *S. australis* according to station would seem to confirm this, except that it occurs not sparsely but very luxuriantly right-down to the edges of the lagoon.

9. Spergularia media.

Station.—(1.) H.C.: In the more sheltered parts of the salt meadows; not very plentiful. (2.) N.Br.: As in (1). (3.) Tu.: Not collected.

Life Form.—A succulent perennial herb of a somewhat loose cushion-like habit.

Stems 3–10 cm. long, branched, generally prostrate, with a few short erect branches. In some cases longer, sparingly branched, straggling stems are given off from the cushion.

Leaves 2–4 cm. long, opposite, in pairs. In the axils of the leaves are short branches, with their young leaves, and so they appear as if arranged in whorls. Probably this is Dr. Cockayne's reason for calling them "tufted" (XIX, p. 348). They are fleshy, almost cylindrical, but slightly

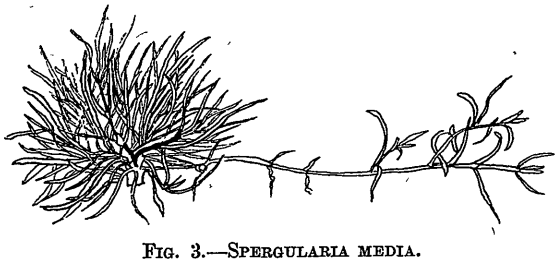

FIG. 3.—SPERGULARIA MEDIA.

Part of cushion with one free branch, half natural size.

flattened on their upper surfaces, and have sharply acute apices. At each node the bases of the young leaves are covered with two membranous stipules, which are opposite and combined for about two-thirds of their length, their sharply pointed apices being free. Later on, when the leaves lengthen and spread out, the two stipules become torn apart. Stems and leaves are covered, but not thickly, with tiny white hairs.

The root is a long stout tap-root, with few rootlets.

No flowers of this species were collected, but fruits were found in April. The fruit is a three-valved capsule.

10. Plagianthus divaricatus.

Station.—(1.) H.C. : (*a.*) A more or less close line marks out the course of almost all the channels; it is noticeable that the bushes do not root actually in the water, but about half-way up their moist banks. (*b.*) Solitary bushes are scattered all over the salt meadow. (*c.*) Lines and clumps break the monotony of the acres of rushes in the marshes; these lines of bushes, in some cases almost straight, at first sight might appear to have been planted in this fashion for hedges, but on close inspection it may be seen that they follow the course of streams, or, at least, damper parts in the marshes. (2.) N.Br.: As at H.C. (3.) Tu.: Only a very few bushes were found, and these, in marked contrast to those at H.C. and N.Br., were in the very driest situation—namely, among the rocks of the railway embankment.

Life Form.—A compact, low-growing, much-branched, coprosma-like shrub, 4–8 ft. high according to Cheeseman, but none were observed over 6 ft. in height. The plant as a whole presents a dull grey appearance, sometimes with a slightly purplish tinge. It is one of the few deciduous New Zealand plants. It is practically deciduous, for in the more exposed parts all the leaves fall off in the beginning of the winter, except a few towards the very innermost parts of the bush, where they are protected by the interlacing mass of branches. The few straggling bushes at Timaru are quite deciduous.

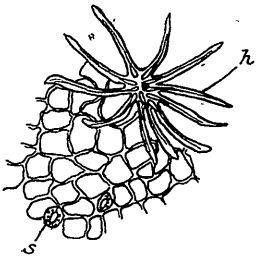

FIG. 4.—PLAGIANTHUS DIVARICATUS.
Epidermis, showing glandular hairs, highly magnified.

The branches are extremely tough, slender, divaricating. Very often they are much interlaced. This is more noticeable in those at H.C. and N.Br. At Tu. they are less branched, and spread out rather more freely.

Leaves are alternate, or, more commonly, fascicled, 2–10 mm. long (though in seedling forms they may be twice this length), linear, obovate, or lanceolate. The margin is entire, and the apex generally obtuse, though sometimes acute. Cheeseman describes the leaf as "one-nerved"; but there is a quite distinct, complex, reticulate venation.

Roots are short and stout, branching horizontally.

A short account of the flower may be given here, as flowers were collected at Heathcote from the 21st June, though Cheeseman gives the period of flowering as September–October. This early flowering is rather surprising so far south, more especially as the winter has been rather severe. Again, of the genus Cheeseman says, "The New Zealand species are practically dicecious, although a few hermaphrodite or female flowers are occasionally mixed with male ones"; but every flower examined was found to be hermaphrodite, though strongly protandrous. It may be possible that the gynœcium in some cases has been overlooked, as it is very small at a stage when the andrœcium is relatively large.

A curious point, too, is that, though typically there are five sepals, almost every calyx had a small extra sepal opposite one of the petals. The andrœcium, again, is worthy of note on account of its large pollen-grains

with conspicuous spiny projections. The stigmatic surface is very markedly papillose.

Fruit was collected in April. It is a dry, downy capsule, splitting irregularly.

N.B.—Many of the bushes are clothed quite thickly with a growth of lichens.

11. Apium prostratum, var. filiforme.

Station.—(1.) H.C.: (*a.*) On the channels, rooting in the edges of the banks, and forming more or less straggling clumps. It is rather remarkable that in one of the channels *A. prostratum* is almost the only plant occupying the banks; the channel is a very moist one, and is very much shaded by the built-up road above, and it is some distance from the river. No bushes of *Plagianthus* and very few of the smaller plants of the channels appear here; but nowhere else is *Apium* so flourishing. (*b.*) It occurs more or less sparingly in the meadows. (2.) N.Br.: As at H.C. (3.) Tu.: (*a.*) A few plants of *Apium* were collected near the lagoon, but they belong, in all probability, to the introduced *Apium graveolens*, as the leaves are larger and very different in shape from the variety *filiforme*. There is a possibility, however, that these are one of the other varieties of *A. prostratum*: the same form was collected in the salt meadows at Heathcote. (*b.*) Undoubted examples of *A. prostratum*, var. *filiforme*, form clumps on the

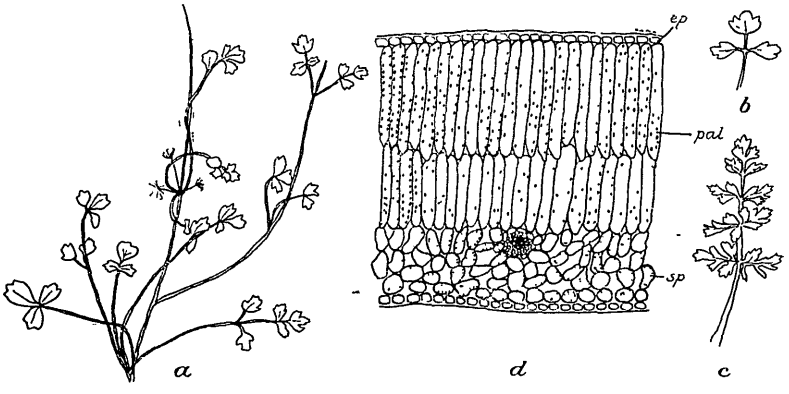

FIG. 5.—APIUM PROSTRATUM, VAR. FILIFORME.

a. Branches, half natural size. *b.* Trifoliate leaf, half natural size. *c.* Leaf, *Apium graveolens* (?), half natural size. *d.* T.S. leaf from plant growing in channel, × 50.

railway embankment. It is remarkable here, also, as in the case of *Plagianthus*, that whereas at H.C. the plant is found mostly in the damper situations, at Tu. it is in the very driest.

Life Form (fig. 5, *a*).—Perennial, perfectly glabrous herb.

Stems slender, up to 60 cm. in length, prostrate or decumbent in the case of plants in the channels; short (about 5 cm.), erect or suberect in the meadow forms.

Leaves fleshy, trifoliate, each leaflet with a short petiole, rarely sessile (fig. 5, *b*). Leaflets 5–15 cm. long, more or less lobed or serrated, with obtuse apices.

Roots are long and stout.

12. Samolus repens.

Station.—(1.) H.C.: (*a.*) In the channels, either actually in the water, or rooting in the moist edges of the banks, associated with *Selliera radicans*, and forming with it a dense, overhanging growth; it is especially luxuriant in the shade of the bushes of *Plagianthus divaricatus*. (*b.*) On the edge of

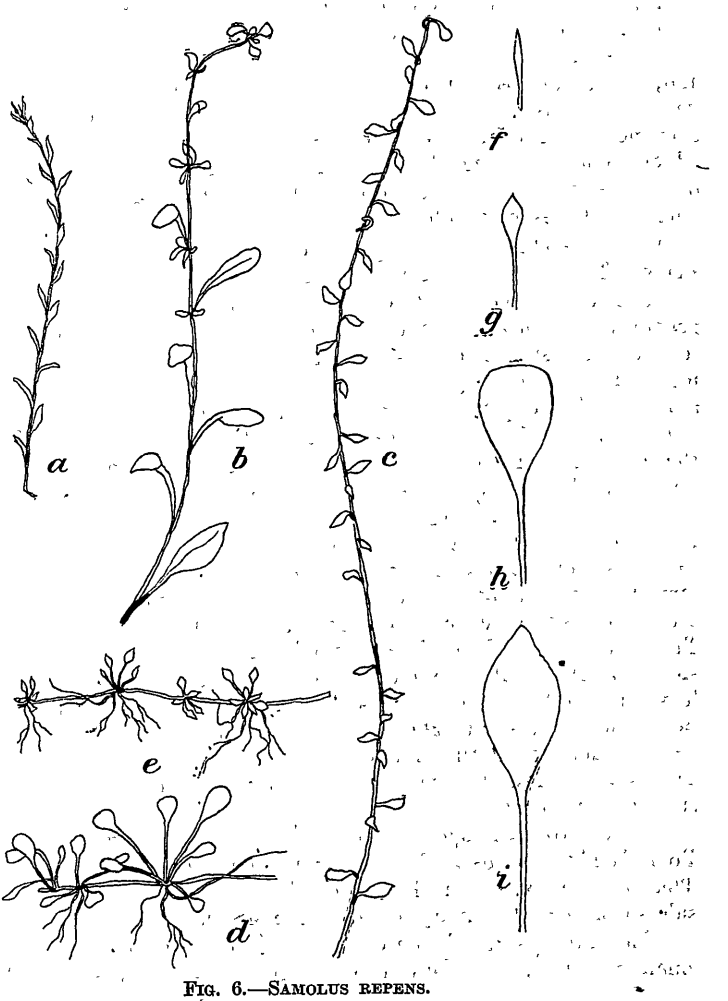

FIG. 6.—SAMOLUS REPENS.

a. Stem of var. *stricta* (?), half natural size. *b.* Ascending branch in the shade of *Plagianthus divaricatus* at H.C., half natural size. *c.* Prostrate branch (N.Br.), half natural size. *d.* Creeping stem from N.Br., half natural size. *e* Creeping stem from H.C., half natural size. *f.* Leaf of *a*, natural size. *g.* Leaf of *e*, natural size. *h.* Leaf of *d*, natural size. *i.* Leaf of *b*, natural size.

the salt marshes, where it occurs more abundantly than any of the typical halophytes of the meadows which have strayed there. (2.) N.Br.: As at H.C. (3.) Tu.: Absent from all formations. It is noteworthy that it is altogether absent from Tu. and also from the meadows at H.C. and N.Br.

Its absence from the salt meadows at Timaru may be accounted for by the fact that the soil there is of a sandy nature; but its presence only in the damp situations at H.C. and N.Br. would seem to point to the conclusion that, when driven from the edges of the lagoons by the more vigorous *Salicornia australis* and *Cotula coronopifolia*, it was unable to thrive in the somewhat dry, exposed salt meadow.

Life Form.—Small perennial herb, with slender stems 10–30 cm. long. According to Cheeseman the stems are glabrous; but, although no actual hairs are visible to the naked eye, the stems have a roughened appearance, and, by running the finger down one of them, one comes in contact with very small, bristle-like projections. The plant grows from a tough creeping rhizome, giving off at the nodes rosettes of leaves and sparingly branched adventitious roots (fig. 6, *a–c*). In the shade of the *Plagianthus* bushes, or of the rushes, however, the stems are erect or ascending, 10–30 cm. long, sometimes giving off stolons from their bases.

Leaves 4–32 mm. long, slightly fleshy, very variable in size, colour, and shape. The margins are invariably entire.

It is remarkable that the prostrate form at N.Br. differs very much in general appearance from the same form at H.C., though the two places are so short a distance apart—three miles. At H.C. the leaves form dense mats of bright-green colour. They are lanceolate in shape, with acute apices, and the petiole is marked off rather sharply from the lamina (fig. 6, *e*). At N.Br. the rosettes are not united into such dense masses, the leaves are of a dull, greyish green, and are obovate with very obtuse apices, while petiole and lamina are not sharply marked off from each other (fig. 6, *d*, *h*). On the erect branches (fig. 6, *b*), in the shade of the *Plagianthus* bushes, the leaves reach their greatest size. Towards the upper part of the branch they are small, with short petioles, or sometimes almost sessile; and they are arranged in alternating whorls. Lower down are larger, single leaves, with petiole and blade of about equal length. These are broadly lanceolate. Stipules are absent in all cases. Fig. 6, *c*, shows a long trailing branch found overhanging a bank at N.Br. The leaves are small, shortly petiolate, and appear singly, not in whorls. This branch was at first mistaken for one of *Selliera radicans;* and the mistake was not detected until a microscopic examination of the leaves was made, as it was remarkably like branches of *Selliera radicans* found in the same situation (fig. 7, *e*).

About two years ago, a plant of *Samolus repens* was brought from the Poor Knights Islands by Dr. Cockayne, and planted in the College rockery. This plant differs so much in general appearance that Dr. Cockayne considers it a separate variety, giving it the MS. name of *stricta.**

The branches are all quite erect, and are very slender. The leaves are small, 6–10 mm. long, quite sessile, bright green, and linear (fig. 6, *a*, *f*).

13. Mimulus repens.

Station.—Collected only at N.Br., and here only in the pools of brackish water in the meadows. All the plants found were completely submerged. It is undoubtedly the dominant species of these pools, though *Cotula coronopifolia* also occurs rather plentifully in patches.

* Trans. N.Z. Inst., vol. xxxix, p. 356.

FIG. 7.—SELLIERA RADICANS.

a. Ascending branch, half natural size. *b*. Leaf of *a*, half natural size. *c*. Creeping stem from salt meadow, half natural size. *d*. Creeping stem from marsh, half natural size. *e*. Stem overhanging bank of channel, half natural size.

Life Form.—Erect perennial herb, perfectly glabrous. Stems thick, succulent, creeping. Roots are emitted at the nodes. Branches erect or ascending, very succulent, sometimes reaching a length of 22 cm. They are perfectly cylindrical.

Leaves small, sessile, in some cases slightly sheathing at the base, 10–13 cm. long. They are fleshy, ovate, have entire margins, and somewhat acute apices.

14. Selliera radicans.

Station.—(1.) H.C.: (*a.*) Overhanging the banks of the channels, where there are long, prostrate, but not rooting, stems, ending in stiff, free branches. (*b.*) Forming a dense matted growth, along with *Salicornia*, in all parts of the salt meadow. (*c.*) On the mud-flats at the edges of the rushes, where it is very luxuriant. (2.) N.Br.: As at H.C. (3.) Tu.: (*a.*) In the meadow, in close mats in the grass. (*b.*) Among the rocks of the railway embankment.

Life Form.—A perennial, perfectly glabrous herb, with yellowish creeping, rooting stems, often being much interlaced, so as to form a thick turf.

Leaves are given off in alternating whorls at the nodes. On the upper part of the free branches they occur singly, though lower down they are again in whorls. They are 4–10 cm. long, spathulate, exstipulate, very fleshy and brittle, with apices acute or sometimes obtuse, margins entire and slightly rolled back. The petiole is not marked off sharply from the lamina, though in the leaves given off from the creeping stems it is rather long. In the salt meadow at Tu., on the other hand, the leaves are almost sessile, though those on the embankment have the ordinary petiole. Again, in the case of the free ascending branches in the masses overhanging the channels at H.C., the upper leaves are practically sessile, their bases slightly clasping the stem (fig. 7, *a*). In the more exposed parts, in the meadows, some of the leaves show beautiful yellow or reddish autumn colouration, a phenomenon somewhat rare in the New Zealand flora. The most brilliant colouring was found in leaves from the embankment at Tu.

Roots are small, white, and sparingly branched.

Mr. Cheeseman has written a very interesting paper on the pollination of the flowers of this species.*

15. Cotula dioica.

Station.—(1.) H.C.: (*a.*) Plentiful in meadows, forming a matted growth. (*b.*) At the edges of the mud-flats. (2.) N.Br.: As at H.C. (3.) Tu.: Out in the meadow among the grasses.

Life Form.—A small, perennial, evergreen herb, with a creeping stem, 3–12 cm. long, rooting at the nodes.

Leaves in tufts, slightly aromatic, rather fleshy, petiolate, exstipulate, and with a membranous sheath at the base. They are very variable in size and shape (fig. 8, *e–h*). They may be spathulate or obovate, crenate, serrate or lobed, sometimes pinnate, the apex being either acute or obtuse. In the lobed forms the lobes may have entire margins or may have irregular serrations towards their apices. As regards size, in the dry parts of the meadow they are from 5–10 mm. long, 2–3 mm. broad (fig. 8, *a*); while in the marshes they may be 4–5 cm. long, 5–12 mm. broad (fig. 8, *c*, *d*). In

* Trans. N.Z. Inst., vol. ix, p. 542.

the more exposed parts of the meadows some of the leaves show a yellow autumn colouration, but it is not of such frequent occurrence nor so brilliant as in *Selliera*. Some of the leaves, however, take on a very peculiar pink colour, as if they had been cut and their cut ends placed in red ink. Flowers were gathered at Tu. as early as July.

Kirk divides *C. dioica* into three species; while Cheeseman gives five varieties of the one species, according to the shape of the leaves. It would

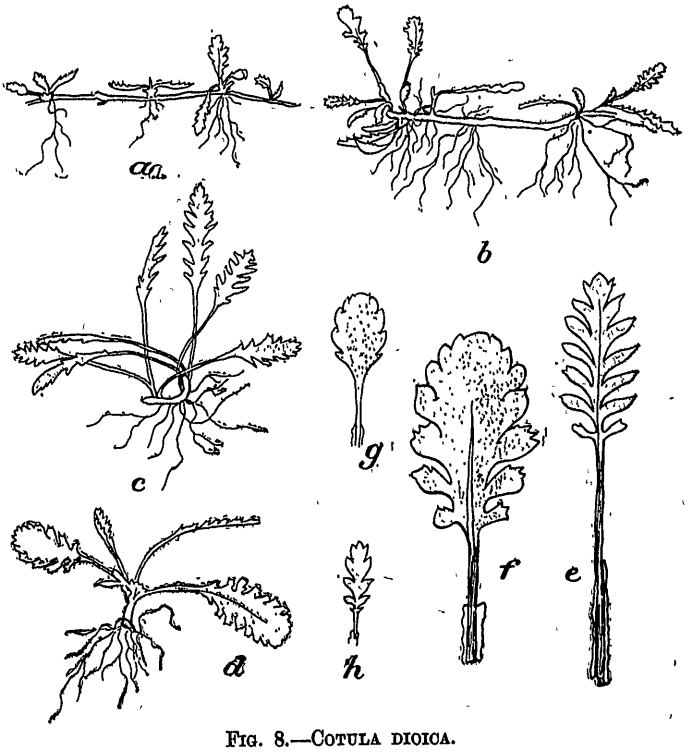

Fig. 8.—Cotula dioica.

a. Creeping stem in driest part of salt meadow, half natural size. *b*. Creeping stem in damper part of salt meadow, half natural size. *c*, *d*. Forms from the marsh, half natural size. *e*, *f*. Leaves from salt marsh, natural size. *g*, *h*. Leaves from salt meadow, natural size.

be difficult to say to which of these varieties those collected at the above stations belong.

16. Cotula coronopifolia.

Station.—(1.) H.C.: (*a*.) In the salt meadow, where it has stout branches and short leaves. (*b*.) Partly or wholly submerged in the water of the channels. (2.) N.Br.: (*a*.) Salt meadows. (*b*.) Wholly submerged in the brackish water of the pools in the meadows. (3.) Tu.: (*a*) Round the edges of the lagoon. (*b*.) A few individuals actually in the water, but not wholly submerged; this, perhaps, may be accounted for by the fact that the water is exceedingly salt.

Life form.—(1.) On land (fig. 9, *b*): A perennial, glabrous, evergreen, succulent herb. The stem consists of a short creeping part and ascending or partially prostrate branches, 10–30 cm. long.; they are not much branched, and have short internodes. Leaves (fig. 9, *h–k*) are scattered,

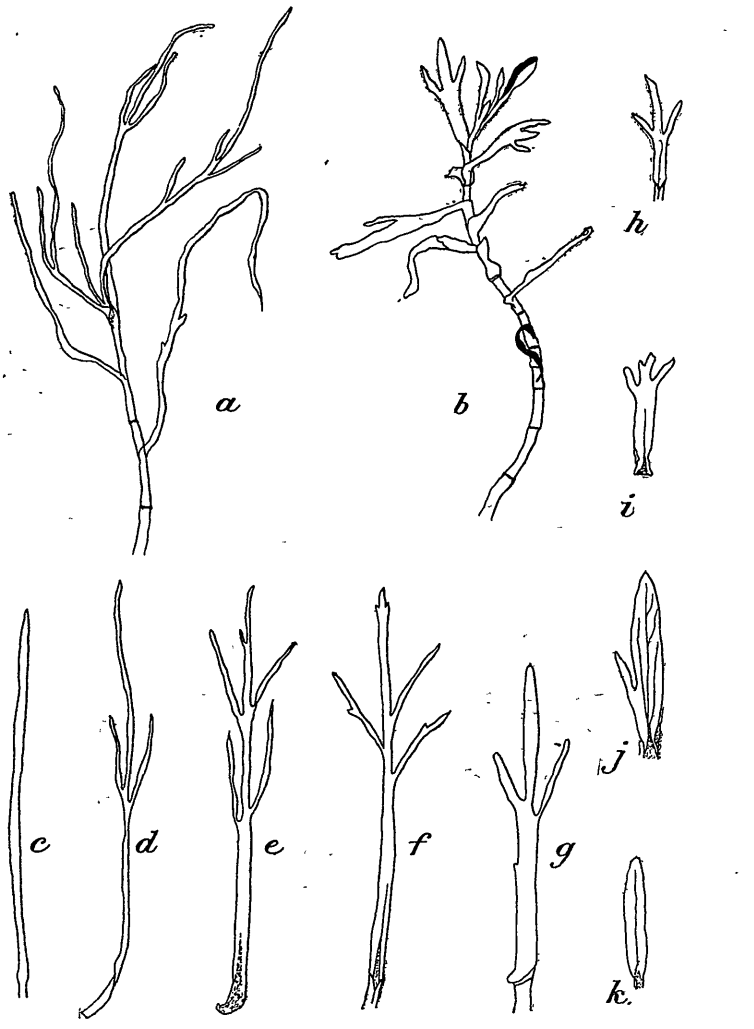

FIG. 9.—COTULA CORONOPIFOLIA.

a. Submerged branch, half natural size. *b*. Branch from damp part of meadow, half natural size. *c*, *f*. Leaves from submerged plant, half natural size. *g*. Floating leaf, half natural size. *h–k*. Leaves from salt meadow, half natural size.

dilated at the base, and clasping the stem almost the whole length of an internode; they are 3–5 cm. long, 4–12 mm. broad, lanceolate, entire or more or less unevenly toothed; margins are slightly recurved, and apices are generally acute; the mid-rib is rather prominent on the lower surface. Roots fairly short, displaying little secondary branching. (2.) Wholly

submerged (fig. 9, *a*): The stems are longer, reaching a length of 40 cm. They are narrower, less rigid, and are generally unbranched. Leaves (fig. 9, *c–f*) also are longer and narrower (9–12 cm. long, 2–5 mm. broad), ribbon-like or finely dissected; they are extremely delicate, so that they droop immediately on being removed from the water. Roots are given off from the nodes right up the stem, except towards the upper end; they are very long, have few rootlets, absolutely no root-hairs, and the upper ones are slightly green.

Fig. 9, *g* shows a floating leaf, which is broader than the submerged ones.

ANATOMY.

No account of the anatomy of the first four species is given, for the reason prefixed to the last section of the paper. With regard to the other species, in most instances the anatomy of the leaf only is described, or of the stem when leaves are absent.

5. Leptocarpus simplex.

Stem.

Epidermis has a cuticle of great thickness. In T.S. this has an apparently cellular structure (fig. 10, *a*), but, as it assumes a yellowish-brown colour with chlor-zinc-iodide, it is assumed that cutin is present. Then, again, by taking longitudinal sections, it is seen that the apparently cellular structure is due to irregularity in the laying-down of the thickening layers, each of which has a wavy outline (fig. 10, *b*).

The stomata occur over the bands of chlorenchyma, and are small, and sunk below the rest of the epidermis. In T.S. two small subsidiary cells appear. In most cases the edges of the cuticle almost meet over them, so that they can scarcely be seen in surface-view.

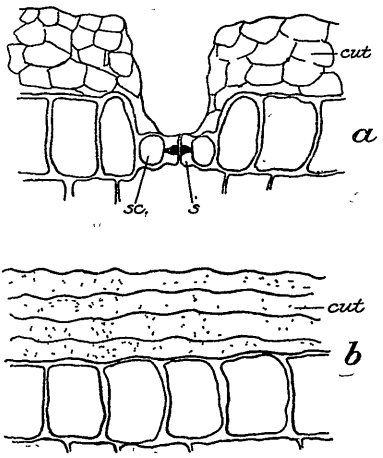

FIG. 10.—LEPTOCARPUS SIMPLEX.

a. T.S. of epidermis, showing cuticle; highly magnified. *b*. L.S. of epidermis showing cuticle; highly magnified.

Chlorenchyma in definite bands 3–4 layers deep, and 6–7 cells wide. The cells are of the regular palisadic type, with somewhat numerous and rather large chromatophores.

Sclerenchyma: Narrow bands of thick-walled cells, alternating with the bands of chlorenchyma.

The f.v. bundles are in three fairly regular circles, the larger ones towards the inside, while the outermost circle is formed of tiny bundles, one beneath each band of sclerenchyma. Each bundle has a mass of sclerenchyma at its upper end, and this sclerenchyma is continued round to form a complete circle, in which the outer bundles are embedded. There is a small amount of phloem in the bundle, and a

xylem with conspicuous annular vessels. Round the whole cylinder is a well-marked pericycle, interrupted at each band of sclerenchyma.

The pith consists of—(1) a tissue of thick-walled cells, rich in starch, evidently assisting in giving rigidity to the stem; (2) the pith proper of large polygonal cells, thin-walled, with few and very small intercellular spaces.

6. Juncus maritimus, var. australiensis.

Stem.

Epidermis with cells of the ordinary type, though rather smaller, and without stomata above the bands of sclerenchyma. The stomata are not sunk in the epidermis, as in the case of *Leptocarpus*. In surface-view the guard-cells are long and narrow, with very much thickened inner walls.

Chlorenchyma consisting of bands 5–6 layers deep. There are numerous small ellipsoidal chlorophyll grains.

Sclerenchyma of narrow, much elongated cells, in narrow bands between the bands of chlorenchyma. Each band is continued to join the sclerenchyma on the outer side of the f.v. bundle immediately beneath.

The f.v. bundles are numerous, and scattered through the pith in very irregular circles. Each has a well-marked bundle-sheath.

The pith is large, and consists of rounded, thin-walled cells, with intercellular spaces of ordinary size. There are also larger lysigenic air-spaces specially towards the outer part of the pith. The schizogenic spaces are smaller than those of most rushes (*e.g.*, in the characteristic stellate parenchyma of *J. conglomeratus*).

7. Atriplex patula.

Leaf.

Epidermis: The cuticle is not thick, and stomata are found on both surfaces. They are not numerous, and have small guard-cells slightly below the level of the other cells. Anthocyan is found in many of the cells. The epidermal cells immediately above and below the midrid are smaller, and have thicker division-walls than the rest of the epidermal cells. Shrunken, dead hairs cover the epidermis.

Mesophyll is formed of palisadic cells, 6–8 layers, with very small intercellular spaces, and small rather scanty chlorophyll grains. Surrounding the midrib is a large mass of colourless parenchymatous cells, polygonal in outline, though those towards the upper surafce are somewhat elongated. They are thin-walled, with the exception of 2–3 layers adjacent to either epidermis.

The midrib is very prominent, and is composed of 4 conspicuous bundles, embedded in a mass of thick-walled cells, and with sclerenchyma at their outer limits.

Stem.

As the stem is of a rather anomalous structure, a short account of it may be given here. Sections were cut and stained very successfully with saffranin and methyl blue. The saffranin picked out cortex, pith, and phloem, while the wood took on an intense blue stain. In section, 4 primary and 4 secondary ridges appear.

Epidermis: In T.S. the cells on the ridges appear smaller; but in surface-view they are longer and narrower than those in the grooves. Stomata are confined to the grooves, and anthocyan is found only in the cells of the ridges.

Cortex of thin-walled hexagonal cells, some of which contain crystals. On the ridges it is modified to form a thick-wall strengthening tissue of small cells, and in the grooves 2–3 layers of chlorenchyma, recalling the structure of the cortex of *Equisetum*.

The f.v. bundles are very anomalous in structure. According to De Bary (i, p. 590–95), "There is first a primary ring of bundles, leaf trace, and perhaps intercalary as well. While the development of these is still proceeding, round the outer margins of their phloems an extra fascicular ring of cambium appears, and forms on its inner side alternately vascular bundles and intermediate tissue; on its outer side, a thin layer of bast parenchyma, or none at all." The intermediate tissue in sections examined seems to have formed a wide layer of wood, which in L.S. appears to consist of tough, fibrous elements. The xylem of the small collateral bundles can be recognised among the intermediate tissue by its thicker walls and larger lumina. The phloem forms small groups interrupting the cambium ring, while further out are groups of thick-walled cells (staining blue), perhaps formed from a second ring of extrafascicular cambium.

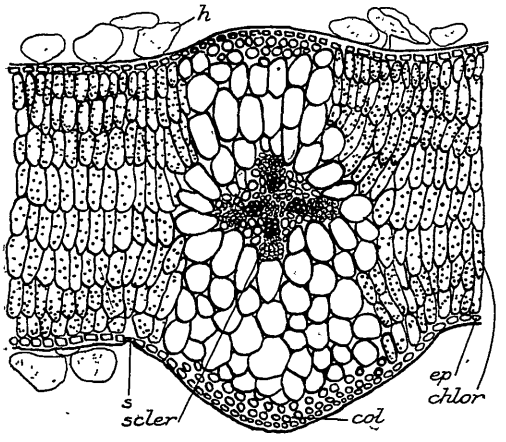

FIG. 11.—ATRIPLEX PATULA

T.S. leaf, × 55.

The pith is large, and consists of rounded, thin-walled cells, some with crystals.

8. Salicornia australis.

Stem (Fig. 2, *b*).

Epidermis: A single layer of cells with a slightly thickened cuticle. The stomata are rather numerous, of medium size, narrow slitted, and not sunk beneath the general surface, though Warming (v, p. 216) says they have been so described. In surface-view the epidermal cells have a regular polygonal outline.

Palisade tissue 2–3 cells thick. In T.S. the cells are long, very narrow, closely packed, and contain numerous small rounded chromatophores.

Water-bearing tissue occupies the greater part of the stem. The cells are polygonal, thin-walled, contain no chromatophores, and have very small intercellular spaces. Towards the outer limits of this tissue there are bundles of tracheides with spiral markings, forming a broken ring parallel with the epidermis. According to De Bary (1) there are scattered tracheides in *Salicornia herbacea;* but they occur in the chlorophyll tissue, and are "perpendicular" to the epidermal cells. Warming (v, p. 215) mentions similar tracheides in the green tissue of *Salicornia herbacea*. It is thought by some authorities that these tracheides serve the purpose of air-storing (XI, 357).

The central cylinder is of a rather anomalous character. There is a well-marked endodermis, beneath which are 2–3 layers of thin-walled cells, followed by bead-like rows of cells; and these in all cases were found to contain green chromatophores, which seems very remarkable in such a deeply seated tissue. Next are 2–3 layers of thin-walled cells, evidently an extra-fascicular cambium such as De Bary describes in *S. herbacea;* and on the inner side of this cambium ring, and evidently formed from it, is a zone of xylem, enclosing a pith containing the original collateral bundles. In the centre is a small medullary cavity.

9. Spergularia media.

Leaf.

Epidermis (fig. 12, *b*) consists of cells with wavy outline, the cuticle being thin, but marked with fine striations. Stomata are rather numerous on both surfaces. Peculiar hairs terminated by rounded knobs perhaps function as hydathodes (fig. 12, *c*).

Mesophyll: (*a.*) On the upper side are 4 layers of palisadic cells with numerous chlorophyll grains: some contain masses of crystals; some contain anthocyan, though this is not present in the epidermis. (*b.*) Colourless parenchyma of thin-walled cells, polygonal, or somewhat rounded in

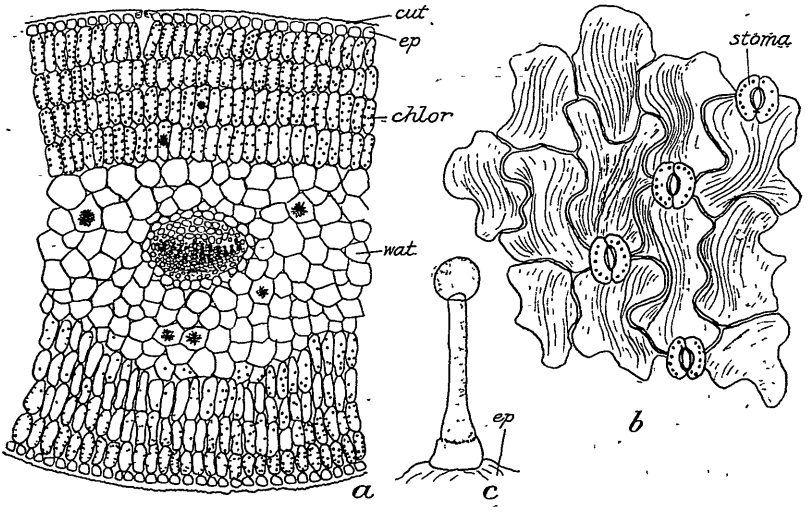

FIG. 12.—SPERGULARIA MEDIA.

a. T.S. leaf, × 32. *b.* Surface-view of epidermis of leaf. *c.* Hair from leaf.

outline, with few and small intercellular spaces; in some cases this occupies about half the width of the leaf and more than one-third of its thickness; masses of crystals are found here also.

The midrib has a well-marked sheath. The xylem is very prominent, but there is little phloem. The whole is embedded in a mass of sclerenchyma.

10. Plagianthus divaricatus.

Leaf.

Epidermis with cells of the ordinary type and a thin cuticle. The stomata are equally numerous on both surfaces, but are not sunk in the epidermis. On the lower side of the leaf are curious stellate hairs (fig. 4), evidently secreting the slimy excretion found on the leaves.

Mesophyll: (*a.*) Palisade parenchyma in 3 layers, 2 of closely packed cells, and a third of cells with larger intercellular spaces; the chlorophyll grains are small, but rather numerous. (*b.*) Spongy parenchyma is largely developed, occupying two-thirds of the mesophyll; the cells are elongated, and the intercellular spaces, though large, are not so large as those of typical spongy parenchyma; the lowest layer next the lower epidermis is of shorter more regular cells; the chlorophyll grains are almost as numerous as in (*a*), though, of course, there are fewer towards the central part of the leaf.

Midrib has a sheath of regular cells and a well-marked phloem. Above and below it, reaching to either epidermis, are colourless cells of the mesophyll.

11. Apium prostratum.

Leaf.

Epidermis consists of small cells with quite thin cuticle. Stomata are numerous, though small, and occur only on the undersurface.

Mesophyll: Two layers of much elongated, palisadic cells, with small, not very numerous, chlorophyll grains. The intercellular spaces are small, and not frequent. This palisadic tissue constitutes three-quarters of the entire mesophyll. The inner layer has shorter cells and fewer chromatophores than the outer.

Vascular bundles are small, with prominent sheath and no sclerenchyma. Fig. 5, *d*, shows one of the smaller veins, not the midrib.

12. Samolus repens.

Leaf.

The epidermis consists of cells rather polygonal in outline, with somewhat thickened outer walls and cuticle. Each cell contains a very conspicuous drop of oil, soluble in ether. The stomata are as numerous on the upper as on the lower side. In the upper epidermis some of the cells have a pinkish hue, due to the presence of anthocyan. This is not found, however, in the cells of the lower epidermis. On both surfaces of the leaf tiny pores are visible to the naked eye. Microscopically examined, in surface-view, these appear as rounded openings, sometimes with apparent cell-walls radiating from the centre. In T.S. (fig. 13, *b*) it is seen that these are not breaks, but invaginations in the epidermal wall. Most of these are filled with greenish grains of wax, which also appear in patches elsewhere on the surface of the leaf. This wax is soluble in ether. In some cases a few very small spherical green algæ were found in the wax. At the bottom of each pit is a glandular hair (fig. 13, *b*). The hair is divided by vertical walls into several cells, supported on a swollen basal cell, evidently but a modified epidermal cell. The cells of the epidermis lining the cavity are somewhat elongated. Warming (v, p. 185) mentions and figures similar glandular hairs ("*kirtelhaar*") in *Glaux maritima*, and notes that Kamienski represents them in *Samolus littoralis*. The hairs in *S. repens* are very like those figured by Miss Ewart (IV) in *Ipomœa paniculata*. They have

the same swollen, supporting basal cell, and the same vertical divisions, though they are in simple pits, not in the elaborate crypts of *Ipomœa*. Warming (v, p. 193), too, describes glandular hairs in *Ipomœa pes-caprœ*.

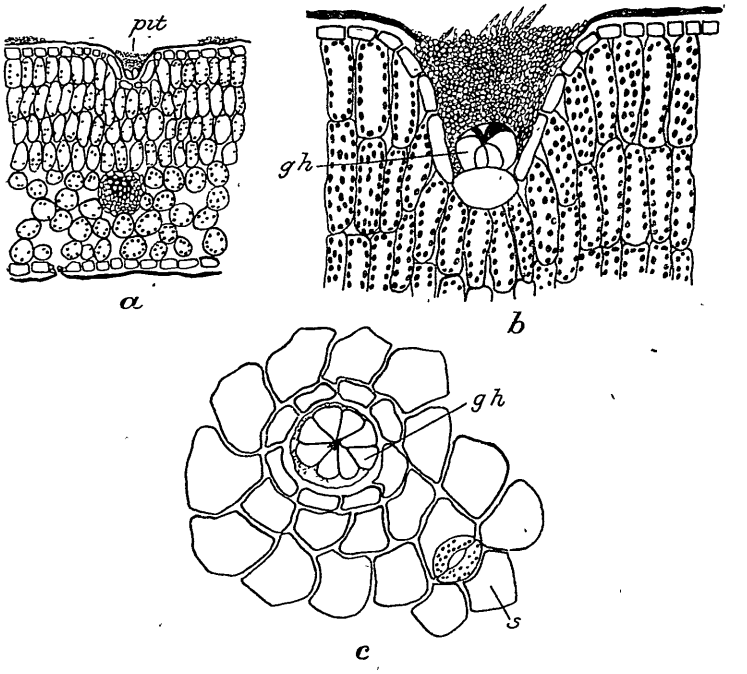

FIG. 13.—SAMOLUS REPENS.

a. T.S. leaf of *b*, × 60. *b*. Pit with glandular hair, highly magnified. *c*. Surface-view of pit with glandular hair, highly magnified

He gives it as his opinion that these hairs, as well as those of *Glaux maritima*, function as hydathodes (v. p. 240).

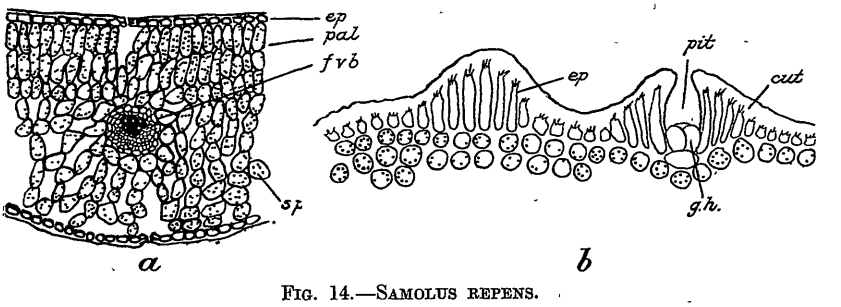

FIG. 14.—SAMOLUS REPENS.

a. T.S. leaf of var. *stricta* (?), ×60. *b*. T.S. epidermis of stem, showing pit with glandular hair; highly magnified.

Mesophyll: (*a*.) Palisade parenchyma consists of 4 rows of cells, about twice as long as they are wide. The chlorophyll grains are small, rather

numerous, and ellipsoidal in shape. (*b*.) Spongy parenchyma, 3 irregular layers with large intercellular spaces; the cells contain few chromatophores. Midrib is small, with definite endodermis, the "starch-sheath" of Brick.

Sections of the stem (fig. 14, *b*) were cut also to investigate the cause of its roughness. It was found that this is due to little projections on the surface, each of which is depressed in the centre to form a deep pit containing a glandular hair, similar to those found on the leaves. All the walls of the epidermis are thickened, the outer one being thickly cuticularised. The cells themselves have curious prolongations towards the outer surface. Each one contains a large drop of oil.

14. Selliera radicans.

The anatomy of two forms of leaf is described: (*a*.) From the free ascending branches of plants overhanging the channels; these leaves have

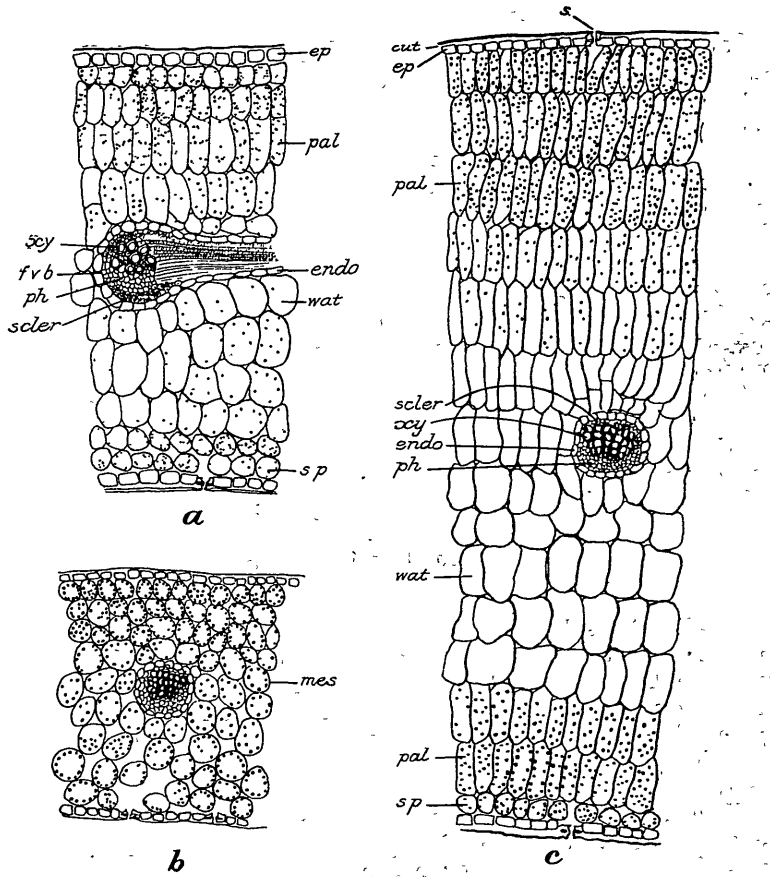

FIG. 15.—SELLIERA RADICANS.

a. T.S. of *b* in fig. 6, × 55. *b*. T.S. of leaf from plant growing in pot, × 55. *c*. T.S. of *d* in fig. 6, × 55.

an average thickness of 1 mm. (*b*.) From the creeping stems on the salt meadows; here the average thickness is 2 mm.

Epidermis on both upper and lower sides has somewhat thickened outer walls and cuticle. Some of the cells of the upper epidermis contain anthocyan. Stomata are of medium size, or rather large, and equally numerous on both surfaces. They are not sunk in the epidermis. The guard-cells have conspicuous chlorophyll grains.

Mesophyll: (*a.*) A single layer of rounded, closely packed cells, with comparatively numerous chlorophyll grains. (*b.*) 2–3 layers of typical palisade parenchyma, of very closely packed cells. (*c.*) 3–4 layers of large, irregular cells, with small intercellular spaces and very few chromatophores. (*d.*) 2 layers of smaller, rounded cells, with larger spaces, forming a kind of reduced spongy parenchyma.

The midrib has a well-marked endodermis, and an upper and lower band of sclerenchyma.

15. Cotula dioica.

Leaf.

Epidermis has a thin cuticle, marked with delicate striations. On both surfaces are pits with glandular hairs. Each hair consists of 3–4 short basal cells, with abundant dark contents, and a narrow terminal cell with clear contents. The hairs are much longer on the lower surface than on the upper, and not situated in such deep pits. Stomata are equally numerous on both surfaces. They are large, with guard-cells containing very conspicuous large spherical chromatophores, found constantly arranged in a definite way, lining the inner wall of the cell.

Mesophyll: (*a.*) 3 layers of irregular, somewhat short cells, with few, but very large, ellipsoidal chromatophores. (*b.*) 4–5 layers of large polygonal cells with few chromatophores, and few very small intercellular spaces; this probably functions as a water-bearing tissue. (*c.*) 2–3 layers of cells, with chromatophores almost as numerous as in *a*; this constitutes a kind of spongy parenchyma of rounded cells, loosely arranged. The lowest row is of smaller more regular cells.

The midrib is fairly large, and has a mass of colourless small-celled parenchyma above and below, though there is no distinct endodermis. The xylem is very conspicuous, the vessels being arranged in parallel rows.

16. Cotula coronopifolia.

Leaf (A, *from Salt Meadows*; B, *Submerged*).

A.—Epidermis has slightly thickened outer walls and cuticle. It is marked with fine striations (*cf. C. dioica*). The stomata are equally numerous on either surface. They are not so large as those of *C. dioica*, and in surface-view (fig. 16, *d*) are seen to be slightly overarched by neighbouring epidermal cells. On both surfaces are peculiar pointed multicellular glandular hairs, recalling those of *C. dioica*, though they are not situated in depressions.

Mesophyll: (*a.*) 3 layers of rounded, closely packed, regular cells, with large but not numerous chromatophores. (*b.*) 10–12 irregular layers of rounded cells with few chlorophyll grains and large intercellular spaces. (*c.*) A single layer of closely packed ellipsoidal cells, with chromatophores as numerous as those in *a*.

Midrib has a prominent sheath, well-marked xylem, and little phloem, embedded in sclerenchyma. There are 2 or 3 layers of colourless parenchymatous cells surrounding the midrib.

B.—The leaf (fig. 16, *c*) here is about half as thick as in A. The same figures and letters are used as in A, and only points of difference are noted.

Epidermis is not cuticularised, and no striations appear on the surface. The epidermal cells are elongated in a direction parallel with the longitudinal axis. There are very few stomata.

Mesophyll: (*a.*) There are only 2 layers of closely packed cells. (*b.*) Only 5–6 layers of loose mesophyll, and the spaces are larger and more numerous. (*c.*) 2 layers of closely packed cells similar to those in (*a*), so that the structure of both sides of the leaf is the same, as might be expected in a submerged plant.

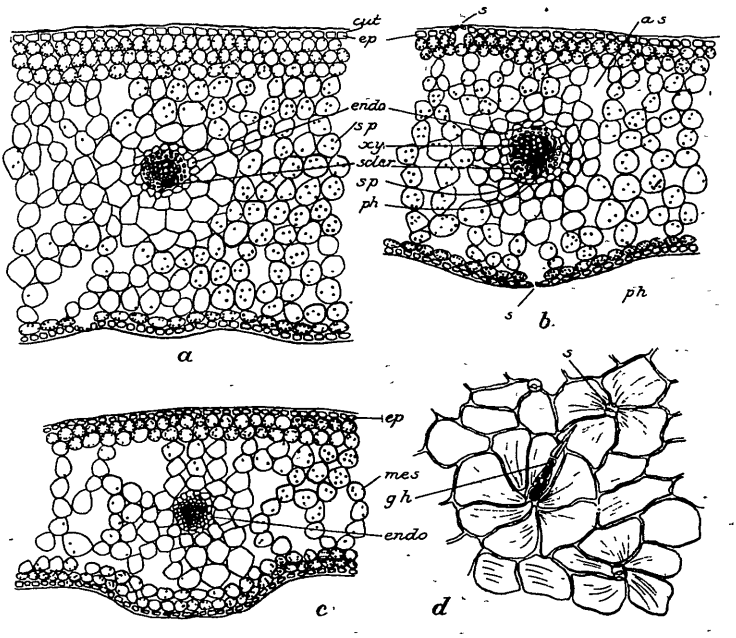

FIG. 16.—COTULA CORONOPIFOLIA.

a. T.S. leaf from meadow, × 55. *b.* T.S. leaf from plant grown in a pot, × 55. *c.* T.S. submerged leaf, × 55. *d.* Surface-view of upper epidermis of leaf *e*, Fig. 9, highly magnified.

The midrib is smaller, has a more prominent phloem, and the xylem elements have not such thickened walls. There is no sclerenchyma.

COMPARISON OF PLANTS GROWN AT CANTERBURY COLLEGE WITH THOSE FROM THEIR NATURAL HABITAT.

The following plants were planted at Canterbury College, some in the flower-beds and some in the greenhouse :—

1. *Salicornia australis.*
2. *Spergularia media.*
3. *Apium prostratum.*
4. *Samolus repens.*
5. *Selliera radicans.*
6. *Cotula dioica.*
7. *Cotula coronopifolia.*

These were planted on the 1st April, and their leaves examined anatomically towards the end of September. Of those in the open flower-beds, none flourished except *Cotula coronopifolia;* but all those planted in the greenhouse with the exception of *Salicornia* grew splendidly. They were plentifully watered with fresh water, but the greenhouse was not artificially heated in any way.

They were found to differ in general appearance from plants from their natural habitat in the following points: (1) They were less compact and less stunted in habit; (2) their leaves were much thinner; (3) their leaves had a brighter green colour.

1. Salicornia australis.

This appeared to die at once, not one little green shoot remaining; but it was watered with the rest, and early in October tiny green shoots appeared on the dry stems.

2. Spergularia media.

The plants lost their cushion-like habit, and developed long, straggling branches, with longer and more flattened leaves. On an average, the leaves were four-fifths of the thickness of those from the meadows.

Anatomical Differences in Leaf.—There was no decrease in the number of layers, though all the cells of the mesophyll were somewhat smaller. The chlorophyll grains were not more numerous, but were larger. The cuticle had no markings on its surface, and this was no doubt due to the fact that the plants were not exposed to such strong insolation.

3. Apium prostratum.

This species grew very vigorously, and on comparing the leaves, first with some which had been in spirit since the 1st April, and then with leaves of plants which were at about the same stage in the natural habit, it was found that their thickness was, on an average, only half that of the other two. Sections being examined, it appeared that this decrease in thickness was due not to a lessened number of layers, but to a diminution in the size of the cells of the palisadic tissue. In all cases the depth of the two layers was less than one-third of that of the corresponding layers in those which had grown in the channels. The spongy parenchyma was as well developed in one case as in the other.

The midrib showed no decrease in size corresponding to the diminished thickness of the whole leaf.

4. Samolus repens.

(1.) *Leaves of Plants grown in the Greenhouse.*—These on an average were but half the thickness of those from the natural habitat. This was due both to reduction in the number of palisadic layers, only three being found, and to a reduction also in their size. There did not appear to be any increase in the number of chlorophyll grains.

(2.) *Leaf of var.* stricta (fig. 14, *a*).—This showed the following differences from that of the ordinary variety from the salt marsh, though it was of the same thickness:—

Epidermis: The outer walls were not so thick or so distinctly cuticularised, and the deposit of wax was less.

Mesophyll: On the whole, there was less differentiation of the tissues. (*a.*) Palisadic parenchyma—3 layers only, and these arranged less regularly, with greater intercellular spaces; the chlorophyll grains were slightly more numerous but not so large. (*b.*) Spongy parenchyma greatly developed, and with somewhat elongated cells.

5. Selliera radicans.

The leaves (fig. 15, *b*) were compared with those on ascending branches (fig. 15, *a*), and were found to be but half their thickness, decrease in size being due to decrease both in the number of layers of cells and in their size. Towards the upper surface, instead of palisade cells there were 3–4 layers of rounded rather closely packed cells, while beneath there were 5–6 irregular layers of somewhat larger rounded cells, with greater intercellular spaces. The chlorophyll bodies were not more numerous, but somewhat larger. The cuticle was much thinner.

6. Cotula dioica.

This species showed very little change, though the leaves were slightly thinner. There was no decrease in the number of layers, though the cells were in some cases somewhat shorter.

7. Cotula coronopifolia.

Leaf (Fig. 16, *b*).

Epidermis had somewhat thinner cuticle.

The palisade parenchyma showed only two rows of closely packed cells, and in most cases the chlorophyll grains were slightly larger, though not more numerous.

The spongy parenchyma was scarcely so well developed, but had rather more intercellular spaces. Probably in the typical halophytic form this may be largely developed to form a water-bearing tissue.

Not too much confidence is placed in these results, as the decrease in thickness in so short a time seems too great to be accounted for by the absence of salt in the soil only. Very probably it was to some extent due to other external conditions, such as their being grown within doors and in pots. Had this comparison been intended for the chief section of the work, time would have been taken to repeat Lesage's classical experiment, and so to confirm the above results. In any case, it must be assumed that the absence of salt in the soil is the principal cause of the decrease in the thickness of the leaves. Then, again, as Lesage found during his experiments, this decrease is due to a lessening of the number of the palisadic layers, or to a diminution of the size of their cells, or to both.

GENERAL CONCLUSIONS.

In the first place, with regard to the life form and external morphology of these New Zealand halophytes, they exhibit, on the whole, the following characteristics:—

(1.) A tendency to adopt a prostrate habit (*Atriplex*, *Selliera*), and to present a more or less stunted appearance (*Plagianthus*). Several explanations have been put forward to account for this stunted condition.

Schimper (x) attributes it to the superabundance of salt in the soil; Warming (v) to an attempt to reduce the transpiring surface. Dr. Cockayne, in his general account of the coastal vegetation of the South Island of New Zealand, points out that the wind must be an important factor.* This seems to be confirmed by the fact that those plants of the salt meadows which have strayed into the marshes, or occupy the channels and are sheltered by the dense growth of rushes or by the *Plagianthus* bushes, have discarded to some extent the prostrate habit (*e.g.*, *Atriplex*, *Selliera*). The direction of the prevailing wind is shown by the bushes of *Plagianthus*, which in the more exposed situations are bent towards the west. It is a well-known fact, however, that excess of light is not conducive to growth; and here on the salt meadows there is a very bright illumination. May not this account, in some degree, for the stunted growth?

(2.) A reduction of the leaves, both as regards number and size (*Plagianthus*). In *Salicornia* they are entirely absent, while in *Leptocarpus* and *Juncus* they are reduced to scales. This must be accounted for, as it generally is, as a modification to reduce the transpiring surface. In the case of *Plagianthus*, however, the wind, again, may be a determining factor in the leaf-reduction, as well as in the adoption of a twiggy divaricating habit.

(3.) A more or less brilliant colouration, especially in the autumn, and this in plants which are not deciduous (*Selliera*, *Cotula dioica*). The colour here evidently is due, as Ganong (xi, p. 355) suggests, to the amount of salt in the soil. Again, some exhibit a reddish colour, due to the presence of anthocyan in the cells (*Atriplex*, *Spergularia*, *&c.*). Many theories have been advanced as to the use of this pigment, one being that it acts as a screen to the chloroplasts, to preserve them from injury from too intense light (vii, p. 282). This would seem a very satisfactory explanation as far as these halophytes are concerned, for on the level unshaded salt meadows they are subjected to strong insolation.

(4.) A great thickness of the leaves. This, perhaps, is the most noteworthy of these characteristics, and will be dealt with more fully under anatomical characters.

(5.) Translucence of the leaves (*e.g.*, *Selliera*, *Spergularia*).

Some authors (*i.e.*, Henslow, and Battandier, whom he quotes) give hairiness as a very general character of halophytic plants; but none of these New Zealand halophytes show any hairiness, except *Atriplex*, with its mealy tomentum of dead hairs, and *Spergularia*, with its sparse covering of white hairs, almost invisible to the naked eye.

Anatomical Characters of the Leaf.

Epidermis: In some cases this shows a very much thickened cuticle (*Leptocarpus*); but, on the whole, it is not strongly developed. The cuticle often has an uneven surface, which in one case (*Spergularia*) became smooth when plants were grown in pots. In all probability this uneven cuticle is a definite adaptation, to guard the leaf against the effect of the strong insolation. In connection with the epidermis, again, glandular hairs are developed (*Plagianthus*, both species of *Cotula*, *Samolus*, *Spergularia*). These

* This, of course, chiefly works by its physiological effect in transpiration, leading to death through drying-up of tissues. There is also a mechanical effect.

are said to function as hydathodes (v). Stomata are rather large, and occur on both surfaces. This last observation does not lend support to the generally accepted view that halophytes exhibit a xerophytic structure. Chrysler (XIV, p. 463) also notes the presence of stomata on both surfaces in maritime plants. However, this may be due in some cases (*i.e.*, *Atriplex*) to the more or less vertical position of the leaves. Again, in very few instances are stomata sunk beneath the general surface of the epidermis; but it would be unreasonable to argue from this that these plants do not show a xerophytic structure, as even the most typical xerophytes do not exhibit every single one of the strictly xerophytic adaptations.

Mesophyll shows the following characteristics: (*a.*) A great development of palisadic tissue, a remarkably xerophytic character, resulting in the checking of too rapid transpiration. (*b.*) A corresponding reduction of the spongy parenchyma. (*c.*) In some cases a development of a definite water-bearing tissue (*Cotula coronopifolia*, *Selliera*, and the stems of *Salicornia*). (*d.*) A great reduction of the intercellular spaces; and no doubt to this is due the translucence of the leaves; this reduction causes a diminishing of the transpiring surface. (*e.*) In some cases chlorophyll grains are few; by experiment it was found that the size of the grains, rather than their number, increased when plants were cultivated away from their native habitat. (*f.*) The vascular system is not particularly well developed. (*g.*) A definite endodermis is almost invariably present, as Brick, who calls it the "starch-sheath," found in many maritime plants.

ORIGIN OF THE HALOPHYTIC FORMATIONS.

Many of the above characters are plainly those of xerophytes, the main object being to reduce the transpiring surface. *Cotula coronopifolia*, however, shows scarcely any of these xerophytic characters, for it has no true palisadic tissue in its leaves, and it has large intercellular spaces in both leaves and stem. This latter fact, above all, would lead to the conclusion that this plant was primarily an aquatic plant, able to frequent brackish-water pools, and that from these it has crept up into the meadows, where it has undergone a few modifications, such as the formation of a water-bearing tissue, to cause it to flourish as it does in its new environment.

Again, *Plagianthus* certainly exhibits characters essentially xerophytic, and is of a type very similar to typical New Zealand xerophytes (*i.e.*, *Coprosmas*). The question to be considered here is whether its xerophytic characters are to be regarded as results of a direct adaptation to its present environment, or whether, primarily a xerophyte, it found those modifications which fitted it for its life as a xerophyte equally useful in its new surroundings. If this latter supposition be correct, it may be said that these halophytic formations have a threefold origin—*i.e.*, from hydrophytes (*Cotula coronopifolia*), xerophytes, and lastly mesophytes, for many of them are to be found inland in typical mesophytic formations (*Cotula dioica*, *Selliera radicans*). Schimper, however, defines halophytes as "salt-enduring xerophytes driven to the shore by competition." In any case, we must agree that these are very probably "ordinary inland plants which have been driven out of the more hospitable ground by better-equipped competitors," and that they "occupy their peculiar station not from choice, but from necessity" (XIX), for when transferred to ordinary soil they grow luxuriantly, while many are found inland.

LETTERING USED IN FIGURES.

a.s.	..	air-space	*mes.*	..	mesophyll.
antho.	..	anthocyan.	*p.*	..	pith.
cam.	..	cambium.	*pal.*	..	palisade parenchyma.
cent. cy.	..	central cylinder.	*ph.*	..	phloem.
chlor.	..	chlorenchyma.	*pr.b.*	..	primary bundle.
col.	..	collenchyma.	*s.*	..	stoma.
cr.	..	crystals.	*s.c.*	..	subsidiary cell.
cut.	..	cuticle.	*scler.*	..	sclerenchyma.
endo.	..	endodermis.	*s.p.*	..	spongy parenchyma.
ep.	..	epidermis.	*st.*	..	stereom tissue.
g.h.	..	glandular hair.	*wat.*	..	water-bearing tissue.
h.	..	hair.	*xy.*	..	xylem.

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