

" THE IDENTIFICATION of GRASSES by LEAF ANATOMY "

T H E S I S

for the Doctorate of Science

- submitted by -

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INTRODUCTION.

According to De Candolle, the world's economic plants are referable to some fifty families. Including, as it does, the cereals and the forage grasses, Gramineae is by far the most important single family. The importance of grass and its products to this country is strikingly brought out in a recent Government publication. Cereals represented £58 millions, and grassland products £147 millions, out of a total of £702 millions, - imports in 1932. The same paper states that in the 1925 census of agricultural production (the latest issued) the value of grassland products for England and Wales was £110.8 millions, or nearly $2\frac{1}{2}$ times the value of the arable crops, (£46 millions), and nearly half the value of the total agricultural output, £225.3 millions.

Swift's oft repeated dictum "that whoever could make two ears of corn or two blades of grass to grow upon a spot of ground where only one grew before, would deserve better of mankind, and do more essential service to his country, than the whole race of politicians put together" (Gulliver's Travels), indicates that the value of good pasture was not unrecognised even two hundred years ago. It was not, however, until the beginning of the present century that a general improvement began. The impetus was largely derived from the now famous Cockle Park experiments. The Seeds Act, by ensuring adequate supplies of good seeds must also be held responsible for much of the improvement. The post war period has witnessed a great increase in pasture at the expense of arable land - the result of unremunerative prices for arable land products. This has focussed attention on herbage species. The suitability of the various species for different conditions has been studied at/

at the research centres. As a result of investigations carried out at Aberystwyth and elsewhere, it has become obvious that the strains within a species are of very variable performance. In the case of Lolium perenne, Phleum pratense and Dactylis glomerata for example, it has been demonstrated that there are strains which have a preponderance of flowering shoots, - others a large proportion of sterile shoots. The former type is suited for hay, but unsuited for pastoral purposes. We have been unwittingly selecting the hay type for years. The pasture type in each case produces relatively little seed per acre and is more costly as a result.

There is everywhere growing evidence that the farmer selects the constituents of his 'seeds mixture' more carefully than formerly. Many, moreover, are evincing a desire to know whether all the species sown are represented in the resulting pasture. In a pasture grazed in orthodox fashion, inflorescences, with which to identify the species constituting the sward, are not available. This is even more true of sports grounds. Moreover, even if the grasses are left undisturbed, there are some seven months during which flowers are not available. It is important, therefore, to be able to recognise grasses in non flowering condition.

Gramineae: general characters.

The most striking fact about this family is that though wind pollinated and monocotyledonous, it has achieved in the world a position of dominance as far as number of individuals is concerned. The family is natural and distinctive, its closest affinity being with the Cyperaceae.^{9.} Bews groups these two families together under his Order Glumiflorae, while³⁶ Hutchison groups both along with the Juncales under his Division Glumiflorae.^{5.} Arber, following the example of Fritsch, prefers to regard/

regard the likeness between Gramineae and Cyperaceae as indicating parallel development, and favours the use of the term Graminaceae for the family and Gramineae for the order.

Here, however, we are less concerned with affinities than the differences between grasses and sedges. Sedges have the linear, ribbon type of leaf common to most grasses, but whereas grasses have double ranked phyllotaxy, sedges usually have their leaves in three ranks. Grasses usually have round stems which are seldom solid, sedges triangular stems which are rarely hollow. Sedges very rarely have a ligule; in grasses it is seldom absent. In addition, of course, there are marked floristic differences, and also it may be added, leaf anatomical differences.

For differentiating grasses amongst themselves in the past, reliance has been placed on morphological characters such as habit; leaf colour and shape; leaf setaceous or linear; ribs present or absent; auricles present or absent; shape of ligule; sheath split or open; colour of basal sheath; glabrous or hirsute; colour and texture of roots; extravaginal or intravaginal branching; leaf folded or rolled in bud.

Keys for identifying grasses in vegetative state have been formulated, notably by Ward, McAlpine and Armstrong in this country. On well grazed pastures and on sports grounds these characteristics are not always available. Moreover, many of the 'characteristics' are not always dependable. To select one species to illustrate this point, Lolium perenne is described as having pink or red basal sheath, and as having leaf folded in bud. Yet, plants do occur having white basal sheath and others have leaf rolled in the bud. (Pl. 3.) The descriptive terms applied in morphology are very relative and it/

it is difficult to know whether one is confronted with small, medium or large structure.

Leaf cross sections present in most cases a ready means of identification. Duval-Jouve^{19,20} was the first who made use of leaf anatomy for purposes of identification. Anatomical characters have also been exploited by Maw, the monographer of the Genus Crocus (utilising leaves) and by Gatin on the Liliaceae, (utilising peduncles).^{3.} Arber referring to her experience in Monocotyledons in general says: "I have been amazed to find how much these leaves vary in anatomy; it appears that any one who chose to make a sufficiently detailed comparative examination, would find it possible to identify not only the family but even in many cases the genus and species from the transverse section of the leaf alone."

This claim, we hope to demonstrate, can be fully substantiated in the Gramineae.

The Utilisation of Leaf Cross-sections in Identification:
Historical.

Duval-Jouve^{20.} (1875) quotes Linnaeus as having said, "Folia in Graminibus ejusdem sunt structurae."^{56.} Pee-Laby quotes Palisot de Beauvois^{8.} (1812) as having repeated Linnaeus in, "Les feuilles sont essentiellement uniformes. On ne les distingue entre elles que par les caracteres suivantes; glabrous ou velues, lisses ou scabres etc."

Pee-Laby attributes the long neglect of the subject to these statements. Botanists did not trouble to verify the parts relating to anatomy, and Linnaeus's opinion was not queried until 1865. About this time several German botanists independently took up the study of grasses. Hingshausen attempted a classification on leaf venation. He it was who first noticed the/

the anastomoses between the parallel veins. Weiss was concerned with the distribution of the stomata, while Pfitzer attempted to explain how they functioned.

^{20.}
In 1875, Duval-Jouve's comprehensive work on the anatomy of grass leaves appeared. Prior to that he had published a paper entitled "Etude anatomique de quelques Graminees, et en particulier des Agropyron de l'Herault." In this paper he

^{19.}
draws upon root, rhizome, haulm and leaf characters for distinctions. The second paper, however, is the more important and is concerned with the anatomy of grass leaves in general.

^{20.}
In it he seeks to explain the function of the various tissues and is the first to suggest the significance of the motor-cells, his "cellules bulliformes."

His sections are taken from a segments of leaf from the lower third of the second - top culm leaf. In 1886 we have a paper by Guntz, which stresses the correlation of structure with climate and habitat.

^{25.}
Schwendener, in "Ueber die Spaltöffnungen der Gramineen und Cyperaceen". Sitzungsbericht der Akad. Berlin 1889, is

^{64.}
occupied with the structure of the stomata. The following year he gives a detailed account of the sclerotic sheath in the same journal.

^{56.}
Pee-Laby (1898) utilises anatomical characters to differentiate certain grasses. He divides them into five main groups as follows:-

1. Surfaces parallel and with equal numbers of stomata on both faces.
2. Upper epidermis (due to sinuosities) two to three times larger than lower surface: greater number of stomata on upper surface.
3. Leaves expanded or acicular; upper surface deeply furrowed; no stomata on lower surface; poorly developed motor-cells.
4. Grasses living in water or submerged places. Air lacunae developed. Stomata equal on both faces. Motor-cells developed.
5. Green parenchyma arranged in concentric rings round the bundles.

In his introduction he says that "It is my purpose first to group the grasses of France according to their anatomical characters: secondly to make known the physiological role of certain leaf tissues based on the arrangement, structure and development of their elements." He states that it is not his "object to replace the natural classification of the grasses, but rather to facilitate and control the determinations made by means of the organs of reproduction." He adds, however, that "in certain cases nevertheless it will be indispensable for distinguishing one species from a neighbouring species, when the characters drawn from the flowers and fruits are too little apparent or are totally absent. In other cases, it will permit, by the anatomical examination of a leaf, the certain and more rapid arrival at the determination of a grass."

He places a number of grasses under one or other of his five groups but describes at length only a few examples from each group. Those fully described are featured by outline drawings.

Pee-Laby's work is a very valuable contribution to this subject especially from the point of view of general anatomy, but he does not provide a key. His sections too were secured from segments from the middle of the second - top culm leaf. He confesses to have utilised only plants grown from seed in the Botanic Gardens, Toulouse.

Raunkiaer in "Danske Naturhistorie", Copenhagen, (1895-99) takes into consideration differences in the anatomy of the leaves, and under each genus mentions peculiarities of leaf structure.

73.
Ward (1901) gives a short dichotomous key for the diagnosis of grasses by their leaf anatomy. Few species are embraced, and it is only claimed to have brought together some of the principal anatomical features in such form that "their/

"their characters may be employed in checking other determinations of grass leaves."

47.

Lewton-Brain (1903), gives -

1. A short account of the general anatomy and histology of grass leaves.
2. Brief descriptions of a number of British grasses, arranged in the form of an artificial key.
3. A grouping of the grasses according to habitat, and a discussion of the question of how far a similarity in environment entails a similarity in leaf structure.

This is one of the most valuable contributions to the subject. He does not state, however, from which part of the plant his leaves for sectioning were taken, nor upon how many specimens his conclusions were based. In some cases immature leaves have been selected, as leaves normally having mid-ribs are portrayed as having none.

61, 62.

Schindler (1917, 1923) presents the anatomical differences for a number of Austrian grasses in key form. Many, however, are not indigenous to Britain. The key is accompanied by good outline drawings. He relies considerably on the stereome as a diagnostic feature. It is strongly shaded in the illustrations.

13.

Recently a work has appeared by Burr and Turner on "British Economic Grasses". The title is given a liberal interpretation and some fifty species are featured. The sections appear to have been made largely from cultivated species. The illustrations are a considerable advance on those of previous publications. The sections, it is stated, have been hand cut, and it appears in many cases that this has led to the cutting of narrow (immature) leaves, with keel and other features undeveloped. In a few cases fortuitous differences between species have been stressed as of diagnostic importance. In one case, Glyceria aquatica, it would appear that there has been a wrong determination of the specimen selected for sectioning.

A key has been based on anatomical characters of fifty two species.

Shoots are also taken into consideration in the formation of the key. Any character which introduces another division into the whole group, or even a part, is valuable. One of the chief characters associated with the shoot is whether it is split or closed. In the case of those with split sheaths - and that is the majority - the distance through which it is split is very variable, and this introduces rather an indecisive character - not of much service in a dichotomous key. The key is partly dichotomous. Rather too much reliance is placed on single and variable character differences, and it is possible in some cases to come to an erroneous conclusion, when attempting to run down some of the common grasses.

The present investigation owed its inception to a desire to test the anatomical method of diagnosis on plants growing under a wide range of conditions. Reference to the works of Lewton-Brain^{47.} and Continental investigators, and a limited experience gained from the direction of essays of advanced agricultural students had impressed the writer with the apparent value of cross sections of grass leaves as a means of identification, during that part of the year, when flowers are not available. It was not clear, however, what degree of constancy could be expected, having regard to edaphic and other considerations. It was known, moreover, as a result of recent investigations, that strains of Lolium perenne, Phleum pratense and Dactylis glomerata existed, which manifested distinct and valuable economic differences of a magnitude comparable with that found in the cereals. These differences were not fortuitous; they had a genetical basis. Were they purely physiological, or had they also an anatomical expression?

Though/

Though from an economic point of view it might not be held necessary to have information on the leaf anatomy of the so-called useless grasses, it was considered that a description of a part could be regarded as reliable only to the extent to which it was based upon a knowledge of the whole.

It has been possible, by means of travelling grants from the Carnegie Trust, to collect specimens in successive seasons from most parts of the British Isles - the Irish Free State excepted. A standard procedure has been adopted in collecting specimens in the field. Half-inch segments of the basal leaves have been taken from about the middle of the lamina. Culm leaves have been examined, when comparison with basal leaves was of special interest. It was deemed an integral part of the work that in each case the plant itself from which the anatomical materials were derived should be preserved as an herbarium specimen. The entire value of such a work as this is dependent upon the correct determination of the plant itself, and in cases where doubt existed, especially in the case of the Bromus arvensis group and Agrostis spp., the specimens have been sent to Kew Herbarium. For varietal determinations of Festuca rubra and F. ovina, I am indebted to Mr. W. O. Howarth, the monographer of the group.

It has been my practice to cut with scissors segments about one half inch long from the middle of the lamina of some three or four mature basal leaves from the plant selected. The segments of leaf were inserted immediately into form-acetic-alcohol, in order to secure fixation before turgor changes took place. Herbarium and anatomical specimens were given the appropriate serial number, and habitat, station, etc. were noted.

A botanic garden of grasses was formed at the College farm. The light loam soil there constituted for many of the grasses an abnormal habitat, especially for the aquatics.
Their/

Their leaf anatomy was examined in the light of this knowledge. Vagabond species, such as Poa annua, which are to be found growing on sandy loams, clay or peat, were taken from diverse habitats in order to determine whether the diagnostic value of leaf cross sections was upset by habitat.

Refractory nature of Grass leaves in sectioning. The lamina in British grasses varies in width from 0.25 mm. in the case of Agrostis setacea, to more than one inch in Arundo phragmites. In the case of the larger species, it is obvious therefore that, unless immature leaves are selected, it will be difficult to obtain by hand good cross sections of even half the leaf. Young leaves are unsatisfactory in those species where the keel is of diagnostic value, since its characteristic form is assumed only in the mature leaf. For purposes of diagnosis, however, it is not essential to obtain either thin or always complete sections; freehand sections are quite adequate, but for making permanent mounts of sufficient merit for drawing, it is desirable, and for photomicrography, it is imperative, to have microtomed sections.

Burr and Turner, in their recent work on grasses, express the view that "with a few exceptions prepared microtome sections are unsatisfactory." It is commonly supposed that the difficulty is occasioned by the high percentage of silica which is present in the leaves of many grasses. In point of fact, however, many of those containing the greatest amount of silica (in Arundo phragmites the percentage silica in the ash is 70%) are as readily sectioned as some with markedly low silica content. Moreover, pre-treatment of the leaves with hydrofluoric acid does not materially assist. It would appear therefore that though silica may be a contributory factor, it is not the primary factor in rendering the leaves difficult to cut by microtome.

Fracturing/

Fracturing occurs mainly in the lignified elements, in the case of sections prepared by the ordinary paraffin method. These tissues shrink appreciably, though not necessarily visibly, in either ethyl or methyl alcohol, and especially in xylol. The lignified elements are then found to drag in front of the microtome blade. Especially is this so if the investigator, desiring anatomical features and disregarding cytological detail, considers that a short alcohol-xylol series is adequate, when severe shrinkage with attendant brittleness results. In grasses, as compared with other more homogeneous plant structures, the difficulty is accentuated by the fact that stereome strands of great strength are embedded in a matrix of comparatively fragile tissue.

Though every precaution be taken in the technique associated with the ordinary paraffin method, grass leaves still prove refractory materials to microtome. At the commencement of this investigation several months were devoted entirely to technique. The latter was altered at every phase where alternatives were available.

Wax of unusually high melting point (135° - 140° F.) was used in an endeavour to hold the sclerenchymatous tissue in place. In addition, various expedients were resorted to, such as pretreatment in cellulose acetate and hydrofluoric acid, neither of which facilitated the task of sectioning. It was clear, however, that xylol was to be avoided as a clearing agent, and that the storage of the leaves in a mixture of equal parts glycerine and 50% alcohol was beneficial. A measure of success was obtained by substituting cedar wood oil for xylol as a clearing agent, and by using an extended and well graduated alcohol series. This, however, was soon superseded by the "n-butyl alcohol method" as used by Larbaud in sectioning woody tissues, and described by Zirkle. He points out/
77.

out that in the ethyl-alcohol-xylol series it is imperative to remove the last trace of moisture before transference to the xylol. Considerable hardening occurs before dehydration is complete. When this is followed by the use of xylol as clearing agent, the lignified elements frequently become so brittle that they are impossible to cut. Mlle. Larbaud has found it possible to eliminate the higher ethyl alcohol-xylol series by using a mixture of n-butyl and ethyl alcohol. The former is soluble in paraffin but is only slightly soluble in water. Equal parts of ethyl and n-butyl alcohol are readily miscible with water; thus it is possible to have a graduated series from 5%-100% of n-butyl alcohol. N-butyl alcohol causes no hardening of the lignified elements and its use renders the inclusion of the higher ethyl alcohol series unnecessary. It is a good clearing agent and wax solvent, so that xylol which causes severe hardening, can be eliminated entirely. The specific gravity of n-butyl alcohol is about 0.8 at 20°C., compared with about 0.87 for xylol. As Zirkle points out, this slight difference in specific gravity is important, for while xylol is heavier than melted paraffin, n-butyl alcohol is slightly lighter. The specimen sinks with the xylol, and is surrounded by almost pure xylol. In the case of n-butyl alcohol, the specimen floats in melted paraffin and infiltration is better. Further in favour of n-butyl alcohol, it may be said that small traces of the alcohol left in the paraffin do not render the wax crumbly as does xylol. It must be emphasised that n-butyl alcohol does not soften materials which have been already hardened by fixation or too rapid dehydration.

Having regard to the almost universal acceptance of the impossibility of obtaining cross sections of grasses by the paraffin/

paraffin method, it may be worth while to record in full the schedule followed in this work, and which has given satisfactory results, in so far as part of the success may be attributed to phases other than dehydrating and clearing. (See Appendix, p.130)

The Grass Leaf: "The Phyllode Theory."

The leaf of a grass consists essentially of a sheath and a limb, with ligule marking the line of junction of the two.
1. Arber (1918) supports and amplifies de Candoll's Phyllode Theory of the origin of the Monocotyledonous leaf (1827). She considers that "the leaves of monocotyledons are equivalent to the leaf base and petiole (or leaf base alone) of the Dicotyledons, the lamina being unrepresented," and "that grass leaves are phyllodes, equivalent to the leaf base and petiole of the Dicotyledons."

12. Bugnon disputes this view and maintains that "the limb of the grass is equivalent to the basal sheath of a Dicotyledon, and the sheath of the grass is a new formation."

Arber is "reluctant to admit any morphological theory which postulates the production of some entirely new organ. The only evolutionary changes among flowering plants about which anything is known are those concerned with suppression, fusion or modification of existing structures." Arber says, against Bugnon's view that "it has the effect of isolating the leaf structure of grasses from that of other Monocotyledons." Arber's thesis is the more acceptable on general grounds, and especially in view of the anatomical evidence which she has adduced from a wide study of Monocotyledonous types.

The grass lamina is not then homologous with that of a Dicotyledon and we shall see that its anatomy is, as would be expected, very dissimilar. As a matter of convenience the term 'leaf' is used throughout this work. In most grasses, and in all/

all British representatives, the veins are parallel to the longest axis of the leaf, and are disposed in a single horizontal series, with the exception of Leersia oryxioides, Panicum spp. and Setaria spp. Diminutive cross connexions (anastomoses) running at a slightly oblique angle, link up adjoining bundles. They appear most frequently in sections of aquatics but are never numerous. In transverse sections of the leaf the vascular bundles are cut through at right angles. They are usually of three orders. A few tropical and sub-tropical grasses have 'net venation.' These, Bews regards as primitive types.

The Vegetative Shoot.

The sheath may be hirsute as in most Bromus spp. or glabrous, e.g. Lolium spp. It is split in most species, e.g. Phleum alpinum (Plate 1) or occasionally entire, e.g. Glyceria aquatica (Plate 2). The enclosed leaf may be convolute in the bud (Plates 1 and 3) or conduplicate (Plate 2). The shoot is generally rounded, less frequently flattened, e.g. Glyceria aquatica and Poa pratensis. It is quadrangular in Melica nutans. Types with flattened shoots will usually be found to have not more than two cell groups flanking the mid-rib. Those with rounded shoots usually have leaves with many motor-cell groups distributed over their entire width. Air cavities are usually prominent in transverse sections, between the bundles. Stereome is markedly stronger on the outer side of the vascular bundle in response to the columnar requirement. It is absent in many cases on the inner side in species where it is strongly represented as girders on the adaxial side of the leaf bundle, e.g. Bromus erectus and Briza media. Stomata are present on both inner and outer epidermis. The sheath in transverse section in any species bears a superficial resemblance/

resemblance to the leaf. Not in the most strongly ribbed species, however, does it exhibit ribs on its inner surface. The differences between the shoots of two different species are of a lesser order than that between their leaves. Indeed the salient features can be seen by simply cutting across the shoot with scissors.

GENERAL ANATOMY AND HISTOLOGY.

General Anatomy.

Water is the most potent factor in determining plant form. Grasses are no exception to the rule. The leaves display a marked variety of forms and these in turn have their anatomical expressions. Grasses from habitats with roughly the same water supply tend to have many features in common. From this point of view they may be grouped under the following heads:-

- (1) Supply of water always present; aquatics.
- (2) Supply of water seldom deficient.
- (3) Supply of water occasionally deficient.
- (4) Supply of water frequently deficient.

In the first group we have:- Glyceria aquatica, G. fluitans and Catabrosa aquatica. They are all characterised by well marked air chambers. Stomata are present on both surfaces.

The second group includes grasses such as Arundo phragmites, Phalaris arundinacea, Leersia oryzoides, Milium effusum, Poa trivialis, etc. All have linear expanded leaves without marked ribs; stomata are present on both surfaces.

In the third group we have as examples A. myosuroides, A. pratensis, Festuca arundinacea, Lolium perenne, L. multiflorum, etc. These grasses are markedly ribbed and have stomata principally on the upper surface. All show a xerophytic tendency.

Ammophila/

Ammophila arenaria, Agropyron junceum, Nardus stricta, Festuca ovina, Agrostis setacea, Aira flexuosa and Corynephorus canescens are typical of the fourth group. In all these grasses the stomata are situated only on the upper surface, the lower surface being strongly cutinised. Moreover, the adaxial surface is either permanently enclosed by the abaxial, or only infrequently exposed. Ribs are very pronounced. All are markedly xerophytic.

These groups represent definite tendencies, but are not by any means mutually exclusive. Deschampsia caespitosa presents rather an anomaly, and has been an enigma to successive investigators. It is deeply ribbed, and strongly cutinised on both surfaces, yet it grows in damp situations. We have a parallel in Ruscus aculeatus with typical xerophytic appearance, but which nevertheless flourishes best in damp soils where its associates are mesophytes or even hygrophytes. Farmer was able to demonstrate in this case, however, that the xerophytic adaptation was associated with extreme slowness of water conduction through the vessels.

Nor is the xerophytic nature of Deschampsia caespitosa accidental. Foresters have told me that 50% of spruce planted in the usual habitat of D. caespitosa die as a result of summer drought, so that the explanation is that this grass is truly xerophytic and is properly to be regarded as an intermittent 'flush' species. Annuals on the whole show little xerophytic adaptation anatomically. In Mibora minima, Aira caryophyllea and A. praecox, however, the leaf surface is markedly reduced - being more or less terete. These and other annuals such as Phleum arenarium frequently have a waxy outer covering, but they are seldom strongly cutinised.

Histology/

are palisade-like, reminding one of the very characteristic
Histology.

The Epidermis. This tissue is to be regarded as a water jacket. Possessing this function, it is in all plants a tissue prone to marked variation. Grasses are represented in every type of habitat. Accordingly it is not surprising to find that the epidermis in this family is more variable than in any other; moreover it presents features found in few others. This tissue has been the subject of special researches by Grob and Prat.^{24. 58.}

In surface view the epidermal cells (excluding motor-cells and stomata) are referable to three types.

1. Long rectangular cells whose lateral walls are strongly corrugated. They make strong union with similar contiguous cells and are exemplified in species of exposed situations, e.g. Ammophila arenaria and Nardus stricta.

2. Long cells with lateral walls arching (elongated hexagons) and without corrugations. They are seen in Holcus lanatus, Dactylis glomerata, Avena sativa, Milium effusum, etc.

3. Small isodiametric cells frequently occur amongst the previous two types.

The elongated cells which run parallel to the long axis of the blade form a contrast to the more or less isodiametric cells of Dicotyledons, and are comparable with the cells found in most petioles. In transverse section, the epidermal cells of a grass leaf are more or less isodiametric, oval, round or brick shaped. Those of the lower surface are as a rule more regular than those of the upper surface. In some species, e.g. Agrostis canina (Plate 75) and Agrostis tenuis (Plate 76) single very large cells occur in the lower epidermis opposite the motor-cells. Epidermal cells are always smaller opposite stereome bands or girders and frequently themselves become sclerotic. In Lolium spp. the lower epidermal cells are/

are palisade-like, reminding one of the very characteristic upper epidermis of some of the Cyperaceae (Plates 6 & 7) - but much smaller.

Contrary to what occurs in Dicotyledons, transpiration is principally from the adaxial surface in the grasses. The lower epidermis therefore is usually more strongly cutinised than the upper. In Ammophila arenaria (Plate 33) the abaxial surface is very markedly cutinised and stomata are confined to the upper surface. The cells of the upper epidermis are frequently arching and uncutinised. In a few species including Poa annua (Plate 43) and Alopecurus geniculatus (Plate 59) the epidermal cells on both sides are arched and only feebly cutinised; in these species, the stomata are almost equally distributed on both sides of the leaf. In some species, e.g. Sesleria coerulea, Avena pratensis, Poa glauca, Festuca rubra var. pruinosa, the leaves are covered with wax. All are xerophytic. A transverse section of Mibora minima (Plate 21) with its thin-walled, arching outer epidermis would suggest that it would prove quite inadequate to the exacting conditions of its habitat. It too, however, has a well defined coating of wax.

Silica is a frequent constituent in grass leaves, especially in the epidermal layers, and, according to Von Mohl, particularly abundant in the cutinised outer walls. De Bary states that the small square cells which occasionally occur amongst the larger ones have especially strongly silicified walls. Various explanations have been advanced to explain a possible use. It may well be that it serves no purpose. Its presence has been seized upon as the cause of the refractory nature of grass leaves in microtoming, but as indicated elsewhere it is the stereome which occasions the difficulty, not/

not the silica. their protection against drought chiefly by

Hairs. Epidermal protrusions in the form of papillae, are abundant on the upper surface of the leaves of Spartina spp. (Plate 15), and Glyceria maritima (Plate 30). Papillae occur on the lower surface only of Leersia oryzoides (Plate 93). Their function is probably the same as that of ordinary hairs, viz. reduction of interchange of air currents in the micro-atmosphere surrounding the leaf. The papillae are closely packed so that the stomata almost deserve the name 'sunken.' Haberlandt was of opinion that papillae acted as condensing lenses, increasing the light available to the chlorenchyma. On the whole, having regard to the fact that they occur on species which are conspicuously xerophytic, it is more probable that they are organs concerned in the reduction of transpiration. We reserve the name 'asperities' for small hook-like projections whose length does not much exceed their width at the base. They occur chiefly on the upper surface, especially opposite the stereome. The length of these structures precludes their being effective in reduction of transpiration. They are distinctly sharp and it may be that their function is protective. Long silky hairs occur on upper and lower epidermis of Lagurus ovatus (Plate 94) and Bromus sterilis (Plate 108) annuals, in both of which the stomata are about equally numerous on both surfaces. Shorter hairs are abundant on both leaf surfaces of Apera spica-venti. The leaves of annuals on the whole exhibit little cutinisation; their chief protective devices are hairs and wax covering. Long hairs and stomata also occur on both sides of Holcus lanatus (Plate 109) which is perennial. Intermediate structures, very stout sharp hairs, are best typified in Triticum junceum (Plate 16). They occur on the summits and slopes of the ribs, but not on the lower surface; they are undoubtedly xerophytic adaptations. Perennials, however/

however, obtain their protection against drought chiefly by strong cutinisation of the lower surface, and by infolding or enrolling of the leaf during drought, so that the upper surface is not exposed.

Hairiness is a less effective device for transpiration control than is cutinisation. It is most frequent and reaches its highest development in annuals. Cutinisation of the lower surface, and the associated enrolment of the leaves to prevent excessive transpiration, must slow down the photosynthetic rate appreciably. Annuals in the short growth period available to them can less afford this than perennials. A thick covering of hairs reduces transpiration without necessitating extreme enrolment. I have noted with interest, however, that there is a very high percentage of fungal infection amongst hairy grasses. Erysiphe graminis has been the most frequent fungal parasite. The cuticle is thin in hairy grasses; moreover the hairs must act as a trap for fungal spores.

It has been suggested that hairy grasses tend to become more glabrous in a moist situation and more pubescent in a dry one. I have noted considerable variation, in grasses belonging to the same species, in hairyness of the leaves, but I have not been able to connect it with the moistness or dryness of the situation in any way. It is true, however, that grasses whose natural habitat is moist do not bear hairs - and that some species inhabiting dry situations do possess them. The suggestion above referred to arises probably rather from expectation than from accurate observation.

Motor-cells, Hinge Cells or Cellules bulliformes.

With the exception of Leersia oryzoides (Plate 93) the motor cells in all British grasses occur on the upper surface only and run parallel to the long axis of the leaf. In Leersia/

Leersia oryzoides, in addition to the normal groups occurring on the upper surface, a group occurs on the lower surface on both sides of the keel. In Dactylis glomerata and Agrostis setacea alone amongst British grasses, there is a single median group; in Poa spp., Glyceria spp., Catabrosa aquatica and Sesleria coerulea, a group occurs on both sides of the mid-rib. In most other species motor-cells are numerous, occurring in all the furrows on upper surface.

Vernation in grasses is of two kinds, viz. conduplicate and convolute. The type which occurs in any species is determined by the distribution of the motor-cells. Leaves having a single or double median row of motor-cells are conduplicate; leaves having motor-cells distributed over their entire width are convolute in the bud. An exception, however, occurs in Lolium perenne which despite having motor-cells in all the furrows usually has conduplicate vernation and is so described in all works on grasses. Convolute vernation - the type which one would expect - does, however, occur. The presence of the motor-cells, especially when they occur in furrows, causes a considerable diminution in the thickness of the chlorophyll tissue. When held up to the light and viewed from the abaxial side these areas occur as 'white lines.' They are well seen in Deschampsia caespitosa and Poa spp.

Viewed externally, motor-cells are shorter than the contiguous epidermal cells. In transverse sections they will be found to occur in groups of three to eight cells. In groups where the cells are few, they are usually large, the central one especially being much larger than the other epidermal cells, e.g. Arundo phragmites (Plate 88); when numerous, e.g. Cynosurus echinatus (Plate 96), they do not much exceed the normal epidermal cells in size. The individual cells are thin-walled and are usually distinctly wedge-shaped, e.g. Cynodon dactylon /

dactylon (Plate 14). In this species, in which the furrows are almost obsolete, the motor-cells are very strongly developed. The same is true of Arundo phragmites. It is noteworthy that in both these species, clear cells should occur in a single tier immediately below the motor cells. In Spartina spp. (Plate 15), Ammophila arenaria (Plate 33) and others in which furrows are markedly developed, the motor-cells are not conspicuously larger than the normal epidermal cells. The walls of these cells are thin; the exterior one is thicker but not cutinised. I have never observed protoplasm or any other content apart from water.

The function of motor-cells has engaged the attention of many botanists since Duval-Jouve first referred to them in 1870. He called them 'cellules bulliformes' i.e. bubble cells, and did not attempt an explanation of their function. Later, (1875) the same worker, having investigated them more fully, describes them at length. He perceived that vernation of the various grass leaves was dependent upon the distribution of the motor-cells. He concluded that enrolling or infolding of grass leaves, as a consequence of drought, was entirely attributable to turgor changes in the motor-cells.

Kerner (1897) emphasising the fact that some grasses have either very small motor-cells or none at all, disputes the assertion that the motor-power resides in the motor-cells alone in all species. He invokes the aid of certain cells situated above the lower epidermis, which, he says, swell and cause differential curvature of the two surfaces. This interpretation does not commend itself on general grounds. He considers that the motor-cells are capable of absorbing moisture from the atmosphere or during rain, and of passing it on to the underlying tissue.

56.
Pee-Laby (1898) p. 242, referring to the furrows of Deschampsia caespitosa, says, "Grace a ces sinuosites, la feuille peut facilement se replier autour de la face superieure, de maniere a ne presenter a l'exterieure que la face inferieure, moins riche en stomates." He then goes on to say that "these movements of the leaf can also be brought about by means of motor-cells, without the help of the large furrows which occupy the place of the assimilating tissue." He, however, gives no explanation as to how the enrolling takes place.

47.
Lewton-Brain considers that "the motor-cells serve the function of bringing about the folding or rolling ---" and that "the change is probably brought about by an alteration in turgidity of the motor-cells, causing them to contract, and thus shortening the upper surface of the leaf."

As we shall see later, this view proves inadequate when we consider species such as Spartina spp. (Plate 15) where the motor-cells are almost obsolete. Armstrong attributes infolding and enrolling of leaves during periods of water shortage entirely to the motor-cells.

9.
Bews states that "the motor-cells --- by losing water under dry conditions cause the leaf blade to roll up towards the margins, and to expand when the motor-cells again become turgid."

13.
Burr and Turner say of the motor-cells that "these cells lose and regain moisture with such rapidity and by controlling the rolling and folding of the blades, regulate the loss of moisture from the plant."

5.
Arber, briefly reviewing the position says that "later writers (than Duval-Jouve) agree that the rolling or unrolling of the leaves is influenced by the loss or uptake of water but it appears that the movements are due, at least in some cases, to/

to changes in the leaf fibres rather than in the epidermis." "The part they (motor-cells) play in the leaf will, I think, remain mysterious until botanists and physicists combine to interpret it."

Duval-Jouve's classical work is still the best treatise on the subject though it is not possible to subscribe to all his findings. The solution of this problem has indeed made little advance since his work was published in 1875. Subsequent workers on grasses, though they have invariably referred to the subject, have in the main been more concerned with the economic aspect of grasses. The examination of the part played by the motor-cells has been uncritical and, as a result, Duval-Jouve's plausible theory or slight modifications of it has been perpetuated in successive works.

Examination of leaf cross-sections of grasses such as Arundo phragmites, Cynodon dactylon, Poa spp., etc. naturally suggests a causal relationship between the motor-cells and the familiar enrolling or infolding of the leaf during periods of drought, for it is noticeable that whereas the motor-cells in the expanded leaf are inflated and wedge-shaped, in the enrolled leaf they are deflated.

In some of the most marked xerophytes, however, e.g. Elymus arenarius (Plate 57), Agropyron junceum (Plate 16) and Spartina spp. (Plate 15) the motor-cells are almost obsolete. Notwithstanding this, the leaves of these species enrol even more rapidly than those with strongly developed motor-cells. In these we must therefore seek for another mechanism to account for the movement.

My own view is that the 'motor-cell interpretation' of leaf movement in the grasses is quite inadequate to account for all the facts, and that the 'motor-cells' are to be regarded primarily as 'accommodation tissue', - lines of weakness in leaves/

leaves which do not possess marked furrow development. To permit of a linear object being rolled into a cylinder, longitudinal triangular furrows must be formed on the side which is to constitute the inner surface of the cylinder. This condition is satisfied in the xerophytic species referred to above. In species with ribless leaves such as Arundo phragmites (Plate 88) these accommodation furrows must be created to permit of the leaf enrolling. That is probably the chief function of the motor-cells and they are most strongly developed in leaves with only small furrows, or in those without them.

The motor-cells are thin walled - the outer being rather thicker than the radial and inner walls. They are never appreciably cutinised, but despite that it is difficult to conceive that a structure such as the grass leaf, so perfectly constructed in respect of the 'water requirement' would permit of cuticular transpiration over such extensive areas as are covered by the motor-cells in many species. Nor do I agree with Kerner that moisture is absorbed by these cells from the atmosphere, for the motor-cells appear to have neither protoplasm or other content apart from water.

Rather do I believe that they rapidly give up their moisture to the contiguous mesophyll cells when required. The loss therefore is inward not outward. The upper mesophyll cells lose moisture more quickly than those of the abaxial side, since the latter surface is usually cutinised and bears considerably fewer stomata in types exhibiting xerophytic adaptation.

The turgor gradient will diminish, therefore, from the abaxial to the adaxial surface and the consequence of this will be a shrinkage of the adaxial surface. Cutinisation prevents decrease in width of the lower surface. The result in/
in/

in leaves having motor-cells distributed over the upper surface is that the leaf halves curve inwards - the convolute type. I have observed in confirmation of this hypothesis that the bases of the ribs of Spartina spp. are narrower in enrolled than in expanded condition, and here the mesophyll penetrates up into the broad ribs. As the mesophyll cells on the adaxial side become replenished with water their turgor will increase and the leaf will enrol. The tension thus formed in the motor-cells will create a vacuum which will induce inflow of water from the mesophyll cells.

Xerophytic species represent a higher development than non-xerophytic. Species with marked motor-cell development are to be regarded as intermediate types. On this view, the motor-cells are to be regarded to some extent as substitutes for furrows. The controlling force in the inward movement of the leaf is located in the mesophyll cells. In strongly xerophytic species such as Agropyron junceum the poor development of the motor-cells certainly deprives them of playing a major part in the enrolling of the leaf. At the same time, the possibility of the motor-cells playing a contributory part in the motor force cannot be entirely excluded, especially as the extraction of water from them by creating a vacuum must cause a lateral tension on the neighbouring cells. This would help us in understanding the infolding of leaves with single median motor-cells group, e.g. Dactylis glomerata (Plate 36) and leaves with two median motor-cell groups, e.g. Poa spp. since the mesophyll layer below the motor-cells is not very deep. It must be emphasised, however, that leaves with one or two median motor-cell groups do not in fact exhibit extensive movement in response to drought. They are either permanently infolded, e.g. Glyceria maritima (Plate 30) or usually exhibit only/

only inward movements of less than 45° , e.g. Dactylis glomerata. The views represented above would have the advantage of harmonising with the modern concept of transpiration control, (Knight) which seeks to emphasise the importance of the mesophyll cells rather than of the stomata. (This latter statement does not refer to the avenue of transpiration which is indisputably through the stomata).

Stomata.

20.

Duval-Jouve noted the quadricellular nature of stomata in the Gramineae but not their specific form. Subsequent writers with a few exceptions have either neglected to describe them in detail or have recorded as Lewton-Brain has done that they "do not present any peculiarities of structure." Their peculiar form has been noted by Haberlandt, Percival and Arber. Each stoma consists of two guard cells and a lateral ancillary cell on each side (Fig. 8a.) The guard cells are strongly thickened in their middle regions so that in longitudinal section they present a dumb-bell like cavity (Fig. 8b). The ends are thin-walled and dilated; opening and closing of the stoma depends entirely upon turgor changes within the latter. In contradistinction to the stomata of Dicotyledons, which are irregularly orientated, those of the Gramineae usually occur in regular lines, of two or more rows, along the sides of the ribs, or contiguous to the motor-cells in ribless species. The slit is always parallel to the long axis of the leaf. (Plate 10) shows a stoma of Avena fatua in median transverse section. The ancillary cells are white, while the thickened median portions of the guard cells appear dark. In the centre of each guard cell the much reduced cavity can be seen at (A). Internal to the stoma can be seen the large 'air space'. The same stoma is seen in Plate 9 (right) at smaller magnification. To the left is a second stoma showing the ancillary cells at (A); the/

the two cells in the centre (B) are the 'dilated ends' of the guard cells. In Triticum sativum and a few other species they are about equally distributed on both sides of the leaf. In xerophytes, such as Ammophila arenaria, they are confined to the adaxial surface. All gradations occur between these two extremes. The Gramineous type of stoma also occurs in the Cyperaceae but in no other family to my knowledge.

The Vascular Bundles.

The leaf venation of our British grasses, in common with most other Monocotyledons, is parallel. A few tropical species have 'net venation'. Between the parallel veins one frequently notices portions of diminutive cross anastomoses - especially in aquatics. They are seldom complete in transverse sections as they follow a somewhat diagonal course between the bundles. Duval-Jouve recognised three orders while Pee-Laby classified them as follows:-

Bundles of the First Order.

Two large vessels and a smaller annular vessel with accompanying intercellular space.

Bundles of the Second Order.

Two large vessels only: no intercellular space.

Bundles of the Third and Fourth Order.

No annular vessels: further differentiated according to the relative amount of lignified tissue.

Bundles of the Fifth Order.

Bundles without lignified elements.

In this work I have referred to the bundles as primary, secondary or tertiary - the latter including Pee-Laby's third, fourth and fifth groups.

Bundles of the first and second order respectively are seen in Agropyrum junceum (Plate 16); and of the first and third/

third order respectively in Spartina Townsendii (Plate 15). The bundles of the Cyperaceae, e.g. Carex binervis (Plate 6) are more pointed than those of the Gramineae. In Mibora minima (Plate 21) in which the bundles are very simple, all are referable to the third order; Aira caryophyllea (Plate 19) possesses bundles of only the second and third order. In the majority of our British species, however, all three orders are represented. The bundles of Leersia oryzoides (Plate 93) are peculiar in that their breadth exceeds their height. Xylem and phloem elements are represented, even in the tertiaries. Molinea coerulea is noteworthy for the very fibrous nature of the bundles. With the exception of Leersia oryzoides where a subsidiary bundle is suspended by a half stereome girder from the top of the mid-rib, overhanging the principal bundle, and Setaria spp. and Panicum spp. where the bundles follow the abaxial contour in the mid-rib, the bundles are situated in one plane. In species with ribs one usually finds one bundle to each rib. Exceptionally amongst British grasses there are 1, 2, or 3 in each rib in Deschampsia caespitosa (Plate 58). In Glyceria fluitans the bundles are situated below the furrows; in this species the ribs are almost entirely devoted to air canals. The larger bundles are well distributed throughout the leaf amongst the smaller ones. In leaves with well defined keel, the mid-rib bundle is usually larger than the other primary bundles. The mid-rib contains many bundles in Setaria spp. and Panicum spp. (8-10 frequently); in a few species in addition to the principal bundle occur two or four subsidiary bundles, but in the majority there is only one. The number of bundles in culm leaves exceeds that in the basal leaves frequently by as much as 60%. In Festuca heterophylla, the top culm leaf may have two to three times as many bundles as the basal setaceous leaves. In general it may be said that the/

the number of bundles decreases successively in each leaf from the top culm leaf downwards. Duval-Jouve and Pee-Laby each utilised the second top culm leaf in their anatomical investigations. Descriptions from culm leaves in most cases provide quite misleading guidance for the diagnosis of species by leaf anatomy from pastures and sports turves. In the basal leaves, the number of bundles varies from three in Mibora minima and Agrostis setacea to as many as one hundred and thirty (or possibly more) in Arundo phragmites.

In cultivated species the number of bundles to each leaf tends to be slightly greater than in species in their natural habitat. The number varies within very narrow limits in the case of leaves with few bundles. Even in leaves where the bundles are numerous and variation accordingly greater, their number is of considerable value in identification.

The Bundle Sheaths.

These consist of an outer colourless or green parenchymatous sheath and an inner sclerotic sheath - the 'mestome sheath' of Schwendener.^{65.} The inner and radial walls of the inner sheath are usually much thicker than the outer wall. Numerous pits occur on the inner wall. This has suggested to Schwendener,¹⁷ De Bary,^{56.} and Pee-Laby its being of an endodermal nature. The strength of the inner sheath is extremely variable; in Triticum junceum (Plate 16) and Festuca juncifolia (Plate 26), for example, it is strongly developed, while in Setaria viridis (Plate 85) it is missing. All degrees of development occur between these extremes. In general it is well formed in leaves in which stereome is abundant and for that reason, as Raunkiaer has suggested it is probable that its function is that of protection to the bundle. Apart from that, however, it completes the girder in species where the latter/

latter is present. Despite the fact that it consists only of a single line of cells, its round or oval shape will give it very considerable strength.

The outer or parenchymatous sheath is thin-walled and colourless in the mature leaf of most British grasses. In Spartina spp. and Cynodon dactylon belonging to the tribe Chlorideae and Panicum spp. (Digitaria and Echinochloa) and Setaria spp. belonging to the tribe Paniceae, it is green. It is well exemplified in Cynodon dactylon (Plate 14) in which the individual cells are very large, and in Spartina Townsendii (Plate 15). In Cynodon dactylon (Plate 14b), the chloroplasts are unusually large and intensely granular; each cell contains some four or five. They are club shaped and radially orientated with their bases towards the bundle. It is a matter of taxonomic interest that the presence of the green sheath is restricted to two tribes - all the members of which belong properly to warmer regions. In these species the normal chlorophyll cells too are situated in a ring around the bundle, but they represent only one quarter of the size of one of the cells of the green sheath. It is probable that the condition is associated with the xerophytic habit, having regard to the habitat of the species concerned. It would however be necessary to study other species sharing this peculiarity in their native habitats before arriving at a true value of the function of the green sheath.

The parenchymatous sheath is usually colourless, possessing few or no chloroplasts except when young. In the case of the tertiary bundles in a few species, chloroplasts are sometimes present but not abundant. In Festuca ovina, F. capillata and F. rubra vars. and some other setaceous leaved types, the outer sheath is conspicuous only on the adaxial side of the bundle. This is due to retention of some chlorophyll

by/

by the cells on the lower side of the bundle. In transverse section (Plate 16) the individual cells are round and not infrequently smaller than the contiguous mesophyll cells; in longitudinal section they are much elongated and readily distinguished from the mesophyll cells even in the young stage when chlorophyll may be present. This thin walled sheath brings the mesophyll cells and the bundle into intimate contact; its function is probably that of transfusion tissue.

Clear celled tissue of one, two, three, or more tiers occurs above the bundles in many species. In Glyceria aquatica (Plate 11c) it is present above and below the bundles. In this species the chlorophyll tissue is restricted to a narrow strip along each epidermis. The clear cells in this case serve to make the only contact between bundle and chlorophyll tissue, and therefore act indisputably as transfusion tissue. A narrow column of clear cells frequently links up the bundle with a stereome band on its upper side, e.g. Lolium perenne, Festuca arundinacea, Glyceria Borreri, etc. In these cases the walls of these clear cells thicken as they approach the stereome band and occasionally the two groups almost imperceptibly merge into each other.

They appear to act as water reservoirs, for at least those towards the bundle collapse during drought. Since they make an intimate contact with the outer sheath it seems probable that they act also as transfusion tissue. The further fact of their forming with a stereome band a 'pillar' to the bundle suggests that they may also play an elementary part mechanically.

Supporting Tissue.

The mechanical tissue found in the leaves of grasses is composed of stereids, long narrow cells, with pointed ends, small/

small lumen and much thickened walls; collectively they are referred to as stereome. It is situated opposite the vascular bundles, on one or both sides, as hypodermal bands or as girders. Stereome also occurs at the margins; less frequently as bands on the lower side opposite the furrows, e.g. Agrostis tenuis (Plate 76) and A. Stolonifera (Plate 77), Deschampsia caespitosa (Plate 58) and Alopecurus geniculatus (Plate 59). In the last two species the additional support is much needed opposite the very deep furrows. In practically all cases, stereome development on the abaxial side much exceeds that on adaxial.

The extensive development of stereome in xerophytic types led Duval-Jouve, Guntz and Volkens to suggest a causal relationship. They noted in aquatics on the other hand feeble stereome development. The correlation between strong stereome development and conditions of actual or physiological drought is however more apparent than real. Ammophila arenaria (Plate 33), Elymus arenarius (Plate 57) and others growing on coastal sands are exposed to very high winds. Their leaves are large and as a consequence a strong, mechanical system is essential. The moor grasses, Nardus stricta (Plate 31) and Molinia coerulea (Plate 104) are also exposed to strong winds and here again stereome is markedly developed. Physiological drought in these grasses has demanded a xerophytic response, just as the actual dryness (to which perhaps must be added physiological drought) has necessitated xerophytic development in the halophytes referred to above. In Ammophila for example, the lower surface is strongly cutinised; the stomata are confined to the upper surface, which in turn is furrowed to permit of enrolment; this condition indeed is practically constant. Xerophytic adaptation has been secured independently of/

of stereome. The leaf forms a stout hollow cylinder in convolute condition. The stereome is developed in a continuous hypodermal layer under the abaxial surface, connecting with vertical girders to the bundles; in addition, exceptionally, there are horizontal girders to the bundles. The xerophytic and mechanical requirements are co-existent and the individual responses to them have been co-ordinated successfully. The stereome, however, plays no part or at most a minor part, in the water requirement of the leaf. Deschampsia flexuosa (Plate 18) exhibits even a higher xerophytic development than Ammophila, for its leaves are practically solid, yet stereome is confined to a peripheral column consisting of a single row of cells.

The amount of stereome in grass leaves varies enormously in the different species. Mibora minima (Plate 21) exhibits no stereome while in Ammophila arenaria (Plate 33) more than 50% of the leaf is devoted to mechanical tissue. Mibora is an ephemeral of low habit. The cell walls and the turgor of the cells themselves prove adequate to its needs. Poa annua is slightly more advanced in its mechanical response in that it has stereome bands - though diminutive - opposite some of the bundles. It is an annual too, of prostrate habit. The leaves are more or less horizontal and lend each other support. Cynosurus echinatus (Plate 96) and Aira caryophyllea (Plate 19) are other annuals exhibiting only feeble stereome development. Annuals as a group possess little mechanical tissue. Apera spica-venti has the strongest mechanical system of all our British annual grasses - all the bundles of first order being strongly girdered. It is a tall grass and though described as annual, I have observed a tendency in it to be biennial. Biennials possess more stereome, while in perennials it attains its maximum development.

Amongst/

Amongst perennials, the aquatic grasses, Glyceria aquatica (Plate 38) Glyceria fluitans (Plate 39) and Catabrosa aquatica have a very sparse development of stereome in relation to their size. They are always, however, assured of the maximum support which that elementary device - the turgor of their cells - will impart. Shade grasses, e.g. Poa nemoralis (Plate 42) Milium effusum (Plate 97), Brachypodium sylvaticum (Plate 98) and Melica uniflora (Plate 95) do not require and possess little stereome.

Meadow grasses, e.g. Phleum pratense (Plate 80) Alopecurus pratensis (Plate 74) and Lolium perenne (Plate 69) show considerable advance in this respect compared with shade types. They usually have strong bands to many of the bundles and in some at least girders to the primary bundles.

Moor grasses, including Sieglingia decumbens (Plate 103), Nardus stricta (Plate 31) Molinia coerulea (Plate 104), Agrostis setacea (Plate 22) and Festuca capillata (Plate 25) are situated in exposed situations and have in all cases a strong mechanical system. It is interesting to note that in these species the roots too share the strong stereome of the aerial organs. One might perhaps have expected in the alpinus Alopecurus alpinus (Plate 60) and Phleum alpinum (Plate 92) a strong mechanical system. They grow however only in the sheltered corries. Stereome is only moderately developed in them.

We have already referred to the mechanical system of the halophytes, Ammophila arenaria (Plate 33), A. baltica (Plate 34), Festuca juncifolia (Plate 26), Agropyron junceum (Plate 55) Corynephorus canescens (Plate 23) Elymus arenarius (Plate 57) Agropyron pungens (Plate 56), Festuca oraria (Plate 27) as possessing stereome to a high degree. A. arenaria, A. baltica, F. juncifolia, and C. canescens are constantly enrolled; all have/

have continuous hypodermal stereome ring on the abaxial side in response to the columnar requirement and represent the highest development of the mechanical system in our native grasses.

Chlorophyll Tissue.

This tissue is poorly differentiated in the grasses. The marginal cells are more regular than those in the centre. They are, however, more or less isodiametric in contrast to the palisade cells of the Dicotyledons. The cells in the middle of the leaf are more irregular in shape, with correspondingly larger intercellular spaces. In the following species the mesophyll cells are unusual in that they have characteristically infolded walls:- Bromus sterilis, B. ramosus, Agropyron repens, Arrhenatherum elatius, Arundo pragnites and Aira praecox. They are seen, much enlarged, for Bromus ramosus in (Plate 12). Excluding a few of the rarer species which I have not encountered, I am able to state that these peculiar cells do not occur in other British grasses.

The distribution of chlorophyll in Phalaris arundinacea var. picta (Gardener's Garters) (Plate 13), - a variegated species, - is interesting. It occurs principally as a narrow layer - occasionally broken - in the lower mesophyll cells. Chlorophyll extends from upper to lower epidermis only in a few places, as narrow columns. Elsewhere it is absent or only sparsely developed. (Anatomically it is identical with the wild form).

Reference has already been made to the fact that chlorophyll is present in the outer parenchymatous sheath of Cynodon dactylon, of Spartina spp. and a few others, none of which is truly indigenous. According to Pee-Laby, this feature/

feature is also exhibited in several desert grasses. It is probably, therefore, a xerophytic adaptation. Chlorophyll occurs in the outer sheath of young leaves in most grasses but is not persistent in the mature leaf, with the exception of the tertiary bundles of a few species.

The mesophyll cells of Phleum spp. commonly contain sphaero-crystals of phlein. They also occur in the sheath and are seen in (Plates 1 & 115). I have never seen them in other species. Their occurrence is so regular as almost to be a diagnostic feature for the genus Phleum.

Air Spaces, Air Canals, etc.

Apart from the intercellular spaces which normally occur in the mesophyll of all grass leaves, especially opposite the stomata, larger irregular air spaces occur in Molinia coerulea (Plate 104), Poa chaixii (Plate 45), Alopecurus geniculatus (Plate 59) and in many others associated with a rather moist habitat. These spaces are to be found especially in the region of the mid-rib. Large air chambers occur in Glyceria aquatica (Plate 38), Glyceria fluitans (Plate 39) and spartina spp. (Plates 52, 53, 54) all of which are aquatics. An intermediate stage between this group and the last is observed in Catabrosa aquatica (Plate 120) where large irregular cavities, not entirely devoid of cells occur. Air chambers are also of frequent occurrence in the Cyperaceae, e.g. Carex binervis (Plate 6) and Luzula multiflora (Plate 7). They are of lysigenetic origin. In Glyceria aquatica, the sides of the chambers bear traces of the disorganised cells, at the expense of which the space originated; here and there the chamber may be even loosely filled with remnants of stellate cells.

In the young leaf of Glyceria aquatica, the mesophyll consists of homogenous green parenchyma. As the leaf develops, they/

they are displaced by stellate cells. The chlorophyll gradually disappears and ultimately the stellate cells themselves disintegrate, leaving only isolated cells attached to the normal mesophyll cells bordering the air chambers. The clear celled diaphragms which contain the vascular bundles form the lateral walls of these chambers. The chambers are interrupted here and there by the existence of cross anastomoses and their surrounding tissue.

In Section II the characteristics of the leaves, of a selection of the grasses examined, as seen in transverse sections, are described in detail. Especial emphasis is placed upon characters of diagnostic value. These characters are used in section III in the formation of a continuously dichotomising key to the species, and in a few cases to some of their varieties. In Ammophila and Spartina spp. respectively, the differences between the congeneric species are not marked, and only the genus has been keyed. In those cases, when the genus is detected, further progress can be made by reference to the full description in section II. In other cases where doubt may exist, reference to the full description of the species will render final determination more possible.

Explanatory Note.

- (1) For 'micron' the figure 'u' has been used throughout, instead of the usual sign.
- (2) In the case of figures relating to leaf thickness or width, appearing in brackets, it is intended to convey that the dimension is to be regarded as unusual.
- (3) The figure in brackets appearing after the name of each species (in the headings to the descriptions) refers to the number of plants examined.

DESCRIPTION of the CROSS-SECTIONS of the LEAVES of
the SPECIES and VARIETIES INCLUDED in this WORK.

Deschampsia flexuosa Trin. (11). (Pl. 18.)

Basal leaves setaceous, almost solid; diameter (400)-440-(480) $\mu = 0.4-0.44-0.48$ mm. Outline of leaf section pentagonal, the base being sharply keeled. Leaf margins practically meeting, forming a very small triangular channel into which the solitary rib of the adaxial side abuts. Bundles usually five. In one case four only were observed. A bundle of the first order occupies an almost central position in the leaf. The others are of the second and third order respectively. All possess well defined double sheaths - the outer is especially well developed. The mesophyll is composed of unusually large, uniform, pentagonal or hexagonal cells, tightly packed. Large air spaces, however, are present especially in the region of the bundles.

The epidermis of the abaxial surface is composed of very large cells which decrease towards the angles. The outer tangential walls and the radial walls, to a lesser extent, are cutinised. The epidermal cells of the adaxial surface are small in comparison with those of the abaxial side. A hypodermal stereome, composed of a single layer of minute stereids, almost uninterruptedly encircles the leaf. Asperities on the adaxial side only. Motor-cells are found in the two narrow grooves which flank the midrib. Stomata are present on the adaxial surface, mainly in close proximity to the motor-cells. Leaf margins acute. No special features are exhibited by var. montana Huds.

Aira/

Aira caryophyllea L. (14) (Pl.19)

Radical leaves permanently folded; the leaf halves parallel, leaving a wide rectangular furrow which reaches to the centre of the setaceous leaf. Diameter 440-620 μ = 0.44 - 0.62 mm. Outline of the section roughly hexagonal; the sides slightly concave. Mid-rib and also two laterals faintly discernible. Stereome hypodermal, very scanty, a few cells only at the angles of the abaxial surface, and at the leaf margins. Bundles five, occasionally seven; one of second order above mid-rib, remainder of the third order, and situated opposite the abaxial ribs. Both sheaths present, though inconspicuous, in the smaller bundles. Mesophyll rather compact, individual cells with infolded walls. Lower epidermal cells very large, decreasing towards the 'corners'; feebly cutinised. Epidermal cells of adaxial surface rather smaller. Motor-cells not well defined, situated at either side of the mid-rib. Stomata confined to adaxial surface. Asperities on ridges of adaxial and abaxial surfaces, and on the margins. Leaf edges obtuse.

Aira praecox L. (8) (Pls.20a, b.)

Leaf section somewhat similar to *A. caryophyllea*. Basal leaves permanently folded; the leaf halves parallel, leaving a narrow rectangular furrow, reaching to about the centre of the setaceous leaf. Diameter 370-470 μ ; outline oval to round, not angular, i.e. abaxial ribs absent or very feeble. Stereome scanty; diminutive hypodermal bands at the margins, sometimes at keel and occasionally on abaxial side opposite lesser bundles. Vascular bundles 3, 4 or 5. Abaxial epidermal cells very large, regular and cutinised. Those of adaxial surface much smaller. Mesophyll cells have infolded walls.

Mibora minima Desv. (11) (Pl. 21).

Leaf capillary; 0.3 mm. - 0.4 mm. diam.; section roughly circular in outline; upper surface 1-3 costate, ribs low. Motor-cells inconspicuous and situated at the base of the narrow furrows flanking the mid-rib. V.Bs. 3, of the third order. No stereome development. Cells of abaxial epidermis relatively large, somewhat irregular, arching and uncutinised. Adaxial surface with smaller, uncutinised, arching cells. The majority of the stomata on this surface. Occasionally short asperities on the summit of the mid-rib and at margins.

Agrostis setacea Curt. (7) (Pl. 22).

Leaf capillary, conduplicate, terete to sub-terete. (250-340 u in diam.) = 0.25-0.34 mm. Neither adaxial nor abaxial surface is ribbed. A narrow channel extending to about the geometrical centre is formed between the leaf halves. Abaxial surface with abundant sub-globose papillae; adaxial with hooked asperities. Vascular bundles 3 or 5 of second and third order. Both sheaths well marked. Mesophyll of isodiametric cells. There is a one-celled continuous or slightly discontinuous band of hypodermal stereome on the abaxial side which extends to the leaf margins. Stomata on the sides of median furrow. Abaxial epidermis cutinised and bearing numerous globular papillae. Adaxial epidermal cells not cutinised and increasing in size towards base of furrow to form the solitary motor-cell group.

Corynephorus canescens Beauv. (6) (Pl. 23.)

Leaf setaceous, terete, about 0.3 mm. diameter; adaxial surface 3-5 costate, V.Bs. 7, one primary, two secondaries and four diminutive tertiaries. Abaxial epidermis papillose, cutinised and sclerotic. Two to three hypodermal layers of cells forming a strong, uninterrupted, peripheral, stereome band.

Adaxial epidermis uncutinised, bearing long asperities. A few stomata in the furrows only. Motor-cells inconspicuous.

Festuca ovina L. (10) (Pl.24.)

Leaves all similar, capillary or setaceous; section more or less oval, longer diameter, 0.3-0.65 mm.; keel rather more pronounced than in F. capillata; 1-3 costate; mid-rib well marked with a deep furrow on each side. Motor-cells not well developed. Abaxial surface strongly cutinised; adaxial much less so and with asperities. Stomata on adaxial face only. V.Bs. 5-7. Inner sheath strongly developed; outer covering only half the V.Bs., i.e. towards the adaxial surface of the leaf. Stereome sub-epidermal, generally poorly developed in a narrow layer, discontinuous or irregular. (Glaucous-green forms have a continuous layer and frequently also a thicker cuticle). Leaf halves frequently unequal.

Festuca capillata Lam. (14) (Pl.25.)

Leaves all similar, capillary or sub-setaceous, section sub-terete 0.3-0.5 mm. diam; less keeled than F. ovina; 1-3 costate; mid-rib not so high as in F. ovina. Motor-cells not well developed. Abaxial surface strongly cutinised; adaxial less so and bearing asperities. Stomata on adaxial face only; usually 5, rarely 7 V.Bs. Inner sheath strongly developed; outer covers only half the circumference - towards the adaxial surface. Stereome strongly developed in a continuous sub-epidermal layer. In var. hirtula, the abaxial epidermis bears occasional short hairs. Leaf halves sometimes unequal.

Festuca/

Festuca juncifolia St. Am. (7) (Pl. 26).

Leaves all similar, permanently folded, juncaceous, sub-cylindrical; longest diameter about 1.1 mm.; shortest diameter 0.9-1.0 mm.; 7-11 bundles; 5 or more costate; continuous sub-epidermal stereome of several layers of cells, also forming caps to the ribs. Asperities numerous on adaxial surface. Abaxial surface strongly cutinised, plane; adaxial less cutinised and bearing the stomata. Vascular bundles with both sheaths present; inner very strongly developed, outer on adaxial side of bundle only.

F. juncifolia St. Am. x F. rubra, var. arenaria Koch = F. oraria Dum. and Bab. (3) (Pl. 27).

Two specimens determined by W. J. Howarth as the above natural hybrid have an external appearance almost intermediate between the parental forms. The sections are 1.1 mm. x 1.0 mm. and 1.0 mm. x 0.9 mm. respectively. In leaf anatomy they resemble F. juncifolia but can be distinguished from latter by their discontinuous sub-epidermal stereome band.

Festuca heterophylla Lam. (6) (Pl. 28.)

Radical leaves capillary; section more or less kite-shaped in outline, 4-(5)-(6) sided - at least the two long sides, bordering the keel, slightly concave; 1-3-(5) costate. 0.4-0.6 mm. diameter; 3-(4)-(5) bundles. (1 primary, 2 secondary and 1 or 2 tertiaries). Small sub-epidermal stereome bands 'below' each bundle and at the margins. Abaxial epidermis strongly cutinised; adaxial with long asperities. Stomata in the furrows. Motor-cells not developed. Cauline leaves linear, expanded, 2-3 mm. broad, 7-11 or more nerved; motor-cells present between the ribs.

Festuca/

Festuca rubra L. emend. How. (30)

Radical leaves setaceous; apices blunt; 3-5-7 costate; 5-7-(9) bundles. Sub-epidermal bands of stereome on abaxial side opposite the V.Bs., at the margins, and less frequently at the summits of the ridges. Motor-cells in the furrows. Stomata on adaxial side only.

Key to sub-species.

- A. Plant densely caespitose; branches mainly intra-vaginal; the extra-vaginal branches all erect or nearly so. F. rubra, sub-sp. fallax. Thuill.
- B. Stock decidedly creeping; branching mainly extra-vaginal; stolons bear brown scale leaves. F. rubra, genuina. Hack.

A. Festuca rubra, sub-sp. fallax Thuill. (Pl. 29a, b.)

Basal leaves usually loosely conduplicate; longest diameter 0.6-0.9 mm. Abaxial surface cutinised; asperities on adaxial surface; 5-7 costate. V.Bs. 5-7. Keel obtuse. Sub-epidermal stereome bands on abaxial side and at margins. Stomata on upper surface; motor-cells in furrows.

B. Festuca rubra, sub-sp. genuina. Hack

Key to Varieties.

(1). Stolons shortly creeping.

(a) Foliage dark green. Radical leaves setaceous. 0.5-0.6-1.0 mm. diam. Keel acute. Leaf halves usually closely conduplicate, 5-7 V.Bs.; sub-epidermal stereome bands on abaxial side opposite the bundles, at the margins, and sometimes a few cells at summits of ridges. Short asperities on adaxial surface.

var. vulgaris. Gaud.
(Pl. 29c).

(b) Radical leaves larger, 0.8-1.0-1.3 mm.; sheath somewhat hairy. Keel sub-acute to acute. Leaf halves generally slightly apart; 7-9 V.Bs.; sub-epidermal stereome bands on abaxial side opposite the V.Bs., or at the margins; 7-9 costate. Abaxial/

Abaxial surface cutinised; adaxial surface covered with sharp hairs.

var. grandiflora Hack. (Pl. 29d.)

(c) Leaves glaucescent (sea green). Radical leaves 0.5-0.8 mm. diam.; keel sub-acute. Leaf halves compressed; 5-7 V.Bs. Small sub-epidermal stereome bands on abaxial side opposite V.Bs. and at the margins; 3-5 costate. Both surfaces especially abaxial, strongly cutinised; cells of adaxial epidermis strongly arching, (almost papillose) and bearing a few short asperities; stomata on adaxial surface, sunken.

var. glaucescens Hegets and Heer.
(Pl. 29e).

(d) Leaves glaucous; 0.8-0.9 mm. in diam.; keel obtuse, rounded; 3-5 costate; 5-7 V.Bs. Abaxial epidermis very strongly cutinised; adaxial to lesser extent and the cells arching (almost papillose). A few short asperities on upper surface. Stomata on adaxial face, sunken. Rather large sub-epidermal bands opposite V.Bs. on abaxial side and at margins. Stereome of margins sometimes merging with that of penultimate V.Bs.

var. pruinosa Hack (Pl. 29f.)

(2). Stolons extensively creeping.

(e) Leaves more or less alike, rather rigid 0.9-1.2 mm. in diam.; 3-5-7 costate; 5-7 V.Bs.; sub-epidermal stereome bands on abaxial side opposite V.Bs. and at margins. Abaxial surface cutinised, adaxial with arching cells and a few short asperities.

var. arenaria Osb. (Pl. 29g.)

Glyceria maritima Wahl. (10) (Pl. 30).

Leaves permanently conduplicate; section ovate c. 1.1 mm. wide; very fleshy, 290-370 u thick. Upper surface with marked mid-rib and flanking motor-cells; no other ribs or keel.

Vascular/

Vascular bundles (13-16) of two orders. Inner and outer sheath, especially latter, conspicuous. Narrow girder above and below median bundle and below two to six of the larger lateral bundles. Small bands of stereome under most of the bundles and at the margins. Transfusion tissue above the four larger lateral bundles. Mesophyll with irregular air spaces. Epidermal cells of both surfaces rather small; abaxial surface strongly cutinised and smooth; adaxial rather less so, and covered with papillae and occasional asperities. Stomata on adaxial surface; a few only on abaxial side. Motor-cells flanking mid-rib on both sides; not conspicuous.

Nardus stricta L. (9) (Pl. 31.)

Leaf section conduplicate, bristle like, roughly circular in outline. Diameter 530-740 μ = 0.53-0.74 mm. Ribbed on adaxial surface; low rounded ribs on abaxial side opposite the bundles. Bundles 5-7; three of first, remainder of third order. In each, an outer and inner sheath present - the latter being particularly well developed. A two-rowed transfusion tissue radiates from the three central bundles towards the apices of the ribs - not from the lateral bundles. All the bundles have broad triangular girders below. The abaxial epidermis forms, together with the girders, a continuous stereome. Marginal stereome unites with that of the lateral bundles. The ribs of the adaxial side have triangular caps of stereome. The chlorophyll-tissue is very compact; it is restricted to about half the volume of the leaf; it forms a sinuous band under the adaxial surface. The epidermis on both surfaces is strongly cutinised. The lower bears occasional hairs. Silicified papillae are abundant on adaxial surface - some/

some are 'L' shaped and are bicellular. Silica is particularly obvious in Nardus in some of the epidermal and sub-epidermal cells adjoining the stomata. The motor-cells, which occupy the basis of the furrows are only slightly larger than the epidermal cells. Blade folded in bud.

Stipa pennata L. (4) (Pl. 32.)

Leaf capillary, sub-terete to ovoid, conduplicate, (0.25 mm.-0.3 mm. x 0.3 mm.-0.6 mm.) Seven to nine vascular bundles, 3 primary, 2 or 0 secondary and 4 tertiary. Both sheaths are present in all bundles, the inner being especially well marked. There are seven to nine ribs corresponding to the bundles. There are two small triangular ribs on each side of mid-rib; mid-rib may be rectangular or rounded; the others are generally rectangular - sometimes with slightly rounded corners. Bundles of the first and second order are strongly girdered above and below; those of the third order below only. There is a narrow but continuous column of hypodermal stereome on the abaxial side of the leaf. On the adaxial side, the girders spread out laterally, forming a thin cap of stereome to the ribs. Simple and inconspicuous motor-cells occupy the bases of the deep, narrow furrows. The stomata are situated towards the bases of the furrows. Numerous asperities occur on the summits of the ribs. The chlorophyll tissue is very compact. Abaxial epidermis very strongly cutinised.

Ammophila arenaria Link. (9) (Pls. 33a, b.)

Outline circular, due to complete involution; diameter 1.5-1.7-(2.0) mm. Lower surface smooth and heavily cutinised. Upper surface with very conspicuous ribs of three orders radiating towards the centre, and bearing long stiff hairs.
Primary/

Primary ribs broadest just below summit. Leaf thickness at primary ribs 440-800 u. Bundles (16-25) of three orders, corresponding to the ribs, are present. Motor-cells present but not strongly developed. Stereome forming wide, uninterrupted, peripheral band with radiating girders to all the bundles. Primary bundles also girdered horizontally. Both bundle sheaths present - the inner especially well developed. Chlorophyll-tissue in narrow 'W' shaped bands of four to five cells deep, following the adaxial contour. Stomata along the sides of the ribs, opposite the chlorophyll tissue, especially bordering the motor-cells. Cells of lower epidermis small, not exceeding the hypodermal stereome cells. Margins right-angled. Leaf convolute in bud.

Ammophila baltica Link. (11) (Pls. 34 a, b, c.)

This species differs from arenaria only in minor details. In baltica the enrolled leaf is of smaller average diameter, 1.0-1.5 mm.; V.Bs. 15-18; thickness 370-620 u; the upper surface bears fewer and much shorter hairs. The marginal lobes of the leaf are more elongated and in most specimens one is peculiarly inturned; leaf margins less seldom in contact with each other than in arenaria. Slight keel present in some specimens.

Agrostis canina L. (12) (Pls. 35a, b.)

Basal leaves setaceous, convolute or conduplicate; 1-1.4 mm. wide when flattened out; 100-120 u thick; (upper leaves expanded, 1.6-2 mm. wide; 100-120 u thick; commonly 11 or 13 V.Bs.) The mid-rib bundle and frequently also other primary bundles girdered. Upper surface with triangular or dome-shaped/

dome-shaped ribs, the larger ones representing about three quarters of the leaf thickness. Lower surface with marked triangular keel and prominences opposite the furrows and bundles. Vascular bundles 5-7-9, of first and third order; all having both sheaths well defined. Stereome bands above and below each bundle, at the margins, and on lower side opposite the furrows. Cells of upper epidermis arching and not cutinised; those of lower somewhat arching and feebly cutinised. Motor-cells at base of each furrow inconspicuous. Stomata chiefly on upper surface; a few on lower. Asperities on upper surface and occasionally on lower.

The leaf anatomy of var. mutica Gaud. and of var. stolonifera Blytt. appears to be identical with that of the type.

Dactylis glomerata L. (10) (Pl. 36).

Leaf expanded or conduplicate; 5-10 mm. wide; keel pronounced with strong apical stereome. Blade of more or less uniform thickness, 140-220 μ thick; much constricted opposite the bundles, and tapering slightly towards the margins. Ribs scarcely perceptible. Vascular bundles, 24-40. Primary bundles, except that of mid-rib, girdered above and below. Of the secondary and tertiary bundles, some have girders below and bands above; others have bands above and/or below, while a few have no stereome. The principal bundles have both sheaths, the smaller ones the outer only. Along with Agrostis setacea unique among British grasses in having a single and median motor-cell group. The majority of the stomata are situated on the upper surface. Large air spaces abundant in the mesophyll between the bundles. Occasional asperities associated/

associated with the stereome, above, below and at the margin. Epidermal cells, irregular, somewhat arching; feebly cutinised. Waxy bloom. Leaf folded in bud.

Dactylis aschersoniana (2) (Pl. 37).

This is a Continental species chiefly confined to broad leaved forests (beech) at high altitudes. Growing plants are notably lighter coloured all over than our British species. In glomerata the diploid chromosome number $2n = 28$; in aschersoniana $2n = 14$.

The leaf section appears to be identical with that of D. glomerata.

Glyceria aquatica Wahl. (12) (Pls. 38a, b.)

Leaf very broad (7-13 mm. wide); expanded or conduplicate. Mid-rib in central depression, with two conspicuous flanking motor-cell groups; upper surface otherwise plane. Lower surface with shallow, or sometimes deep triangular keel; otherwise plane. Leaf halves elliptic in outline below; 300-470 μ thick. Vascular bundles of three orders (25-49); outer bundle sheath very prominent; inner less conspicuous. The outer sheath links up with the transfusion tissue, forming prominent clear-celled pillars between the upper and lower surfaces. Large rectangular or square air chambers occupy the intermediate spaces. Chlorophyll tissue restricted to a few rows of cells, especially along upper and lower margins of the air chambers. Large stellate cells occasionally seen abutting from sides of the air chambers. Stereome bands at keel, leaf margins, and above and below each bundle. Further diminutive bands of two or three cells sometimes occur at intermediate points/

points. Upper and lower epidermises moderately cutinised - especially the lower. Stomata rather more plentiful on upper surface. The motor-cells are situated on the top of a single tier of very small clear isodiametric cells. Leaf margins acute.

Glyceria fluitans Br. (10) (Pl. 39.)

Leaf broad (5-8 mm. wide), expanded or conduplicate. Mid-rib very prominent. Ribs also on upper surface between the vascular bundles. Lower surface keeled and with distinct ridges opposite the bundles. Leaf thickest mid-way between mid-rib and the margins (240-320 u thick). Vascular bundles large, of three orders - (21-33). Outer bundle sheath conspicuous, inner less well marked. A few cells of transfusion tissue link up the bundles with small, hypodermal, stereome bands, above and below. Fairly large pentagonal air chambers occupy the intervening spaces. Chlorophyll tissue reduced to a few layers surrounding the air chambers, especially on their upper and lower surfaces. A few large irregular stellate aerenchymatous cells abut from the chlorenchyma into the air chambers. Small stereome bands are present at the keel, above and below the bundles and at the summits of the ridges. Lower epidermis feebly cutinised, upper uncutinised. Short pointed papillae very plentiful on lower surface, fewer on upper surface. Large rounded papillae emanate from the stereome bands on the lower surface and from the summits of the ribs, on upper surface. Stomata rather more plentiful on upper surface. Two motor-cell groups flanking mid-rib; underlying cushion of clear cells absent. Leaf margins acute. Leaf folded in bud.



Glyceria fluitans,
var. plicata Fries (8) (Pl. 40.)

Has distinctive features and can be recognised from the type. Leaf rather thinner, upper surface rib-less apart from the rather low mid-rib. Leaf upper and lower surfaces practically parallel. Vascular bundles smaller. Air-chambers rectangular and considerably smaller. Transfusion tissue very conspicuous above and below all bundles. In Glyceria fluitans the transfusion tissue is restricted by the presence of the furrows. Both leaf surfaces thickly covered with papillae. Those emanating from the stereome bands of the lower surface very large and globular, causing a ridged appearance. Vascular bundles rather smaller.

Poa trivialis L. (16) (Pl. 41a).

Blade expanded or somewhat conduplicate; 2.5-3-(3.5) mm. wide, and 120-150-(190) μ thick. The two median motor-cell groups are situated in a central depression, and are separated by the low mid-rib. Otherwise there are no ribs on the upper surface. The lower surface has a very prominent, generally sharply wedge-shaped keel, its length much exceeding its breadth. There are frequently also slight ridges opposite the larger bundles. The bundles are of three orders (13-15); each with double sheath. Stereome feebly developed in bands at the base of the keel, at the margins and above and below the larger bundles. In the case of the smaller bundles, stereome bands are present above only, or are absent. Occasionally, there appear one or two diminutive epidermal stereome bands between the bundles on the upper surface. The epidermal cells are large on both surfaces; they are largest mid-way between the stereome bands, somewhat decreasing in size towards the bands.

Lower/

Lower surface slightly cutinised; upper epidermal cells arched. There are many hooked asperities on the upper surface, particularly opposite the stereome bands. A few may occur on the lower surface, especially on the keel. Stomata are present on both surfaces; the majority, however, are on the upper. Chlorophyll tissue loosely fitting. Chloroplasts very conspicuous.

Poa trivialis L. (Pl. 41b.)

One form met differs from the type, though still retaining the chief features. The leaf is much wider, 5 mm., and relatively thin, 150 u. There are 19 V.Bs. instead of the usual 13 or 15. Ribs are developed above and below each bundle, and additional prominence given to them by the fact that they are generally crowned by one or two very stout asperities. The epidermal cells on both sides are rather irregular in size; one or two very large cells appear mid-way between the stereome bands. One primary bundle in each leaf half is girdered, and another on one side only with girder below. Though differing from the type rather considerably, the deep keel and abundant asperities afford a clue to anatomical identification. Schlinder figures this form as his type, but I have met only one in the seventeen specimens examined, and the others have been remarkably uniform.

Poa nemoralis L. (10) (Pl. 42).

Blade expanded or conduplicate, thin, 100-140 u thick. Leaf thickest about middle of each leaf half. Apart from the low mid-rib which separates the two flanking motor-cell groups, there are no ribs on upper surface. Lower surface keeled and with slight ridges opposite the principal bundles. Bundles of three/

three orders, 13-15; outer sheath conspicuous, inner less so; small stereome bands at the margins, and above and below all but a few tertiary bundles. In some thin-leaved forms, the principal bundles, with the exception of that of the mid-rib, are girdered. Epidermal cells fairly large, somewhat irregular and arching; cuticle very thin. Majority of stomata on upper surface. Chlorophyll dense. Leaf margins bluntly pointed or rounded.

Poa annua L. (17) (Pl. 43.)

Blade expanded or conduplicate, thin, (90)-120-(135) μ in thickness; blade of more or less uniform thickness throughout. Width 2.5-3.5 mm., occasionally as much as 4 mm. Margins rounded. Upper surface rib-less; lower surface keeled. Vascular bundles of three orders (13 or 15 common). Inner and outer sheaths are present in all, but the former is inconspicuous in tertiary bundles. Stereome scanty, present as very small bands above and below most of the bundles, and at the margins; larger band at the base of the keel. Epidermal cells regular in size and relatively large, somewhat arching and feebly cutinised. Stomata about equally distributed on both surfaces. Occasionally a few asperities on upper surface between the veins. Motor-cell groups flank mid-rib on both sides.

Avena pubescens Huds. (5) (Pl. 44.)

Leaf expanded or conduplicate, rather broad, 5-6 mm.; thick. Mid-rib above low and rounded; keel prominent, triangular. Blade much constricted on both sides, opposite the bundles, especially opposite the larger ones. V.Bs. 17-23. Blade thick in/

in proportion to width, 290-350 u; broadest at centre of each leaf half. Upper and lower epidermal cells large and arching; the lower epidermis occasionally feebly cutinised. Lower epidermis bears a few scattered hairs, especially opposite the V.Bs.; the upper to a less degree. Chief bundles girdered below; sometimes also they have bands above connected to the bundle by transfusion tissue. The smaller bundles are mainly without stereome. Stereome bands at keel and margins feeble. Leaf conduplicate in bud.

Poa chaixii Vill. (8) (Pl. 45.)

Leaf very broad, c. 5.0 mm., expanded or conduplicate; very thin in relation to breadth, thickness c.130 u. Mid-rib situated in median depression; otherwise no ribs on upper surface. Lower surface with narrow deep keel and prominences opposite primary and secondary bundles. Leaf thickest about middle of each leaf half, decreasing towards the mid-rib and towards the acute leaf-margins. Vascular bundles of three orders 33-39; primary and secondary with conspicuous outer sheath and less conspicuous inner sheath. Tertiary bundles with outer sheath and inconspicuous inner sheath. Primary bundles, with exception of that of mid-rib, girdered above and below; secondaries fully girdered, or above or below only. Tertiaries mainly without stereome, but some have half girders or a single band, and a few even have full girders. Swallow-tail band at base of keel; small bands also at leaf edges. Epidermal cells small and strongly cutinised on both surfaces. Stomata on both sides. Very occasional asperities on upper surface opposite bundles, especially at mid-rib and at the margins. Mesophyll compact, of hexagonal cells but with irregular air-spaces, between adjoining bundles.

Poa compressa L. (4) (Pl. 46.)

Blade expanded or conduplicate; 2.5-5.5 mm. wide; motor-cells conspicuous. Leaf only very slightly constricted opposite bundle girders. Keel well developed; no ridges on lower surface opposite the bundles. Leaf thickness more or less uniform throughout, about 150 u, rather thicker about the middle of each leaf half. The leaf tapers abruptly at the margin. Vascular bundles of three orders, 15-27; both sheaths are present, though inner is inconspicuous in some of the tertiaries. Most of the bundles are girdered; transfusion tissue not interpolated between adaxial stereome and bundles as in P. pratensis. Girders about equal the width of the bundle and are parallel-sided, not wedge shaped. A few of the lateral tertiaries may have stereome band above and below, or above or below only, or absent. Epidermal cells of both surfaces only feebly cutinised. The epidermal cells (especially of the upper surface) are conspicuously larger mid-way between the girders, decreasing laterally. Very occasional asperities occur opposite girders. Stomata about equally distributed on both sides. A motor-cell group flanks mid-rib on both sides.

Poa pratensis L. (11) (Pls. 47a, b.)

Blade expanded, conduplicate; 2.5-4.0 mm. wide; 150-220 u thick. The motor-cell groups are situated in the median depression and are separated by the low mid-rib. There are no other ribs on the upper surface. Both surfaces present a somewhat undulating appearance, due to fact that leaf is constricted where the stereome and especially the girders occur. The lower surface is keeled, the depth of the keel about equalling its breadth; it is neither so large nor so sharp as in P. trivialis. There/

There are no ridges on the lower surface opposite the bundles. The leaf halves are thickest about the middle of each half. The leaf tapers abruptly at the margins, forming an obtuse margin. Bundles of three orders, 15-25, each with a double sheath. There is a broad stereome band below mid-rib bundle; broad wedge-shaped girders below other large bundles; small bands above connect with the bundle through transfusion tissue. Epidermal cells moderately large, those of the upper surface arched; of the lower surface cutinised. Occasional short asperities on upper surface arising from the stereome bands. Majority of stomata on the upper surface. Mesophyll cells tightly fitting but frequently large irregular air spaces are found. Motor-cell groups flank both sides of the mid-rib.

Poa alpina L. (3) (Pl. 49).

Leaf expanded or conduplicate, very broad, c. 5.0 mm., and thick, c. 250 u. Motor-cell groups situated in median depression, separated by the low mid-rib; otherwise no ribs on upper surface. Keel shallow and wedge-shaped, leaf thickness there not much exceeding remainder. Surfaces more or less parallel and leaf margins obtuse. Veins 23-30. Bundles of three orders, narrow, pear-shaped. Outer sheath conspicuous in all; inner inconspicuous especially in smaller bundles. Larger bundles with narrow triangular girders, or almost girdered, below; triangular bands above with apices towards bundles. Tertiaries, generally without any stereome, alternate with larger bundles; a few have stereome bands below, or above and below. Epidermal cells moderately large, the upper arching, the lower cutinised. Majority of stomata are on upper surface. Chlorenchyma very compact. Asperities absent. Leaf margins obtuse.

Poa alpina, var. acutifolia Dr. = (P. stricta Syme = P. laxa
Bab.) (2) (Pl. 48).

Leaf about half width of type, 200 u thick, V.Bs. 13.
Leaf decidedly constricted especially opposite larger bundles.
Cells of upper epidermis largest mid-way between the bundles.
Motor-cells not conspicuous. A few asperities on upper surface.

Avena pratensis L. (8) (Pl. 50).

Leaf expanded or frequently conduplicate, narrow 2-3-
(5)mm. Mid-rib with rounded keel below and low flat rib above,
with two flanking motor-cell groups; otherwise rib-less.
The blade is very thick in proportion to its breadth, about
300 u thick, narrowing somewhat towards the mid-rib and margins.
Lower epidermis cells elongated and strongly cutinised. Upper
epidermis cells arched, more irregular in size; usually not
cutinised; (strongly cutinised however, in case of var. alpina)
Bundles of two orders, 11-15-(17); the larger ones have narrow
girders below and narrow column of transfusion tissue above,
linking up with the stereome bands above. The smaller bundles
have no stereome. Stereome very strongly developed at margins,
in arrow-head formation. Very strong crescentic band of
stereome at the base of the keel or sometimes girdered; no
stereome above mid-rib bundle. Both bundle sheaths are
present - the outer especially being conspicuous. Stomata
more numerous on adaxial surface; a few only on abaxial side.
Motor-cells conspicuous; a group on each side of the mid-rib
in the deep furrows. The mesophyll is composed of large
tightly-fitting cells, but has well demarcated air cavities.
Nuclei very large and conspicuous. The leaf margins are flat
on the upper surface and rounded below. There are occasional
short asperities on the adaxial surface, but no hairs. Margins
obtuse. Leaf conduplicate in bud.

Sesleria coerulea Ard. (6) (Pl. 51.)

Leaf expanded or slightly conduplicate 3-4.6 mm. wide; c.200 u thick; of more or less uniform thickness throughout. Keel triangular, with rounded apex. Mid-rib low and rounded, situated in central depression, otherwise ribless. Well marked motor-cells on each side of mid-rib. Vascular bundles of three orders (16-25). Inner and outer sheaths prominent. Bundles of first and second order girdered, those of third order girdered above or not at all. The girders which give this species its characteristic appearance are very narrow in comparison with the vascular bundles; they comprise one to three rows of cells only. The stereome of the mid-rib occupies the base of the keel and generally narrows to join the bundle as a girder - presenting a mushroom-like appearance in section. On its upper side the mid-rib bundle has a very narrow girder composed of one or two rows of cells only. Leaf margins sub-acute, with strong stereome bands. Mesophyll compact towards each epidermis, but large though somewhat diffuse air spaces lie between consecutive bundles. The lower epidermis is composed of large regular cells twice the size of those of the upper epidermis; it is strongly cutinised. The cells of the upper epidermis are slightly arched and only faintly cutinised. Stomata confined to upper surface.

Spartina stricta Roth. (12) (pl. 52.)

Leaf broad, expanded or convolute, thick; more or less uniformly so throughout, tapering abruptly to the acute margin. Upper surface ribbed; lower ribless. The ribs are rectangular in the main and represent about half the leaf thickness; a few ribs are sometimes triangular and shorter than the rest.

Vascular/

Vascular bundles 31-38-(49), (average 36), of three orders. The inner sclerotic sheath is strongly developed in all. The outer sheath is composed of large cells containing chloroplasts and arranged characteristically in flask-form around the bundle - the neck occupying the middle of the rib. Stereome is represented in narrow sub-epidermal bands on the top of each rib and below each bundle; also at the margins; circular air chambers occur below each furrow, mid-way between the bundles. The chlorophyll-tissue is situated in a narrow band along the sides of the ribs and extending slightly downwards. Upper, and especially the lower epidermis heavily cutinised. Upper surface studded over with short papillae. Stomata restricted to upper surface, generally towards the bases of the furrows. Motor-cells inconspicuous.

Spartina alterniflora Loiss. (7) (Pl. 53.)

As in S. stricta but with 44-58 V.Bs. (average 50); the leaf wider, decidedly thicker at mid-rib, (370)-515-735 u., and tapering gradually to an acute thin margin. The ribs do not represent half the leaf thickness at centre of leaf.

Spartina townsendii Groves (8) (Pl. 54.)

As in alterniflora, but narrower, with 38-45 V.Bs. Leaf thickest at centre, gradually becoming thinner outwards, and ultimately tapering rather abruptly; 426-661 u thick at mid-rib.

Agropyron/

Agropyron junceum Beauv (9) (Pl. 55.)

Leaves linear, but usually partially to completely convolute; 3-4.5 mm. wide when flattened out, and 320-400 u thick. Upper surface strongly ribbed; ribs of three orders. Primary ribs broadest at base of Ammophila spp. Keel rounded, practically obsolete. Bundles of three orders, 15-19, each with inner and outer sheath well defined. Primary and secondary bundles girdered below. Bands above in all but a few tertiary linked up through transfusion tissue with the bundles. Continuous narrow hypodermal layer of stereome on lower side. Bundles never girdered laterally. Mesophyll cells compact; individual cells with markedly infolded walls. Chlorenchyma abundant, not restricted to sides of channels. Motor-cells in all the furrows but not very conspicuous. Stomata confined to upper surface. Cells of lower epidermis relatively large, much exceeding the hypodermal and upper epidermal cells in size. Lower surface strongly cutinised; upper much less so. Abundant short stout hairs on upper surface only. Margins obtuse.

Agropyron pungens R. & S. (12) (Pl. 56.)

Leaf expanded or convolute; very thick, 4-6 mm. wide, and 265-309 u thick. Upper surface strongly ribbed; the ribs are of three orders, the larger ones representing half the leaf thickness. The primary ribs are flat topped and have steeply sloping sides. The secondary ribs are slightly rounded or flat topped, while the tertiary ribs are triangular. The mid-rib is broader than the other ribs and flat topped. In addition to the principal bundle there are frequently two subsidiary bundles. The lower surface is plane, receding somewhat/

somewhat opposite the stereome girders. Vascular bundles about 21, of three orders. Both sheaths well defined. With the exception of a few tertiary bundles, all are strongly girdered below, while above they may also be girdered, or large, thick-walled, clear cells may be interpolated between the bundle and a stereome band. Stereome also strong at margins. Both surfaces are markedly cutinised. Majority of stomata on upper surface. The motor-cells are very conspicuous and occupy the bases of the deep channels. Occasional short asperities occur at the rib summits and margins. Mesophyll very compact, the individual cells with infolded walls. Leaf margins acute.

Elymus arenarius L. (11) (Pl. 57.)

Leaf broad, expanded or convolute; 440-550 u thick. Ribs of three orders. The larger ribs represent rather more than half the thickness of the leaf. The ribs in the main are rounded on the top; a few are flat and the smaller ones are frequently pointed. The bundles, 24-56, are of three orders and occupy ribs of corresponding size. Inner and outer sheaths are strongly developed in each bundle. The leaf halves are frequently assymetrical both in respect of width and size of ribs. All bundles are girdered below, but the smaller ones have only a band of stereome above. The girders spread out at the tops of the ribs, presenting a 'T' formation. The girders are distinct in the basal leaves; in the culm leaves, as in Ammophila, they are connected on the adaxial side by a peripheral stereome. The abaxial epidermis is of small cells which are strongly cutinised. The epidermal cells of the adaxial surface are also cutinised, though less strongly. The crests and flanks of the ribs only of the adaxial surface bear/

bear stout asperities. Some three to five roundish cells constitute the motor-cell group at the base of the channels. Stomata are plentiful on the sides of the ridges, especially towards their bases. Chlorophyll tissue is more plentiful than in Ammophila and many other xerophytes. Leaf margins attenuated. Leaf rolled in bud.

Deschampsia caespitosa Beauv. (14) (Pl. 58.)

In section the leaf may be expanded or convolute; width usually 2-3 mm.; 350-440-(700) μ thick; 7-(9) costate; no keel. Ribs appear as isosceles triangles, with acute or blunt apices. Furrows almost reaching to lower epidermis; each with a motor-cell group at base. Under each motor-cell group lies a cushion composed of a single layer of clear ovate-shaped cells. Each rib possesses usually two to three bundles, one primary, the others being of secondary and/or tertiary order. Occasionally, one or two ribs contain 4 V.Bs. or the majority may contain one only, but in the latter case at least one rib contains more than one bundle. Both sheaths are present in all the bundles. A strong stereome cap to each rib, and a triangular band is present under each primary bundle. There are stereome straps opposite each furrow and along the margins. Air spaces conspicuous in mesophyll. Both upper and lower epidermis is strongly cutinised. Epidermal cells linear and well defined. Stomata on flanks of ridges. Short asperities on ridges and at margins. Leaf rolled in bud.

D. caespitosa var. alpina R. & S. (8)

This variety, sometimes elevated to specific rank, does not appear to differ in leaf anatomy from the type.

Alopecurus geniculatus L. (10) (Pl. 59a).

Leaf expanded or convolute; 2.5-5 mm. wide; 290-340 u thick. Ribs on upper surface uniform, very acute, at least three quarters of the leaf thickness. Lower surface ridged opposite the vascular bundles and the furrows - each ridge characteristically capped by a large rounded cell or cells. Keel scarcely more prominent than the ridges. Air-spaces are markedly developed in the mesophyll. Vascular Bundles 12-20, of two orders. Outer sheath very prominent in all bundles; inner not conspicuous in those of second order. Small stereome bands at the summits of the ribs, and on lower surface opposite the bundles and the furrows. Motor-cells in the furrows. Stomata about equal on both surfaces. Asperities numerous on upper surface; a few only on lower surface. Epidermal cells arching and inflated, especially on the upper surface. Cuticle poorly developed.

var. bulbosus Gouan (Pl. 59b).

Leaf anatomy of the one specimen encountered is practically identical with that of the species. There are only eleven V.Bs. however, and the leaf is rather thinner.

Alopecurus alpinus Sm. (10) (Pl. 60.)

Leaf expanded; up to 4.4 mm. wide; 260-440 u thick. Upper surface with high triangular ribs representing three fourths of the leaf thickness. (The culm leaves have rounded or flat topped ribs.) Lower surface with shallow triangular keel and with ridges opposite the furrows, and to a lesser extent opposite the bundles. Ridges do not have large round apical cells at their apices. Vascular bundles, 7-21, of two orders. Outer sheath prominent in all; inner not conspicuous in those of second order. Transfusion tissue above primary bundles/

bundles. Diminutive hypodermal stereome bands at the summits of the ribs, and on the lower surface opposite the vascular bundles and the furrows. Mid-rib bundle girdered; other primaries also may be girdered above and below or below only. Epidermal cells uniform, not inflated. Lower epidermis cutinised in most cases. Motor-cells well developed in the furrows. Stomata principally on upper surface along the flanks of the ribs, - a few only on lower surface. Large asperities on ribs, especially at summits; much fewer and shorter on lower surface.

Koeleria spp. (11) (Pl. 61.)

Blade expanded or convolute, 2.0-2.5 mm. wide and 290-440 μ thick. Upper surface deeply ribbed; ribs mixed; primary rectangular, and representing about two thirds of the thickness of the leaf; secondary ribs more or less triangular; tertiary very low or obsolete. V.Bs. 11-15. Leaves hairy, pubescent or sub-glabrous, K. vallesiana. Stereome forming wide, sub-epidermal bands, one or more cells deep, at summits of ribs and opposite V.Bs. and furrows below. Lower surface cutinised. The genus is readily distinguishable from all other genera by leaf anatomy. The species however are very similar. Whereas K. gracilis Pers. and K. albescens D.C. are hirsute and pubescent respectively, K. vallesiana A. and G. is almost glabrous; and whereas the stereome bands in those two genera are composed of a single tier of cells, in K. vallesiana they are of two or three tiers. The latter species differs from the others, too, in having stomata on the lower surface of the leaf. K. gracilis and its variety britannica (Domin.) are identical anatomically, thus lending support to the modern view that the latter does not merit species rank.

Festuca bromoides L. (F. sciuroides Roth.) (Vulpia bromoides
S. F. Gray).
(Pl. 62.)

Leaf linear, expanded or convolute, 0.9-1.3 mm. wide and 120-150-(180) u thick. Upper surface with sub-acute ribs representing one half to two thirds of the leaf thickness; marginal lobe large. Lower surface with shallow but well defined keel and slight ribs opposite lateral bundles. V.Bs. 5, less frequently 7. Bundles of three orders, each with double sheath. Diminutive stereome bands above and below each bundle and larger bands at the margins. Epidermal cells regular; the lower strongly cutinised, the upper ones arching. Motor-cell groups conspicuous in furrows. Stomata confined to upper surface. Stout sharp hairs at summits of ribs, absent below.

Festuca Myuros L. (Vulpia myuros. Gmel.) (3) (Pl. 63a, b.)

Appears to come very near F. bromoides L. Actual measurements etc. for those examined; width 1.3 mm., 1.5 mm. and 1.9 mm.; thickness 176 u, 162 u and 176 u. V.Bs. 5, 7, and 9. Ribs rounded and not exceeding one half the entire thickness of leaf.

Festuca rigida Kunth. (10) (Pl. 64.)

Leaf linear, expanded or somewhat convolute, 0.9-1.7 mm. wide and 130-220 u thick. Upper surface with rounded ribs representing about half the leaf thickness. Lower surface rib-less; keel almost obsolete; no ribs opposite the V.Bs. Vascular bundles 7-13, of two orders. Both sheaths present but inner inconspicuous in smaller bundles. Chlorophyll in rings
or/

or partial rings around the V.Bs. Diminutive stereome bands at the margins, above and below larger bundles and above or below some of others. Lower surface cutinised; cells of upper epidermis round and somewhat arching. Motor-cell groups conspicuous in the furrows. Stomata chiefly on upper surface. A few asperities on upper surface, absent below.

Alopecurus myosuroides Huds. (14) (Pl. 65.)

Leaf expanded or frequently convolute; about 3.5 mm. wide and 175-235 μ thick. Upper surface with rather broad triangular or somewhat rounded ribs of uniform size, representing about half the leaf thickness. Lower surface with shallow, triangular keel and conspicuous ridges opposite the bundles. Vascular bundles 10-17, of two orders. Only the outer bundle sheath is conspicuous. Diminutive stereome bands present on the upper surface at the apices of the ribs; on the lower surface at the tips of the ridges and of the leaf margins, and occasionally opposite the furrows. Keel sometimes girdered below, less frequently the other primaries. Motor-cells in each furrow, not conspicuous. Short asperities on the summits of the ribs; less frequently on the lower surface, on the ridges and opposite the motor-cells. Lower surface somewhat cutinised.

Cynosurus cristatus L. (15) (Pl. 68.)

Leaf expanded, 3-4 mm. wide, 150-280 μ thick; upper surface with rounded ribs of more or less uniform size representing about half the leaf thickness. Lower surface inconspicuously keeled. Bundles (circa 15) of three orders, all except one or two/

two of the tertiary with small upper and lower epidermal stereome bands. Motor-cells conspicuous in channels. Stomata on flanks of ribs, especially along the edge of the motor-cell group. Leaf margins distinctly rounded (cf. *Lolium* spp.) and with well represented crescentic stereome band. Ultimate channel on either side of leaf frequently missing or poorly developed, thus the marginal lobe appears to possess two bundles. These points serve to distinguish this species from *Lolium* spp. Epidermal cells of lower surface rather large and with well defined cuticle. A few asperities on the rib summits. Leaf usually conduplicate in shoot.

Lolium perenne L. (23) (Pl. 69)

Leaf expanded, the halves tending to be revolute. 2.5-4.0-(5) mm. wide; 220-320 u thick; decreasing slightly towards the mid-rib and margins. Lower surface keeled, cutinised and seldom bearing stomata. Upper surface with broad, dome-shaped, regular ribs of about two thirds the thickness of the blade, their walls sloping steeply; each has a wide, sickle-shaped cap of stereome. Broad flattened stereome band at base of keel; smaller epidermal bands under each of the larger bundles, less frequently under the other bundles. The bundles are of two orders - 13-21, each with a double sheath. Transfusion tissue inconspicuous, of one or two rows of cells above central bundle. Motor cells in furrows not much exceeding epidermal cells except in the case of those bordering the mid-rib. Stomata on flanks of ridges, especially bordering motor-cells, rarely on lower surface. Occasional short asperities on the ridges. Leaf margins sub-acute. Lower epidermal cells very regular, 'palisade' like; rather strongly cutinised; upper less so.

Lolium multiflorum Lam. (20) (Pl. 70.)

Leaf expanded, edges generally upturned; 4.0-7.0 mm. broad; 220-300-(441) μ thick. Differs from L. perenne in the following respects. Lower surface with broader, shallower keel. Ribs irregular, more pointed, with gently sloping rounded or triangular sides. Mid-rib sometimes flat above. Stereome bands in ribs small and generally isodiametric, not sickle shaped. V.Bs. 15-22. Small bands below each primary bundle. (Forms with flat-topped mid-rib may even have girders below. Pl. 84.) Stereome bands not infrequently also below some of the secondary bundles. Transfusion tissue of two or more rows - the individual cells being larger than in perenne. The mid-rib frequently contains, in addition to the primary bundle, two secondary ones. Motor-cells equally prominent in all the furrows. Asperities longer and more numerous. Leaf thickest towards the centre, tapering to the acute margins. Lower epidermal cells very regular, rectangular, less strongly cutinised. Leaf convolute in bud.

Lolium temulentum L. (3) (Pl. 66.)

Appears to come very near to L. multiflorum. The ribs are flatter but more pointed. The epidermal cells are very conspicuous, especially below, and are larger than in L. multiflorum; cells of outer bundle sheath very conspicuous.

Lolium remotum Schrank. (2) (Pl. 67.)

This species is not unlike L. temulentum but there is no keel. Ribs on upper surface blunter and more steeply sloping. Epidermal cells near summits of ribs large and bladder like.

Apera spica-venti Beauv. (5) (Pl. 71.)

Leaf broad, about 1 cm.; 250-300 u thick. The leaf is strongly ribbed on both adaxial and abaxial surfaces. The abaxial ribs are flatly triangular. Those of the adaxial surface are of three orders, the primary ones being flat on the top, the remainder pointed. The bundles, about forty in number, are of three orders, and all have well defined double sheath. Those of the first order are strongly girdered; girders wedge-shaped, broadening outwards; one or two bundles of the second order have girders above while the others have stereome band above and below. The mid-rib is discernible by its stronger girder and by its broad, flat, almost obsolete rib on the adaxial side. Stout hooked asperities and occasional hairs abundant on the summits of the ribs of the upper surface; not so marked on the lower ribs. Epidermal cells arching on both sides. Stomata rather more abundant on adaxial side. Motor-cells rather weakly developed. Leaf convolute in bud.

Trisetum flavescens Beauv. (7) (Pl. 72.)

Leaf relatively thick, (160-220 u), expanded, slightly convolute, and with rounded ribs on upper surface; width (3.5-6.4 mm.) Lower surface with rounded keel and slight ridges opposite the bundles, and, sometimes, opposite the furrows. Long hairs arise from the summits and flanks of the ribs. A few scattered hairs appear on the lower surface. Bundles of three orders, 15-29, all with double sheath, the outer being strongly developed. Bundles of the first order are usually girdered below and above, or below, with stereome bands above and transfusion tissue connexions thereto. Those of/

of the second order have bands above and below; transfusion tissue usually connects bundle with upper stereome band. Bundles of the third order have stereome band above, or none at all. The basal girder of the keel may be broadly wedge-shaped, or it may take the form of a semi-lunar band of stereome connected with the bundle by a narrow column of sclereids. The leaf margins taper, but finish abruptly with a crescentic cap of stereome. The epidermal cells on both surfaces are large and isodiametric, arching and only feebly cutinised; lower epidermis generally strongly cutinised under terminal lobes. One or two, usually one, especially large cell abuts from the lower epidermis opposite the furrows, and from below the bundles of the third order. Prominences also occur opposite the other bundles, but they originate rather from a group of two or three small cells capping the stereome. The furrows on the upper surface penetrate about half way through the leaf. They are rounded and have motor-cells at their bases not greatly exceeding the normal epidermal cells. Stomata are situated mainly on the upper surface. Leaf convolute in bud.

Arrhenatherum elatius M. & K. (14) (Pls. 73, 102.)

Blade expanded or convolute; up to 9 mm. wide and 220 u thick; upper surface with low, flat-topped ribs of two orders; primary side-ribs twice as broad as high. Lower surface with prominent wedge-shaped keel; thickness here twice that at primary side-ribs. Slightly elevated ribs opposite bundles on lower surface; also slightly outwards curving opposite some of motor-cell groups. Vascular bundles of three orders, usually 25-30; tertiaries alternate with primary and secondary bundles. All have double sheaths, but inner feebly developed in tertiaries. Mid-rib/

Mid-rib contains in addition to principal bundle usually two subsidiaries. Median bundle has broad, wedge-shaped girder below, and three to four tiers of transfusion cells connecting with small hypodermal stereome band above. The primary bundles and the secondaries girdered above and below. Tertiaries may occasionally be girdered, or have bands above and below, or above or below, or absent. Stereome scanty at margins. Epidermal cells on both sides spherical, somewhat arching and not markedly cutinised. Stomata principally on upper surface. Motor-cells usually conspicuous. Short asperities and occasional hairs on both surfaces. Mesophyll cells with characteristic infolded walls.

var. tuberosum Gilib.

Elevated to species rank by some authorities, this variety is identical in leaf anatomy with the type.

Alopecurus pratensis L. (8) (Pls. 74a, b.)

Leaf 5.5-9 mm. wide; expanded or slightly convolute; 175-220-(295) μ thick; not usually exceeding 300 μ at mid-rib. The ribs are low and broad, of two orders, the primary representing about half the leaf thickness. They may have either flat or broadly dome-shaped tops. The smaller ribs are roughly triangular. The mid-rib is broad and flat-topped and generally possesses one primary and two tertiary bundles. On the abaxial side the keel is fairly prominent, and the stereome bands and girders abut from the surface to form slight prominences. Bundles of three orders 15-26. Primary and secondary bundles girdered, tertiary with diminutive stereome bands above and below. Primary mid-rib bundle with narrow girder/

girder below equalling, or only slightly exceeding, the bundle in width. Transfusion tissue and stereome band above. Both bundle sheaths present. Transfusion tissue not prominent. Upper and lower epidermis feebly cutinised. Stomata more plentiful on upper surface. Motor-cells in the furrows well developed; 45-60 u deep. A few short asperities on the adaxial surface, at the margins, and, to a lesser extent, on abaxial side. Margins acute. Leaf convolute in bud.

Agrostis tenuis Sibth. (12) (Pl. 76.)

Leaf expanded or convolute; 2.6-4.0 mm. wide; 110-161 u thick. Upper surface with ribs of two orders. Ribs rounded and the sides falling away rather steeply, their width not exceeding their height. Lower surface with inconspicuous or obsolete keel and slight prominences opposite the bundles. Vascular bundles 13-19, of three orders. Both sheaths prominent. Primary bundles girdered above and below; secondary and tertiary with small bands above and below. Stereome scanty at margins. Small bands occasionally present on lower side opposite the furrows. Lower epidermis of small regular cells. Upper of larger, somewhat irregular, arching cells. Neither epidermis markedly cutinised. Stomata on both surfaces; more plentiful on upper. Motor-cells in furrows, sometimes not well defined. Asperities on both surfaces. Leaf margins acute.

A form growing on a sandy habitat with strongly convolute leaf had a very marked cuticle to lower epidermis, and asperities only on upper surface; only 9 V.Bs.; stomata principally on upper surface.

var. aristata: leaf anatomy conforms to type.

Agrostis stolonifera L. (12) (Pl. 77.)

Leaf expanded or convolute rather thin 3.5-4.5 mm.; 100-162 u thick. Ribs of two orders, flatly triangular or rounded. Sides of ribs fall away very gently, the width of the ribs exceeding their height. Lower surface with slight or nearly obsolete keel and small ridges opposite the bundles. Vascular bundles 13-27 (usually about 15), of three orders, all with double sheath. Marginal lobes with one bundle only. Primary bundles girdered above and below. Other bundles with small stereome bands above and below. Two or three inconspicuous hypodermal stereome cells sometimes present on lower side opposite the furrows. Stereome scanty at margins. Cells of upper and lower epidermis somewhat irregular, roundish and slightly arching; (those of lower surface smaller than those of upper.) Neither epidermis markedly cutinised. Stomata on both surfaces; most abundant on upper. Motor-cells in all the furrows but only moderately conspicuous. Asperities on both surfaces especially the lower, and at the sub-acute margins. No difference in anatomical structure was noted in var. compacta Hartm.; var. maritima Koch.; var. prorepens Koch.

Agrostis nigra With. (11) (Pl. 78.)

Leaf expanded or convolute; 4-8 mm. wide; 191-221 u thick; upper surface with ribs of two orders. The larger ribs are rounded, the others triangular; sides of the ribs fairly steeply sloping. Lower surface with slight or nearly obsolete keel and small prominences opposite the bundles. Vascular bundles (17)-25-35, of three orders, all with both sheaths well defined. In addition to principal bundle, mid-rib frequently has two subsidiary bundles; the marginal lobes also/

also commonly contain two bundles. Primary bundles girdered above and below; mid-rib bundle below only, with stereome band above; other bundles have small bands above and below. There are two or three inconspicuous sub-epidermal stereome cells on lower side opposite the furrows. Stereome scanty at margins. Cells of upper larger than those of lower epidermis; both somewhat irregular, roundish and arching. Neither epidermis markedly cutinised. Stomata on both surfaces, most abundant on upper. Motor-cells conspicuous in all the furrows. Asperities abundant on both surfaces, especially the lower; also present at sub-acute margins.

Festuca gigantea Vill. (14) (Pl. 79.)

Leaf broad, expanded or frequently convolute; 6-10 mm. wide; (150)-190-250 μ thick. Upper surface with low, broad, rounded ribs. Mid-rib very broad and plane above. Lower surface with wide, deep, rounded, characteristic keel - two to three times exceeding thickness of leaf at primary side ribs (368-588 μ). Otherwise lower surface rib-less, but it has a gently undulating outline. The leaf tapers away gradually from the large mid-rib to the very acute margins. Vascular bundles (13)-18-25, of three orders, mainly tertiary. Outer sheath marked in all; inner less so. Larger bundles with small girders at least below. Tertiary bundles have small stereome bands above and below, or above or below. Principal mid-rib bundle not girdered above. Stereome scanty at margins. In addition to the principal bundle, the mid-rib may possess one or two pairs of subsidiary bundles. Transfusion tissue very prominent in mid-rib, and occasionally interpolated between other primary bundles and an upper stereome band. The mesophyll contains a number of irregular air-spaces. Lower epidermal cells/

cells large and irregular; their radial walls longest; moderately cutinised. Those of upper epidermis rather smaller, arched and not markedly cutinised. Stomata rarely present on lower surface. Motor-cells in all the furrows usually strongly developed. Occasional hooked asperities on the upper surface and at the margins.

Phleum pratense L. (16) (Pls. 80a, b.; 115).

Leaf expanded or somewhat convolute; usually 6-8 mm. wide; 150-190 μ thick. Upper surface with low flat-topped or rounded ribs, or ribs of both types. Ribs sometimes almost obsolete. Lower surface not ribbed but gently outwards curving opposite the furrows, giving to the leaf in some specimens a sinuous outline. Keel slight but very characteristic, formed by the protrusion of the mid-rib girder. The lower girder is either (a) rounded and much protruding, or (b) wedge-shaped and less protruding. Vascular bundles 17-30; of three orders. Outer and inner sheath well developed in both. Primary bundles equal about half the leaf thickness; they are usually strongly girdered. Those of the third order may be girdered above, with stereome band below or vice versa; or there may be hypodermal bands above and below. Motor-cells well defined. Stomata present on both surfaces; the majority, however, on upper surface flanking the motor-cell groups. Epidermal cells roundish, rather irregular and feebly cutinised on both surfaces; on lower surface one or two cells, larger than the rest, opposite the furrows. Asperities occur on both surfaces opposite the stereome and at the acute leaf margins. Chlorophyll-tissue compact but with well defined, though small, air spaces. Green sphaerocrystals of phlein commonly present in/

in the mesophyll and epidermal cells, so frequently as to be of diagnostic value. It also occurs, however, in other Phleum spp.

var. nodosum Schreb.

Leaves 3-4 mm. wide; 100-150 u thick; V.Bs. 18-22; keel girder not prominent.

var. stoloniferum Bab.

Leaves 2.5 mm. wide; 74 u thick; V.Bs. 14. Anatomically identical with species.

Phleum arenarium L. (5) (Pl. 81.)

Leaf expanded or convolute; 2.6-3.4 mm. wide and 150-180 u thick. Ribs low, with conspicuous motor-cell groups in each furrow. Keel absent. The primary ribs are flat, the others rounded. Bundles of three orders, about 14 in number; all with outer sheath well defined, inner only feebly developed.

Usually three to five primary bundles, equalling one third to one quarter of the thickness of the leaf. The mid-rib bundle is girdered below only, the others above and below. The secondary bundles are girdered below, with diminutive bands above. Stereome is absent, or only a trace above, in the case of the tertiary bundles. The chlorophyll tissue is compact and formed of large cells tending to be ranged in rows round the vascular bundles. The epidermal cells on both surfaces are large, roundish, irregular and arching. Especially large globular cells frequently appear on the lower surface opposite the furrows and occasionally opposite the bundles. On neither surface is the epidermis strongly cutinised. Stomata equally distributed on both sides. Marginal lobes of leaf short and obtuse, with diminutive stereome band and, frequently, asperities. Occasional asperities also occur on the summits of the ribs.

Festuca arundinacea Schreb. (12) (Pls. 82a, b.)

Leaf expanded or frequently convolute; 5-7-9 mm. wide; 300-500 u thick, exceeding 300 u at mid-rib. Upper surface with ribs of two orders. Those of first order flat or somewhat rounded, and those of second order triangular. They vary somewhat in shape in different specimens. Mid-rib generally has one primary and two tertiary bundles. The ribs of first order represent about two thirds of the leaf thickness. Lower surface usually with rounded keel. Otherwise ribless when expanded. In convolute position, however, the leaf tends to be ribbed opposite the bundles. Motor-cells large, very conspicuous, 70-120 u deep. Vascular bundles, 11-22, mainly of first and second order. Both sheaths present in all bundles, the outer especially well marked. Those of first and second order girdered, above and below, or with girder below and band and transfusion tissue above; of third order with bands above and below, or above or below only. The primary mid-rib bundle has a very strong wedge-shaped girder below, twice as broad as the bundle itself; transfusion tissue and stereome band above. The lateral bundles in mid-rib also usually have conspicuous transfusion tissue. Lower epidermal cells strongly cutinised - upper much less so. Stomata mainly on upper surface - a very few on lower. A few stout asperities on both surfaces and at margins. Margins sub-acute. Leaf convolute in bud.

Festuca pratense Huds. (7) (Pl. 83.)

The leaf anatomy of this species, as might be expected, approximates closely to that of F. arundinacea. Leaf 4.5-8 mm. wide, and 220-265 u thick. Ribs of three orders; exceeding 300 u at mid-rib. Motor-cells only 50-60 u deep. V.Bs. 14-21 keel less pronounced; lateral bundles of mid-rib without transfusion/

transfusion tissue or very feebly developed. Mid-rib built on a smaller scale. Bundles less frequently girdered. Transfusion tissue forms narrower columns above the bundles where present. Asperities slender.

Setaria viridis Beauv. (8) (Pl. 85.)

Leaf expanded, 5-8 mm. broad, thin about 130 u. Upper surface not ribbed but prominences opposite many of the bundles. Lower surface with broad wedge-shaped or rounded keel, slight ridges opposite the large bundles, and small prominences opposite many of the smaller bundles. Vascular bundles very numerous 100-160. Primaries 7-11, the remainder tertiary; 7-13 tertiaries between each two primaries. Inner sheath missing; outer conspicuous especially in tertiaries, and containing chloroplasts. Median bundle of keel girdered below. Some of the other bundles with diminutive stereome bands below, occasionally above; larger stereome bands at the margins. Chlorenchyma forms a narrow band between the two epidermises - the cells forming rings round the V.Bs. Hexagonal crystals numerous in mesophyll. Latter follows the abaxial contour in the keel, leaving on its upper side a large triangular area of clear cells. Motor-cells almost continuous on upper surface - each group overlying about two tertiary V.Bs. Small asperities on both faces. Stomata above and below.

Setaria glauca Beauv. (11) (Pl. 86.)

Leaf expanded, (5)-7-9 mm. wide, 150-180 u thick. Upper surface without ribs or prominences; lower with deep triangular keel. Vascular bundles very numerous (60)80-110. Primaries 7-9-11, the remainder tertiary; 8-10 small bundles between each/

each two large. Inner sheath missing; outer very prominent, especially in the tertiaries and containing chlorophyll. All the primary bundles and sometimes two tertiaries in mid-rib, girdered below and with girder or band above; (median bundle never girdered above). Occasionally, diminutive stereome band above or below a few of the tertiary bundles; small band at the margins. Chlorenchyma forms a narrow band between the upper and lower epidermis, the cells forming rings around the bundles. Bundles and chlorophyll tissue follow the abaxial contour in mid-rib, leaving a large triangle of clear cells above. Epidermal cells very large on both sides, the two together representing two thirds of the leaf thickness. Stomata on both surfaces, the greater number being on upper surface.

Cynodon dactylon Pers. (7) (Pl. 87.)

Leaf expanded or convolute, 2-3 mms. wide and about 120 μ thick. Upper surface with slightly elevated, flat or crescentic ribs. Latter accentuated by the presence of deeply seated motor-cells in intervening furrows. Lower surface with corresponding though even lower ribs. Keel just perceptible. Vascular bundles relatively large, of three orders, 15-24; three to four tertiary bundles alternate with a larger primary or secondary bundle. Inner sheath present in case of primary and secondary bundles. Parenchymatous sheath to all bundles of large conspicuous cells containing chloroplasts and with dense granular appearance. Normal chlorenchyma very restricted and radiating in a narrow circle around the green parenchymatous sheath. Stereome forming bands at margins and shallow girders to the primary and secondary bundles. A band, comprising/

comprising only some 3-4 cells, above and below the tertiaries. Both surfaces are cutinised, and bear abundant papillae and occasionally long hairs with multicellular bases; the hairs in some cases emanate actually from the motor-cells. Motor-cells in all the furrows; deep and laterally compressed, so that the lateral cells are seated on the shoulders of the central cell. One or more clear cells are situated underneath the large central cell.

Arundo phragmites L. (12) (Pl. 88.)

Leaf as much as one inch broad; 150-175-(220) u thick, the thickness being remarkably uniform throughout. Ribs low, flat, practically obsolete. Bundles very numerous, (50-130), of three orders, the majority being of the third order. They are very large, each with inner and outer sheath. The outer sheath is especially conspicuous, the inner only in the primary bundles. All the bundles are girdered, with the exception, sometimes, of a few of the smaller ones which may have girders below only, or none. Cross-anastomoses not infrequent between the bundles. Transfusion-tissue is very conspicuous in some leaves in the region of the mid-rib; in others, however, it may be entirely wanting. Chlorophyll tissue very compact - the walls of the individual cells being infolded. The chlorenchyma is strongly undulating in form owing to the deep-seated nature of the motor-cells. The cells of both upper and lower epidermis are minute and cutinised. Stomata are abundant on both surfaces. There are no hairs, but a few very short papillae are present, especially on lower surface. The motor-cells are deeply seated, generally penetrating half-way through the leaf. They exhibit an interesting and peculiar arrangement of/

of the individual cells. A very large pear-shaped cell occupies the centre, extending from the base of the depression to the epidermis. Two smaller cells on each shoulder of this cell make up the group. The leaf margins are pointed and are protected by a band of stereome which takes the form of an arrow head. Leaf convolute in bud.

Hordeum nodosum L. (8) (Pl. 89.)

Leaf expanded or slightly convolute; narrow, 1-3 mm. wide; about 150 μ thick. Ribs on upper surface conspicuous, rounded, representing usually about half the leaf thickness. Keel inconspicuous to obsolete. V.Bs. 10-16, of three orders. Both sheaths present in all, but inner inconspicuous in tertiaries. Bundles practically all girdered, at least on lower side; a few tertiaries may have bands only above and below. Cells of lower epidermis moderately to strongly cutinised. Occasional long hairs on both surfaces; in some specimens they are absent. Asperities numerous on upper surface; a few below. Motor-cells conspicuous in all the furrows. Stomata chiefly on upper surface. Leaf rolled in bud.

Holcus mollis L. (8) (Pl. 90.)

The blade is expanded or slightly convolute, 7-8 mm. wide; 100-205 μ thick. Ribs rounded, variable in height but not exceeding half the leaf thickness. Mid-rib low, flat, containing one primary and two subsidiary bundles. Lower surface with shallow to obsolete keel; abaxial surface has an undulating outline. Hairs on both surfaces are much shorter than in lanatus. The leaf margins are more tapered. Stereome at base of keel isodiametric, not flattened. Bundles of three orders/

orders, each with double sheath. All are girdered except those of the third order which may have a band of stereome above, or none. Transfusion tissue less conspicuous than in H. lanatus. In other respects the two species are alike.

Phleum phleoides Simonk. (4) (Pl. 91.)

Leaf expanded or convolute; 3-4.4 mm. wide and 132-150 u thick. Upper surface with low flat ribs more or less alternating with smaller rounded ones. There are no ribs or keel to lower surface. Bundles of two orders, 19-29. Inner sheath most conspicuous in large bundles, outer one in small bundles. The large bundles are very strongly girdered; the stereome broadening towards both surfaces. Apart from those in the ribs, one or two small bundles also occur opposite the furrows. None of the smaller bundles has any stereome. Chlorophyll tissue very compact. The epidermal cells are small, round, irregular and arching, decreasing in size towards the girders. The shallow furrows contain well defined motor-cells. Stomata most abundant on upper surface. They are not strongly cutinised. The leaf is thickest at the mid-rib and tapers gradually on both sides to an acute margin of stereome. The strength and shape of the girders distinguishes this species from other Phleum spp.

Phleum alpinum L. (8) (Pls. 92a, b.)

Leaf expanded or convolute; thick in relation to its breadth; 2.5-3.6 mm. wide and 165-220 u thick. Ribs rather low, rounded or slightly flattened; irregular, sometimes nearly obsolete. The lower surface never sinuous. Keel weakly developed/

developed or absent; the lower girder to mid-rib bundle wedge shaped, not rounded and not markedly projecting from the lower epidermis. Vascular bundles of three orders, c.13, the primary ones not equalling half the thickness of the leaf. Larger bundles have rather narrow girders. Transfusion tissue may be interpolated between the stereome and the bundle. The smaller bundles have stereome bands above and, or, below, or none. Inner and outer bundle sheaths present in all bundles but the inner not conspicuous. Epidermal cells of both surfaces rather irregular, roundish and somewhat arching; neither surface strongly cutinised. Motor-cells conspicuous. Stomata not plentiful, principally situated on the upper surface. Asperities on upper surface opposite the bundles; occasionally there on lower surface. Chlorophyll-tissue very compact. Leaf margins acute. Phlein crystals abundant in mesophyll.

Diploid and tetraploid forms which had been cultivated at the Scottish Plant Breeding Station had leaves 6.5 and 7 mm. wide, and 220 and 235 μ thick, and 22 and 27 V.Bs. respectively. Apart from their greater dimensions they did not differ much from each other or from diploid forms of mountainous origin.

Leersia oryzoides Sw. (6) (Pl. 93.)

Leaf about one centimetre broad; thin, about 80-90 μ thick; expanded or convolute; ribs practically obsolete on upper surface. Leaf halves frequently unequal. Lower surface ribless but with large semi-lunar keel about four times exceeding the thickness of the remainder of the leaf. Motor-cell groups very numerous, c.60, very large, extending about half way through the lamina. A rather anomalous construction is seen in/
in/

in the presence of a group of motor-cells on the lower surface, on each side of the keel. There are some sixty vascular bundles, about thirteen being of the first order, the remainder of the third order. The primary bundles are very large and unusual in that the horizontal diameter is greater than the vertical. They extend almost from lower to upper epidermis. The vessels are extraordinarily large. Both sheaths are present, the inner sclerotic sheath being very prominent. Large bundles girdered above and below; lower girder very thin, about equalling the width of bundle; upper girder only half as wide but deeper. Tertiary bundles diminutive, each with outer sheath conspicuous, inner scarcely marked. There is a stereome band above and below each bundle. Construction of the mid-rib unusual and characteristic of the species. A wide narrow arc of stereome occupies the base of keel and upon this the very large central primary bundle rests, so that this bundle is much below the level of the other bundles. The central and greater portion of the mid-rib is composed of large, thin-walled, clear, parenchymatous cells. On each side of the principal bundle, and situated on the verge of the clear-celled tissue, are large, subsidiary, tertiary bundles, girdered below. There is also a large tertiary bundle suspended from the top of the mid-rib by a strong stereome band opposite the principal bundle. Chlorophyll tissue in the mid-rib is confined to a narrow strip underlying its upper surface. Elsewhere, the chlorophyll tissue is compact and has a very corrugated upper outline due to the deeply situated motor-cells. Both upper and lower epidermis are cutinised and papillose, as seen under the high power. Asperities occur on both surfaces, especially opposite the vascular bundles and at the margins. Stomata about equally distributed on both sides.

Lagurus ovatus L. (10) (Pl.94.)

Leaf wide, about 1 cm., expanded; moderately thick, 175-220 u. Upper surface with low undulating ribs of two orders - lower surface with broad triangular keel containing one primary and two tertiary bundles. Both surfaces with abundant long hairs - some of which exceed in length the thickness of the leaf by three or four times. Vascular bundles, 22-35, - distant from each other - of first and third order; many of the latter almost obsolete. The primary bundles have inner and outer sheath well marked; neither is well marked in the tertiary bundles. Majority of the primary bundles girdered below, but above a few transfusion cells may be interpolated between bundle and stereome. Mid-rib primary bundle may have triangular girder below or only stereome band; transfusion and stereome band above. There are diminutive stereome bands at the leaf margins and above a few of the small bundles of third order. The epidermal cells are large and arching; very feebly cutinised on both surfaces. Motor-cell groups wide, in all the shallow furrows. Stomata small and not plentiful; about equally distributed on both sides of the leaf - the upper surface bearing slightly the greater number. The leaf margins are rounded.

Melica uniflora Retz. (9) (Pl. 95.)

Leaf expanded or convolute; 4.2-6.0 mm. wide; extremely thin, 58-88 u thick. Upper surface with low, undulating or almost obsolete ribs. Keel prominent, narrow, wedge-shaped, with rounded base. The lower surface is ribbed opposite the bundles. Vascular bundles, 15-19, of three orders; distant from each other. Both bundle sheaths present but the inner not conspicuous in tertiary bundles. All bundles girdered above and below, the upper being twice as wide as the lower. Stereome/

Stereome at the base of keel, semi-lunar and sometimes connected to the bundle by a few stereome cells. Upper and lower epidermal cells arched, and without marked cutin. Stomata very few, and situated on the upper surface only. Motor-cells fairly conspicuous, the individual cells roundish, six or seven cells forming each group. The middle cells do not greatly exceed the lateral ones in size. The larger individual cells are about twice the size of the lower epidermal cells. Long hairs occur occasionally opposite the bundles on upper surface; a few asperities are found on both surfaces.

Cynosurus echinatus L. (4) (Pl. 96.)

Leaf expanded; thin, c.150 u.; upper surface with low, regular, undulating, distant ribs. A few asperities at the summits of the ribs. Lower surface with acute triangular keel. Bundles of three orders. Outer bundle sheath conspicuous, inner feebly developed only in primary bundles. Motor-cell groups very wide but shallow. Stomata equally prevalent on both sides of leaf.

Stereome bands feebly developed at keel, and above and below the larger bundles and some of the smaller bundles; absent at margins. Epidermal cells on both surfaces irregular, arched and uncutinised. Margins rounded.

Milium effusum L. (8) (Pl. 97.)

Leaf expanded or slightly convolute 8 mm.-1 cm. wide; very thin in relation to the breadth, 90-120-(150) u. Keel very prominent, bluntly triangular; the leaf thickness here 450-550 u; leaf rib-less elsewhere. Epidermal cells rounded, rather irregular, arching and sparsely cutinised. Bundles of three/

three orders, 23-29, widely spaced. Those of first and second order girdered above and below with the exception of the mid-rib bundle which is girdered below only; the latter girder is characteristically 'T' formed. Others with stereome bands above and below or above only. Transfusion tissue is prominent in the case of the mid-rib bundle and the bundles on either side of it, linking up the bundles with their overlying stereome bands. Both sheaths present but inner inconspicuous in bundles of the third order. Motor-cells shallow, in groups of five or six, orientated almost in the same plane, and becoming inconspicuous towards the leaf margins. Stomata mainly on upper surface. Short papillae occasionally present opposite the stereome and at the margins; latter acute. Leaf convolute in bud.

Brachypodium sylvaticum R. & S. (15) (Pl. 98.)

Leaf expanded, or convolute, broad and relatively very thin; 7-9.5 mm. wide; 60-100 u thick at side ribs and about 260 u at mid-rib. V.Bs. 27-45 (average 35). Ribs on upper surface low, wide and undulating, to almost obsolete. Lower surface with roughly rectangular keel. Vascular bundles distant, of three orders. Primary bundles almost equal to leaf thickness. Both sheaths present in all bundles, but inner inconspicuous in tertiaries. Practically all bundles girdered above and below; mid-rib bundle may have only strong bands above and below, with transfusion tissue between upper band of stereome and bundle. Mesophyll compact - only 2-3 cells deep at furrows. Upper epidermis cells somewhat arching and not cutinised; lower variably but never strongly cutinised. Upper surface with asperities, short hairs, and scattered long hairs; lower with few asperities and very occasional long hairs/

hairs. Stomata confined to upper surface. Motor-cells quite conspicuous, occupying the low, wide furrows. Leaf margins obtuse, frequently truncate.

Calamagrostis epigeois Roth (9) (Pls. 99, 105)

Leaf broad, 5-8.5 mm.; thin in the main, 150-220 μ ; expanded or convolute. Ribs of two orders on upper surface. There are usually 4-6 semi-lunar ribs of first order, much higher than those of second order which are almost obsolete; the leaf thickness at the primary side ribs is about twice that at the secondary ribs. The lower surface has a strong broadly wedge-shaped keel, the leaf thickness here being two or three times greater than elsewhere. The vascular bundles, 25-36 are of first and second order. The former are very large, equalling the thickness of the leaf at its thinner parts. In addition to a large central bundle, the mid-rib may contain 2 or 4 subsidiary bundles, or they may be absent. There are usually 3 small bundles between each pair of primaries. Both bundle sheaths are present, the inner sclerotic sheath being very conspicuous. The V.Bs. are strongly girdered above and below with the exception of the inner pair of subsidiary bundles in the mid-rib, which may be girdered below only. The girders, especially of the mid-rib bundles, tend to abut from the lower surface. In the case of the primary bundle of the mid-rib, the girder is widest at the keel and narrows upwards. In the side ribs the girders of the primary bundles are widest on the adaxial side and narrow towards the abaxial surface. There are small, laterally placed stereome bands in the lower epidermis opposite the motor-cells. The leaf margins are pointed and strongly protected with stereome. The mesophyll is compact except in the mid-rib where there are frequently/

frequently air spaces on each side of the chief bundle. The motor-cells are large and conspicuous, equalling half the thickness of the thinner parts of the lamina. In deflated position they project beyond the epidermis. Owing to their great size, the chlorophyll tissue presents a deeply corrugated appearance. The epidermal cells, especially on upper surface, are small; very strongly cutinised on both surfaces. Stomata are almost entirely confined to the upper surface. Short asperities on the lower surface, especially opposite the bundles.

Calamagrostis canescens Gmel. (Pl. 106)

The leaves of the only plant examined differed from C. epigeois as follows:- Leaf thinner, 130 u; motor-cell groups twice as wide but only half as deep. Stereome above the primary bundles (excluding mid-rib) twice as broad as below, whereas in epigeois it is only slightly wider above. Asperities abundant on upper surface of leaf. Lower surface strongly cutinised; upper not. The shallower motor-cells give a more flatly corrugated outline to the chlorophyll tissue.

Bromus ramosus Huds. (14) (Pls. 100a, b.)

Leaf broad, expanded or somewhat convolute; 6-10 mm. wide; 118-221 u thick; 300-558-(800) u at keel. Ribs on upper surface low, flat or practically obsolete; mid-rib plane above. Lower surface with prominent, broad, wedge-shaped keel; otherwise plane or sometimes undulating. Upper and lower surfaces more or less parallel except at mid-rib, where leaf thickness is about three times that at the primary side-ribs. Vascular bundles, commonly 21-25, of three orders.

Both/

Both sheaths present - the inner being the more conspicuous. Majority of bundles girdered; on lower side girder narrows away from bundle; neither girder so wide as bundles. Mid-rib contains in addition to the principal bundle usually two subsidiary bundles. The principal bundle possesses a strong girder below which broadens out mushroomwisw to form the base of keel. On its upper side a column of transfusion-tissue links up with a stereome band, or there may be a narrow girder. Some of the tertiary bundles are girdered on one side only, with or without a stereome band on other side. Stereome scanty at margins. Irregular air spaces in mesophyll, especially in region of mid-rib. Mesophyll composed of very irregular cells with infolded walls. Epidermal cells roundish, somewhat irregular, arching and not markedly cutinised. Conspicuous motor-cells on upper surface between each pair of bundles, small or absent between principal mid-rib bundle and the subsidiary bundles. Stomata on both sides - the majority on upper surface. Occasional long hairs on upper surface opposite the bundles, less frequently on lower surface. (Hairs frequently absent from thin section though scattered hairs quite apparent on entire leaf). Margins sub-acute. Leaf convolute in bud.

Anthoxanthum odoratum L. (12) (Pl. 101).

The blade may be expanded or convolute; 3-5 mm. wide; 150-190 u thick; adaxial surface bears gently undulating ribs. Abaxial side generally possesses a well defined keel. The lower epidermis frequently protrudes slightly mid-way between the bundles (i.e. opposite the furrows), and this is accentuated by the fact that the protrusion is capped by a cell which is larger than the remaining epidermal cells and because of the retrusion/

retrusion of the epidermal stereome opposite the bundles. The bundles, 15-21, are of three orders. Those of the first and second are girdered. The primary bundles are large in relation to the thickness of the leaf, and the girders are completed on either side by a very few stereids. The girders in the side-ribs tend to narrow outwards. The smaller bundles have generally very slender stereome bands above and below, but either one or both may be absent. The epidermal cells are large and a little irregular. The lower surface is sometimes slightly cutinised. Asperities on both sides: there are occasional hairs on both faces and at the margins. Motor-cells conspicuous at the base of the low, flat furrows. Stomata are present on both surfaces, but they are less frequent on the abaxial side. Leaf margins sub-acute.

Sieglingia desumbens Bernh. (10) (Pl. 103)

Leaf is expanded; 3-4 mm. wide; thick and fleshy, 160-220 u thick. Leaf margins generally rather blunt. There is a flat rounded keel on the lower surface. The upper surface is generally ribless apart from the mid-rib which lies in a slight depression. There is a prominent, many-celled motor-cell group on both sides of the mid-rib. They are deep seated, reaching half way to the lower epidermis. In addition, there are smaller and flatter groups mid-way between each pair of bundles, gradually decreasing in size towards the margins. Different plants vary considerably in the number of motor-cell groups, some having only three groups on each half leaf; in others they extend to the marginal bundles. In one specimen a motor-cell group was present on the lower surface, between the ultimate and penultimate bundles. Lower surface is very strongly cutinised, the upper less so, sometimes very feebly/

feebly. Stomata are confined to the upper surface. Hairs absent. The bundles, 13-19, are of three orders - mainly of the third. The inner sheath is strongly developed; the outer is not conspicuous in the smaller bundles. All bundles are girdered with the exception of one or two of the third order in which stereome is present as a girder above, or entirely absent. Anastomoses frequently seen in sections. The chlorophyll tissue is formed of rather small, very compact cells. Leaf conduplicate in bud.

Molinea coerulea Moench. (14) (Pl. 104.)

Leaf 4-6 mm. broad; thin, 100-150 u, and frequently convolute. Leaf usually twice as thick at mid-rib as elsewhere, but frequently tapering off so gradually that a keel is not conspicuous. Upper surface with low, flat, or somewhat rounded ribs, slightly depressed at their summits. Bundles of three orders, (20)-30-37. Inner and outer sheaths present, the inner very prominent. Primary bundles very fibrous. The mid-rib is very strongly girdered, and in addition there may be laterally directed sub-epidermal bands. The primary bundles of the side ribs have also strong girders. Bundles of the second and most of those of the third order are girdered. Upper and lower epidermal cells minute and strongly cutinised. Motor-cell groups rather narrow but deeply seated. The central cell is large and pear-shaped, the others rapidly decreasing in size laterally. Sections occasionally show one or two long hairs from the upper surface. Asperities are found at the margins of the motor-cells and on the lower surface, especially on the keel. The mesophyll cells are isodiametric, compact, and densely filled with chlorophyll/

chlorophyll. The incursions made by the motor-cells give the chlorophyll tissue a corrugated outline in section. Air cavities sometimes appear in the mid-rib on either side of the bundle. Stomata not numerous; mainly on upper surface. Leaf margins acute, composed largely of stereome. Leaf convolute in bud.

Bromus erectus Huds. (11) (Pls. 107a, b.)

Leaf expanded or slightly convolute; thick - thickness more or less uniform throughout; 3.4-6 mm. wide and 235-300 μ thick. Upper surface with ribs of two or three orders. Primary and secondary ribs broadly rectangular, of variable but never great height; crowns slightly indented. The tertiary ribs may be rectangular or rounded. Leaf thickest at mid-rib and keel discernible; otherwise no ribs on lower surface. Vascular bundles, 15-19, of three orders. Both sheaths present but outer not conspicuous in larger bundles. Primary and secondary bundles very strongly girdered. Mid-rib girder bluntly wedge-shaped; other girders equal bundle at point of contact and widen gently towards both surfaces. Tertiary bundles have girder or band above only. Mesophyll cells very compact. Lower epidermal cells larger than upper and with well defined cuticle; upper arched and without marked cuticle. Stomata principally on upper surface, bordering the motor-cells. Motor-cells very conspicuous in furrows, tending to project above the epidermis in flaccid condition. A few asperities on upper surface; occasional hairs occur on both surfaces. Margins sub-acute; stereome scanty at edges. Leaf convolute in bud.

Bromus sterilis L. (10) (Pl. 108.)

Leaf expanded or slightly convolute, 2.8-4.6 mm. wide; rather thin, (88)-103-176 μ thick. Upper surface with broad, low, rounded ribs of three orders; mid-rib plane above. Lower surface keeled; keel wedge-shaped with rounded base; leaf thickness at keel about twice that at primary side-ribs. Vascular bundles, 13-22, mainly of first or third order. Inner and outer bundle sheaths moderately conspicuous in larger bundles. Only the outer noticeable in tertiary bundles. Larger bundles girdered; tertiary bundles usually without even stereome bands. Stereome scanty at margins. Mesophyll with irregular air spaces; individual cells irregular and having infolded walls. Upper and lower epidermal cells roundish, fairly large and arching; neither surface markedly cutinised. Long hairs abundant on both surfaces. Stomata about equally distributed on both sides. Motor-cells in all the furrows scarcely more conspicuous than ordinary epidermal cells. Leaf margins obtuse.

Holcus lanatus L. (14) (Pl. 109.)

Leaf expanded, occasionally convolute; 5-6 mm. wide; 150-190 μ thick. Ribs low and undulating, of three orders, the primary having flattish, the others crescentic tops. Keel conspicuous and wedge-shaped. The lower surface sometimes presents a gently undulating appearance, due to protrusion opposite the furrows, and retrusion opposite the girders. The bundles (about 20) are of three orders. Those of the first and second orders (except that of the mid-rib) are girdered above and below. Those of the third order may have bands above or below, but stereome is generally absent from them. At the base of the keel there is a low, flat, stereome band/

band which is connected to the bundle by a narrow strip of transfusion tissue. The leaf is thin except at the mid-rib, and the primary bundles occupy nearly half the thickness. The furrows on either side of the mid-rib are obsolete and the mid-rib possesses a primary and two subsidiary additional bundles. Transfusion tissue is well developed, (3-4 tiers of cells) over the primary bundle, and to a lesser extent over the subsidiary bundles of the mid-rib. Both sheaths are present in all bundles. The epidermal cells of the abaxial surface are large, irregular, round or oval, and arching. Especially large oval epidermal cells appear opposite the furrows. The epidermal cells of the adaxial surface are similar to those of the lower surface, but smaller and increasing in size towards the summits of the ridges. Asperities and very long hairs on both sides. Motor-cells are conspicuous. Stomata present on both surfaces. Irregular air spaces are distributed through the mesophyll. Margins tapering, rounded. Leaf convolute in bud.

Hierochloe odorata Wahl. (5) (Pl. 110.)

Leaf expanded, or slightly convolute; 4-5 mm. wide; of more or less uniform thickness throughout, 150-180 μ thick. Upper surface with low undulating ribs; motor-cells prominent in all the furrows. Lower surface faintly keeled. Vascular bundles of three orders, 12-18; both inner and outer bundle sheaths present. All the bundles girdered, with exception of one or two of the smaller ones. Stomata chiefly situated on the upper surface, along margins of the motor-cell groups; a very few only on lower surface. Cells of both upper and lower epidermis large and regular; lower strongly cutinised. Upper surface bears scattered hairs; occasional hairs on lower surface. Leaf margins acute.

Bromus hordeaceus L. (8) (Pl. 111.)

Leaf expanded or slightly convolute; 2.6-3.6 mm. wide; 176-191 μ thick. Upper surface with low, rounded, or somewhat flattened ribs, or ribs almost obsolete. Lower surface with shallow, wedge-shaped keel and slight ridges opposite the bundles. Vascular bundles 10-15, of three orders; both sheaths present in all, the inner especially being conspicuous in the larger bundles. Primary bundles girdered on both sides. The secondary bundles have girder or stereome band above, and band below, while the tertiary bundles have band above and below, or above, or none. A few irregular air spaces especially in region of mid-rib. Mesophyll cells without infolded walls. Epidermal cells roundish, regular and arching; cuticle not marked. Long hairs are present on both surfaces especially from the summits of the ribs. Stomata about equally distributed on both sides. Motor-cells present in all furrows but not very conspicuous. Margins pointed but not acute; stereome scanty.

Agropyron repens Beauv. (11) (Pl. 112.)

Leaf expanded; 4-8 mm. wide and 130-190 μ thick. Upper surface with low, rounded ribs; lower with broad, shallow keel and ridges opposite the bundles. Vascular bundles 23-29; of three orders. In addition to principal bundle, mid-rib frequently contains 2 subsidiary bundles. Both bundle sheaths present in all, the inner being rather more conspicuous. Primary and secondary bundles girdered; some of the tertiary may also be feebly girdered or have bands above and below or none. Lower epidermis more strongly cutinised than upper, but neither very strongly. Mesophyll cells have infolded walls. Stomata on both surfaces but the majority on upper.

Well/

Well marked motor-cells occupy the furrows. A few asperities and occasional long hairs on the ribs. Very occasionally a few asperities on lower surface. Leaf margins acute and with long stereome.

Neither var. leersianum Gray nor var. lasiorachis Hack. differ anatomically from the type, except that the lower epidermis of the latter is more strongly cutinised.

Agropyron caninum Beauv. (5) (Pl. 113).

The leaf section is very like that of A. repens. It differs however in the following respects. Leaf considerably thinner, 102-132 u thick; ribs lower and motor-cell groups wider, shallower and less conspicuous. Ridges on lower surface more marked. Stereome more abundant and stronger. Lower epidermis cells arching; very feebly cutinised. Hooked asperities prominent on lower surface.

Hordeum murinum L. (10) (Pl. 114.)

Leaf expanded or slightly convolute; 3-5 mm. wide; leaf thin, 120-150 u thick. Ribs on upper surface low, undulating, to almost obsolete; mid-rib flat above. Lower surface with broad shallow keel, otherwise rib-less. Vascular bundles 16-23; of three orders. The suppression, in many specimens, of the two furrows flanking the mid-rib gives the mid-rib the appearance of having 3 V.Bs. All bundles have double sheath, but neither is conspicuous except the inner one in primary bundles. Primary and secondary bundles girdered, at least below; a few of the tertiaries may have small stereome bands above only or none. Transfusion tissue conspicuous/

conspicuous above mid-rib bundle. Cells of upper epidermis arching, those of lower feebly cutinised. Occasional long hairs on both surfaces. Asperities fairly numerous, especially on upper surface. Motor cells fairly conspicuous in furrows. Stomata rather more plentiful on upper surface. Leaf rolled in bud.

Melica nutans L. (7) (Pl. 116.)

Leaf broad and thin, expanded or convolute; 5-6 mm. wide; about 130 u thick. Upper surface with low, broad, rounded ribs; keel wedge shaped with rounded base. Vascular bundles large, 13-20, of three orders. Inner and outer bundle sheaths prominent in all. All the side-rib bundles have strong girders above and narrower ones below. The stereome at the keel is wedge-shaped with rounded base, and connects at its apex with the bundle. Small stereome bands also occur on lower surface opposite the furrows and also at the leaf margins. Lower epidermis strongly cutinised; upper epidermis formed of arching cells and not cutinised. Stomata are situated on the upper surface only. There are numerous sharp asperities on upper surface, very few on lower. Motor-cells conspicuous, occupying the wide furrows. Blade convolute in shoot; latter quadrangular in section.

Briza media L. (12) (Pl. 117.)

Leaf expanded or frequently somewhat convolute; about 3 mm. wide and 130-150 u thick. Upper surface with fairly prominent ribs, of two orders; (a) low, flat; (b) slightly higher and rounded. The mid-rib, however, is entirely flat above/

above. The lower surface is rib-less apart from the rather bluntly wedge-shaped keel. The bundles are of three orders (15), the primary and secondary being in the flat-topped ribs. Both sheaths are present. Primary and secondary bundles are girdered. The tertiary have either stereome bands above and below, or above or below only, or none at all. Opposite the girders particularly, but also opposite the stereome bands, there are slight depressions in both surfaces. Marginal stereome almost obsolete. Motor-cells conspicuous in all the furrows. Stomata mainly on upper surface, bordering the motor-cells. Epidermal cells large, regular and arching on both sides; feebly cutinised. Occasional asperities on both surfaces, notably opposite the stereome. Chlorophyll cells of irregular shape, loosely fitting; large air spaces opposite the stomata. Margins sub-acute to acute; leaf convolute in bud.

Avena fatua L. (9) (Pl. 118.)

Leaf expanded or convolute; about 1 cm. wide, and 200-250 μ thick. The upper surface has low undulating ribs; mid-rib broad and flat. On the lower surface there is a low, wide, wedge-shaped keel and slight ridges opposite the bundles; short asperities on both surfaces opposite the bundles and at the margins. The bundles are of three orders, (c.15); majority of the third order. Both sheaths present; the outer very conspicuous. Stereome scanty. The larger bundles are girdered, while of the smaller bundles a few have girders above or below; some have bands, while many have no stereome. Transfusion tissue conspicuous above mid-rib bundle. The mesophyll is composed of rather loosely fitting cells. Stomata very large and abundant; about equally distributed on both sides/

sides; prominent air cavities are usually seen opposite each one. Motor-cells large and conspicuous in the shallow channels. Cells of both upper and lower epidermis large, irregular and arching, not appreciably cutinised. Margins sub-acute, stereome scanty at tips. Leaf convolute in bud.

Phalaris arundinacea L. (14) (Pl. 119.)

Leaf expanded, frequently 1 cm. broad; 150-200 μ thick. Upper surface with almost obsolete ribs (more conspicuous when leaf is convolute, i.e. when motor-cells are collapsed). Keel broadly triangular with rounded base. On the lower surface there are also small ridges opposite the bundles. Vascular bundles numerous (25)-40-52, of three orders; all have both sheaths well defined. The larger bundles are girdered, while stereome bands are formed above and below the smaller ones; the stereome slightly protrudes below to form the prominences already referred to. In mature leaves there are generally two or four subsidiary bundles in the mid-rib, in addition to the main bundle. All are girdered below and have transfusion tissue linking up with bands above. Lower epidermal cells small on whole, but three or four cells opposite the motor-cell groups exceed the size of the neighbouring cells considerably. Both surfaces only feebly cutinised. Stomata equally distributed on both sides. Motor-cells very conspicuous, nearly as deep as broad. Both upper and lower epidermis only feebly cutinised. A few asperities on lower surface and at the edges. Margins acute. Leaf convolute in bud.

The variegated form has a similar anatomical structure. The chlorophyll, however, is restricted to a thin layer in the lower/

lower mesophyll cells; only in a few places does it extend from the lower to the upper epidermis.

Explanatory Note.

In the dichotomous key which follows, the width of page has made it impracticable to render more apparent successive subdivisions by means of differential placing. The major divisions are, however, distinguished in this way. Apart from the first division, for which numerals 1 and 2 are used, alphabetic capitals have been utilised in making contrasting groups, e.g. A.1 and A.2 and B.1 and B.2. The sequence of species in the key has formed the basis of the plate numbers. Plate numbers are placed after the name of the grass in each case, both in the full descriptions and in the key. The arrangement of the species is the same in both, with the exception of one or two congeneric species which it was convenient to leave together in the description, so that the plate numbers form a means of cross reference. One or two species have been given a double entry in the key because of variability in size of rib, or other character.

KEY TO SOME HUNDRED SPECIES OF BRITISH GRASSES

AND SOME OF THEIR VARIETIES, BASED UPON THE ANATOMY

OF THEIR BASAL LEAVES, AS SEEN IN TRANSVERSE SECTIONS.

LEAVES CAPILIARY, SETACEOUS or JUNCACEOUS; i.e. PERMANENTLY
CONDUPLICATE or CONVOLUTE and the LEAF EDGES APPROXIMATE.

A.1. Vascular bundles not girdered.

B.1. Abaxial surface feebly cutinised; greatest diam.
0.3-0.6 mm.; adaxial side 1-3 costate.

C.1. Leaf angular. V.Bs.5.

D.1. Slender hypodermal stereome ring on adaxial side.

Leaf pentagonal, almost solid. Deschampsia flexuosa
Trin. (Pl. 18.)

D.2. No hypodermal stereome ring but diminutive stereome
bands at angles. Leaf hexagonal.

E.1. Sides slightly concave. Diam. 0.44-0.6 mm.

Aira caryophyllea L.
(Pl. 19.)

E.2. Sides plane. Diam. 0.37-0.47 mm.

Aira praecox L.
(Pls. 20a, b.)

C.2. Leaf more or less circular; 0.3-0.4 mm. Abaxial
epidermal cells arching; not cutinised; V.Bs.3.

very small.

Mibora minima Desv.
(Pl. 21)

B.2. Abaxial surface strongly cutinised; adaxial side
0-3-5 eostate.

F.1. Section roundish or oval; diam. 0.25-0.65 mm.;

keel not pronounced, usually well developed hypodermal
stereome ring.

G.1. One motor-cell group only - no ribs; 0.25-0.34 mm.

diam. Abaxial surface markedly papillose.

Agrostis setacea Curt.
(Pl. 22.)

G.2. At least two motor-cell groups.

H.1. Abaxial surface markedly papillose; section round.

Corynephorus canescens Beauv.
(Pl. 23.)

H.2. Abaxial surface not papillose; two motor-cell groups.

J.1. Section oval, keel generally recognisable. Hypodermal stereome ring discontinuous except in glaucous green forms.

Festuca ovina L. (Pl. 24.)

J.2. Section sub-terete, not keeled. Hypodermal stereome ring continuous.

Festuca capillata Lam.
(Pl. 25.)

F.2. Section angular; basal and greater portion of section wedge-shaped; upper tapering in opposite direction to the margins from penultimate or ultimate lateral bundles to form a low triangle.

K.1. Strong hypodermal stereome ring on abaxial side.

L.1. Ring continuous. Festuca juncifolia St. Am.
(Pl. 26.)

L.2. Ring discontinuous. Festuca oraria Dum. et Bab.
(Pl. 27.)

K.2. No hypodermal stereome ring, but definite bands at angles of abaxial surface.

M.1. Usually 3, occasionally 4 or 5 V.Bs.

Festuca heterophylla Lam.
(pls. 28a, b.)

M.2. 5-9 V.Bs.

Festuca rubra, sub-spp. et vars.
(Pls. 29a to g.)

A.2. Vascular bundles girdered at least below.

B.1. Leaves fleshy with two motor-cell rows; conduplicate; no ribs apart from mid-rib; adaxial surface papillose; 13-16 V.Bs. Glyceria maritima Wahl.
(Pl. 30.)

B.2. Leaves with at least 4 motor-cell rows.

C.1. Leaves coriaceous. Adaxial surface very strongly cutinised.

- D.1. Vascular bundles not exceeding 9. Ribs of not more than two orders.
- E.1. Leaf setaceous. Strong wedge-shaped girders below V.Bs., and connecting by a narrow hypodermal layer; almost twice as broad as V.Bs.; V.Bs. 5-7. Section roughly circular. Longest diam. 0.53-0.73 mm.
Definite keel. Nardus stricta L. (Pl. 31.)
- E.2. V.Bs. 7-9; leaf capillary, sub-terete to ovoid. Girders parallel-sided and not exceeding V.Bs. in width. Longest diam. 0.3-0.6 mm. No keel. Stipa pennata L. (Pl. 32.)
- D.2. Vascular bundles 15-25. Ribs of three orders. Strong hypodermal stereome on abaxial side.
- F.1. Leaf terete 1.5-1.7-(2.0) mm. Strong girders vertically and horizontally to V.Bs. Primary ribs narrow inwards. Leaf 440-800 u. thick. V.Bs. 15-25.
Ammophila arenaria Link. (Pls. 33a, b.)
A. baltica Link (Pls. 34a, b, c.)
- F.2. Leaf crescentic, sometimes completely convolute. Primary ribs broaden inwards. Strong vertical but never horizontal girders to V.Bs. Leaf thickness 320-400 u. V.Bs. 15-19. Agropyron junceum, Beauv. (Pl. 55.)
- C.2. Leaf not coreaceous, distinctly linear type, but infolded or enrolled; neither surface strongly cutinised. Leaf 100-120 u thick; upper surface with triangular or dome-shaped ribs representing three quarters of leaf thickness. Lower surface with triangular keel. V.Bs. 5-7-9. Cauline leaves expanded.
Agrostis canina L. (Pls. 35a, b.)

2. LEAVES LINEAR; WHEN CONVOLUTE OR CONDUPPLICATE, TEMPORARY NATURE APPARENT FROM DEFLATED CONDITION OF MOTOR-CELLS and the GENERAL APPEARANCE. LEAF EDGES NOT USUALLY APPROXIMATE in CONVOLUTE CONDITION.

A.1. Motor-cells flanking mid-rib not exceeding two in number; usually conspicuous.

B.1. One median motor-cell group only.

Dactylis glomerata L. (Pl. 36.)
Dactylis aschersoniana (Pl. 37.)

B.2. Two median motor-cell groups.

C.1. Large air chambers between consecutive bundles.

D.1. Ribs or ridges absent from both surfaces.

Glyceria aquatica Wahl.
(Pls. 38a, b.)

D.2. Lower surface at least prominently ridged.

E.1. Upper surface ribbed between the V.Bs; air chambers pentagonal.

Glyceria fluitans Br. (Pl. 39.)
air

E.2. Upper surface ribless; air chambers quadrangular.

Glyceria fluitans, var. plicata Fr.
(Pl. 40.)

C.2. No air chambers but sometimes irregular air spaces in mesophyll.

F.1. Bundles not girdered above or below.

G.1. Depth of keel much exceeding its width. Asperities

numerous especially on upper surface, opposite the V.Bs.
Poa trivialis, L. (Pls. 41a, b.)

G.2. Depth of keel not exceeding its width. Few asperities.

H.1. Lower surface ridged opposite principal bundles.

Poa nemoralis L. (Pl. 42.)

H.2. Lower surface not ridged opposite principal bundles.

Poa annua L. (Pl. 43.)

F.2. Bundles girdered at least below.

J.1. Lower epidermis bears a few long scattered hairs.

Leaf much constricted opposite the primary bundles.

Avena pubescens Huds. (Pl. 44.)

J.2. No long hairs on either epidermis.

- K.1. Girders below bundles strong; at least equalling the width of the primary V.Bs.
- L.1. Leaf less than 150 u thick; upper epidermis strongly cutinised. V.Bs. exceeding 30 in number. Leaf margins very acute. Irregular air spaces in mesophyll very conspicuous. Poa chaixii Vill. (Pl. 45.)
- L.2. Leaf not less than 150 u thick; upper epidermis cells arching and seldom cutinised. V.Bs. less than 30 in number. Leaf margins pointed but not very acute.
- M.1. Girders below primary V.Bs. parallel-sided and not exceeding the bundle in width. Upper epidermal cells largest mid-way between V.Bs. Poa compressa L. (Pl. 46.)
- M.2. Girders below V.Bs. broadly wedge-shaped and exceeding bundle in width. Upper epidermal cells more or less uniform in size. Poa pratensis L. (Pls. 47a, b.)
- K.2. Girders below bundles not equalling them in width. Leaves thick, usually more than 200 u.
- N.1. Leaves markedly constricted opposite the primary bundles. V.Bs. c.13. Poa alpina, var. acutifolia Dr. = P. stricta Syme. (Pl. 48.)
- N.2. Leaves not constricted opposite the primary bundles.
- O.1. Girders below larger bundles distinctly triangular. Stereome feebly developed at keel and margins. Leaf c.5.0 mm. wide. Keel low and triangular. Poa alpina, L. (Pl. 49.)
- O.2. Girders below bundles parallel-sided, rather narrow. Stereome strongly developed at keel and margins. Lower surface strongly cutinised.
- P.1. Keel distinctly rounded. Leaf c.300 u thick. Stereome exceptionally strong at keel and margins. V.Bs. 11-15-(17), round and very large. Avena pratensis L. (Pl. 50.)

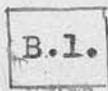
P.2. Keel triangular with rounded apex. Leaf c.200 u thick.

V.Bs. pear-shaped 16-25.

Sesleria coerulea Ard.
(Pl. 51.)



A.2. Motor-cells in all the furrows and exceeding two in number.



B.1. Ribs conspicuous, representing at least half the leaf thickness.

C.1. Large air chambers present beneath each furrow.

Upper surface markedly papillose (seen under high power). Ribs high, rectangular. Halophytes.

Spartina alterniflora Loiss.
Spartina Townsendii Groves.
Spartina stricta Roth.
(Pls. 52, 53, 54.)

C.2. Air chambers absent under the furrows.

D.1. Leaves glaucous, coriaceous. Ribs of three orders.

Both surfaces strongly cutinised. Majority of stomata on upper surface. Leaves usually enrolled or crescentic. Ps Halophytes.

E.1. Strong continuous hypodermal stereome ring below.

V.Bs. girdered. Adaxial surface covered with short hairs.

F.1. V.Bs. with horizontal as well as vertical girders.

Primary ribs broadest near apices. (These species may occasionally come in here.)

Ammophila arenaria Link (Pl. 33.)
Ammophila baltica Link (Pl. 34.)

F.2. V.Bs. with vertical girders only. Primary ribs

broadest at their bases. Agropyron junceum Beauv.
(Pl. 55.)

E.2. Girders distinct below; not connected by hypodermal stereome; asperities but not long hairs on adaxial surface.

G.1. Girders parallel sided. Leaf margins not attenuated

Occasional asperities on ribs. Leaf 265-309 u thick.
Agropyron pungens R. & S.
(Pl. 56.)

- G.2. Girders distinctly wedge-shaped below; characteristically 'T' formed above. Leaf margins attenuated. Abundant asperities on ribs. Leaf 440-550 u thick.
Elymus arenarius L (Pl. 57.)
- D.2. Leaves not coriaceous.
- H.1. Vascular bundles with stereome bands above and below but none girdered.
- J.1. Ribs triangular, very conspicuous, the primary representing at least three fourths of the total leaf thickness.
- K.1. Each rib containing more than one V.B.; 7-9 costate. Both surfaces strongly cutinised. Stereome bands very strong above and below bundles; smaller bands below, opposite the furrows. No ridges on lower side opposite the V.Bs. and the furrows.
Deschampsia caespitosa Beauv.
(Pl. 58.)
- K.2. Each rib containing only one V.B. Lower surface may be cutinised. Stereome bands comparatively weak. Small ridges on lower surface opposite the V.Bs. and the furrows.
- L.1. Ridges on lower surface opposite the V.Bs. and the furrows pronounced - each ridge with a large rounded cell or cells at its apex. Epidermal cells inflated, especially the upper. Lower epidermis not cutinised. Stomata about equal on both surfaces.
Alopecurus geniculatus L.
(Pls. 59a, b.)
- L.2. Ridges on lower surface opposite the V.Bs. and the furrows not pronounced - the ridges do not have large round apical cell cap. Epidermal cells uniform, not inflated. Lower usually cutinised. Stomata principally on upper surface. Alopecurus alpinus Sm.
(Pls. 60a, b.)
- J.2. Ribs representing not more than two thirds of the leaf thickness at most.
- M.1./

- M.1. Ribs mixed, of three orders (i.e. having different shapes). Primary ribs rectangular - very prominent. Hypodermal stereome cap to each rib. Strong bands below, opposite the V.Bs. and the furrows.
Koeleria spp. (Pl. 61.)
- M.2. Ribs not mixed. Primary ribs never rectangular.
- N.1. Upper surface distinctly hairy. Stereome poorly developed. Festuca bromoides L. = Vulpia bromoides Gray (Pl. 62.)
Festuca myuros L. = Vulpia myuros Gray (Pls. 63a, b.)
- N.2. Upper surface without hairs.
- O.1. Chlorophyll tissue in rings or partial rings around the V.Bs. Festuca rigida, Kunth. (Pl. 64.)
- O.2. Chlorophyll tissue normal in type.
- P.1. Lower surface with distinct protrusions opposite the V.Bs. Lower epidermal cells small, slightly arching and feebly cutinised. Alopecurus myosuroides Huds. (Pl. 65.)
- P.2. Lower surface without protrusions opposite the V.Bs. The lower epidermal cells palisade-like, large and strongly cutinised.
- Q.1. All the ribs triangular (pointed).
Lolium temulentum L. (pl. 66.)
Lolium remotum Schrank (Pl. 67.)
- Q.2. Majority of ribs rounded.
- R.1. Leaf margins obtuse (usually rounded) with strong crescentic stereome cap. Ultimate furrows on each side poorly developed, or frequently missing so that there appear to be two V.Bs. in marginal lobe. Ribs do not exceed half the leaf thickness. Stereome bands not exceeding V.Bs. in width.
Cynosurus cristatus L. (Pl. 68.)

R.2./

R.2. Leaf margins acute to sub-acute, not rounded.

Stereome poorly developed at margins in isodiametric bands. Ultimate furrows on each side well developed and only one V.B. in marginal lobe. Ribs exceed half the leaf thickness.

S.1. Leaf halves usually revolute. Ribs dome shaped, regular in shape; sides steeply sloping. Stereome bands at rib summits wider than V.Bs. and crescentic. Mid-rib not flat and containing only one V.B. Transfusion tissue present above primary V.Bs.

Lolium perenne L. (Pl.69.)

S.2. Leaf halves usually involute. Ribs irregular in shape, and more pointed; sides less steeply sloping. Stereome bands at rib summits tending to be isodiametric. Mid-rib sometimes flat above and containing three V.Bs. Transfusion tissue conspicuous above primary V.Bs.

Lolium multiflorum Lam.
(Pl. 70.)

H.2. Some of the V.Bs. at least having stereome girders.

A.1. Mid-rib bundle only, girdered below. Upper surface with low triangular or somewhat rounded ribs of uniform size. Lower surface with shallow triangular keel and conspicuous ridges opposite the V.Bs.

Bundles (10-17). (This species occasionally comes here.)
Alopecurus myosuroides Huds.

A.2. More than mid-rib bundle girdered.

B.1. Lower surface definitely ribbed (more than prominences) with numerous asperities from the rib summits.

Apera spica-venti Beauv. (Pl.71.)

B.2. Lower surface sometimes with protrusions opposite the V.Bs. but never ribs.

C.1. Leaf upper and lower surface bearing hairs.

D.1. Prominent rounded keel. Ribs on upper surface

rounded. Secondary V.Bs. not girdered. Leaf margins thick, obtuse and with crescentic stereome cap.

Large spherical cells in lower epidermis abut from opposite furrows and the tertiary V.Bs. Mesophyll cells normal.

Trisetum flavescens Beauv.
(Pl. 72.)

D.2. Wedge-shaped keel. Ribs on upper surface broad, squarish or broadly rounded, very variable in height. Secondary V.Bs. girdered. Leaf margins thin and with feeble stereome development. No large cells in lower epidermis opposite furrows and V.Bs. Mesophyll cells with characteristic infolded walls.

Arrhenatherum elatius M. & K.
(Pl. 73.)

C.2. Leaf upper and lower surface without hairs.

E.1. Lower surface with definite protrusions from opposite the V.Bs.

F.1. Ribs broad, flat topped and rounded. Primary and secondary bundles girdered. Never stereome bands on lower side opposite the furrows. Margins acute.

Mid-rib with primary and two subsidiary bundles.

175-220-(290) u thick. Motor-cells 45-50 u deep.

Alopecurus pratensis L.
(Pls. 74a, b.)

F.2. Ribs round and triangular. Only primary bundles girdered. Stereome bands on lower side opposite the furrows. Margins usually sub-acute.

G.1. Ribs rounded, with steeply sloping sides, at least two-thirds of the leaf thickness.

H.1. Ribs representing three fourths of leaf thickness. Commonly 11 or 13 V.Bs. Asperities on upper surface only. Keel evident. Blade 100-120 u thick. The expanded non-setaceous leaves of A. canina come here.

Agrostis canina L. (Pl. 75.)

H.2. Ribs not representing more than two thirds of leaf thickness. 13-19 V.Bs. Asperities on both surfaces. Keel inconspicuous or obsolete. Blade 110-160 u thick.

Agrostis tenuis Sibth. (Pl. 76.)

G.2. Ribs rounded or both rounded and triangular, sides less steeply sloping; ribs equalling about half the leaf thickness.

J.1. Ribs very gently sloping. In each marginal lobe only one bundle. Occasionally small hypodermal stereome bands opposite the furrows on lower surface. Mid-rib very occasionally contains three V.Bs.

Leaf 100-162 μ thick. V.Bs. 13-27.
Agrostis stolonifera L.
(Pl. 77.)

J.2. Ribs more steeply sloping. In each marginal lobe frequently two V.Bs. Small hypodermal stereome bands opposite the furrows on lower side. Mid-rib frequently contains three V.Bs. Leaf 191-221 μ thick.

V.Bs. (17)-25-35. Agrostis nigra With.
(Pl. 78.)

E.2. Lower surface having no protrusions opposite the V.Bs.

K.1. Keel very conspicuous, broad and rounded; two to three times exceeding thickness of primary side ribs. Primary side ribs, (variable in height) very broad and flattened. Mid-rib contains 3-5 V.Bs. Leaf tapers markedly from mid-rib to acute margins.

Festuca gigantea Vill. (Pl. 79.)

K.2. Keel not twice the thickness of the primary side ribs.

L.1. Upper and lower epidermal cells arching, less than 220 μ thick; one or two round cells much larger than the rest opposite the furrows. Green sphaerocrystals of phlein commonly present in mesophyll.

M.1. Lower surface outward curving opposite the furrows in many specimens, giving it a sinuous outline. Mid-rib bundle girdered above and below. Girder below protruding beyond the epidermis in semi-circular

- form; sometimes wedge-shaped. Leaf margins sub-acute to acute. Primary V.Bs. equal to about half of the leaf thickness. Phleum pratense L. (Pls. 80a, b.)
- M.2. Lower surface less sinuous. Mid-rib bundle girdered below only, the stereome not protruding beyond the epidermis. Primary V.Bs. equal one third to one quarter of the leaf thickness. Leaf margins obtuse. Phleum arenarium L (Pl. 81.)
- L.2. Lower epidermal cells cutinised, not arching. Leaf more than 220 u thick. No unusually large cells on lower surface opposite furrows. Phlein crystals never present.
- N.1. Lower surface very strongly cutinised. Motor-cells very conspicuous. Bundles of first and second order girdered.
- O.1. Leaf 300-500 u thick. Motor-cells 70-120 u deep. Keel more pronounced. Subsidiary V.Bs. of mid-rib, when present, have transfusion tissue above. Festuca arundinacea Schreb. (Pl. 82.)
- O.2. Leaf 220-265 u thick. Motor cells 50-60 u deep. Keel less pronounced. Subsidiary V.Bs. of mid-rib, when present, without transfusion tissue or with feeble development. Festuca pratensis Huds. (Pl. 83.)
- N.2. Lower surface not very strongly cutinised. Motor-cells less conspicuous. Bundles of first order occasionally girdered, but not those of second order. (This species infrequently comes here). Lolium multiflorum Lam. (Pl. 84.)

B.2. Ribs absent or inconspicuous; never equalling half the leaf thickness.

A.1. Chlorophyll in definite rings around the V.Bs.

B.1./

- B.1. Upper surface ribless. Keel triangular, very pronounced. Mid-rib contains several V.Bs. which follow the abaxial contour. Mid-rib mainly composed of clear-celled tissue. Bundles numerous 60-110. Motor-cells in broad bands markedly defined from the epidermal cells.
- C.1. Upper surface without ribs or prominences. Keel broader than deep. Epidermal cells - the upper and lower together - not representing one half of the entire leaf thickness. Leaf about 130 μ thick.
Setaria viridis Beauv.
(Pl. 85.)
- C.2. Upper surface not ribbed but having prominences opposite many of the V.Bs. Keel about as deep as wide. Epidermal cells unusually large on both sides - the upper and lower together representing two-thirds of the entire leaf thickness. Leaf 150-180 μ thick.
Setaria glauca Beauv.
(Pl. 86.)
- B.2. Upper surface bearing slightly elevated ribs. Motor-cell groups narrow but very deeply seated. Keel not well defined. Mid-rib contains one V.B. only. Leaf about 120 μ thick. Cynodon dactylon,
Pers. (Pl. 87.)
- A.2. Chlorophyll not in definite rings around the V.Bs.
- D.1. Keel obsolete or inconspicuous.
- E.1. Vascular bundles very numerous, usually 50-100. Ribs on upper surface practically obsolete. Motor-cells deeply seated, reaching half way through leaf (the lateral cells of the group seated on shoulder of large median pear-shaped cell). Both surfaces papillose.
Arundo phragmites L.
(Pl. 88.)
- E.2. Vascular bundles less than 50. Ribs on upper surface low but definite. Motor-cell groups composed of cells lying laterally to each other and not reaching half way through leaf. Neither surface papillose.

- F.1. Hairs on both surfaces.
- G.1. Keel obsolete. Ribs low and undulating, tending to be flattened. Lower surface plane and cutinised. Hairs short and sharp. Leaf narrow, 1-3 mm. wide; one V.B. to mid-rib. Hordeum nodosum L. (Pl. 89.)
- G.2. Keel very shallow and inconspicuous. Ribs low and rounded. Under surface distinctly undulating, the cells somewhat arching. Hairs long. Leaf 7-8 mm. wide. Generally three V.Bs. to mid-rib. Holcus mollis L. (Pl.90.)
- F.2. No hairs on either surface. Phlein crystals present as green sphaeroids in mesophyll.
- H.1. Girders to primary V.Bs. very strong, exceeding V.Bs. in width, distinctly widening towards both surfaces. Ribs very low. Leaf 132-150 u thick. V.Bs. 19-29. Phleum phleoides Simonk. (Pl. 91.)
- H.2. Girders to primary V.Bs. rather narrow, not exceeding V.Bs. in width, not widening towards both surfaces. Ribs well developed. Leaf 165-220 u thick. V.Bs. c.13. Phleum alpinum L. (Pls.92a,b.)
- D.2. Keel always apparent, sometimes very pronounced.
- J.1. Keel very strongly developed; leaf thickness here at least twice exceeding that at primary side-ribs.
- K.1. Mid-rib containing two bundles in same vertical plane. Horizontal diameter of V.Bs. greater than vertical. Mid-rib largely composed of clear celled tissue devoid of chlorophyll. Leerzia oryzoides Sw. (Pl. 93.)
- K.2. Mid-rib not containing two bundles in the same vertical plane. Vertical diameter of V.Bs., greater than horizontal. Only a few clear cells in mid-rib.
- L.1. Leaf conspicuously hairy; leaf 175-220 u thick.

M.1. Hairs long, some of which exceed in length the leaf thickness by three or four times, and very numerous on both surfaces. Motor-cell groups shallow and wide. Smaller bundles diminutive. Not all the primary bundles girdered. Stomata about equal on both surfaces. Mesophyll cells normal. Lagurus ovatus L
(Pl. 94.)

M.2. Hairs short and sharp, about equalling in length the leaf thickness, not so abundant. Motor-cell groups rather deep and narrow. All the primary and secondary bundles girdered. Stomata mainly on upper surface. Mesophyll cells with infolded walls.
Arrhenatherum elatius M. & K.

L.2. Leaf not conspicuously hairy.

N.1. Motor-cells shallow, several times broader than deep. Leaves thin.

O.1. Lower surface ribbed opposite the V.Bs. Leaf thickness 58-88 u. Keel narrow, triangular, with rounded base. Occasional long hairs opposite the bundles on upper surface. V.Bs. 15-19.
Melica uniflora Retz.
(Pl. 95.)

O.2. Lower surface not ribbed opposite the V.Bs.

P.1. Keel triangular, very acute. V.Bs. less than 20 in number. Stereome very feebly developed. Small isodiametric band at base of keel stereome absent at margins.
Cynosurus echinatus L.
(Pl. 96.)

P.2. Keel usually wedge-shaped with truncate base; when not truncate, base is rounded, not acute. V.Bs. exceeding 20 in number. Stereome rather strongly developed. Primary and secondary V.Bs. girdered; strong, flat band (or girder to V.B.) at base of keel.

- Q.1. Lamina perceptibly tapering towards the margins; latter acute. Leaf 90-120-(150) u thick; 450-550 u at keel. Three or more V.Bs. in mid-rib.
Milium effusum L. (Pl. 97.)
- Q.2. Lamina of more or less uniform thickness throughout (apart from mid-rib); margin obtuse, frequently truncate. Leaf 60-100 u thick at primary side-ribs; not exceeding 300 u at keel. Only one V.B. in mid-rib.
Brachypodium sylvaticum R. & S. (Pl. 98.)
- N.2. Motor-cells rather deeply seated, their width not more than 2-3 times exceeding their depth.
- R.1. Epidermal cells very strongly cutinised on both surfaces. Girders to practically all the V.Bs. very strongly developed. Girders to primary side-ribs considerably broader on adaxial side. Lower girders to mid-rib bundles protrude beyond the epidermis. Motor-cells deeply seated, in narrow groups, tending to project above the epidermis in deflated condition.
Calamagrostis epigeios Roth (Pl. 99.)
- R.2. Epidermal cells not markedly cutinised on either side.
- S.1. Keel very large - two and a half to three times exceeding thickness of primary side ribs. V.Bs. strongly girdered.
- T.1. Keel definitely rounded. Upper surface with low, broad, rounded ribs. Leaf tapers to a very acute margin. Girder to primary mid-rib bundle about equal in width to bundle. Mesophyll cells normal. Very short hairs on upper surface. Festuca gigantea Vill.
= Bromus giganteus L.
- T.2. Keel definitely wedge-shaped; upper surface with low, flat or practically obsolete ribs. Leaf thickness more or less uniform throughout; margins sub-acute. Girder to primary mid-rib bundle twice

as broad as the bundle. Girders to primary V.Bs. in side-ribs narrow towards lower epidermis.

Mesophyll cells with infolded walls. A few long hairs on both surfaces. Bromus ramosus Huds.
(Pls. 100a, b.)

S.2. Keel not more than twice exceeding primary side ribs in depth.

U.1. Keel triangular, with rounded base. Leaf 150-190 μ thick. Lower epidermis frequently protruding opposite furrows, giving sinuous outline; (the protrusion generally capped by a very large cell) V.Bs. 15-21. One bundle in mid-rib. Stomata on both surfaces. Mesophyll cells normal. Occasional hairs on both surfaces. Anthoxanthum odoratum L.
(Fig. 101.)

U.2. Keel broadly wedge-shaped. Leaf about 220 μ thick. V.Bs. 25-30. Usually three V.Bs. in mid-rib. Stomata principally on upper surface. Mesophyll cells with infolded walls. Occasional hairs on both surfaces. Arrhenatherum elatius M. & K.
(Pl. 102.)

J.2. Keel not very strongly developed: thickness here not twice exceeding that at primary side ribs.

A.1. Motor-cells flanking the mid-rib on each side two or three times exceeding size of neighbouring motor-cell group. Motor-cells markedly decreasing in size towards margins. Leaf margins obtuse; blade 160-220 μ thick; flat rounded keel. Mid-rib low and rounded, in central depression; otherwise upper surface with ribs obsolete or almost obsolete. Lower surface strongly cutinised; V.Bs. 13-19; practically all bundles girdered; girders very strong. Sieglingia decumbens Bernh.
(Pl. 103.)

A.2. Motor-cell groups flanking mid-rib not conspicuously larger than neighbouring motor-cell groups.

B.1. Stereome girders to primary side-rib bundles much exceeding width of bundles.

C.1. Practically all the bundles girdered. Blade not usually exceeding 220 μ thick. V.Bs. usually more than 20.

D.1. Keel rounded, wide and seldom conspicuous. Blade 100-150 μ thick. Primary ribs do not much exceed secondary ribs. V.Bs. (20)-30-37, very fibrous. Girders to primary side-rib bundles broadest on adaxial side. Girder to principal mid-rib bundle much exceeding width of bundle at lower extremity.

Molinia coerulea Moench.

(Pl. 104.)

D.2. Keel broadly triangular; blade 150-220 μ thick; usually 4-6 semi-lunar lateral ribs of first order on upper surface, much more conspicuous than secondary ribs. V.Bs. 25-36. Mid-rib frequently contains in addition to principal bundle 2 or 4 subsidiary bundles - the girders to these V.Bs. abutting on lower surface beyond epidermis. Girders to primary side-rib bundles parallel-sided. Girder to principal mid-rib bundle not usually exceeding width of bundle.

C. *canescens* has a somewhat similar appearance.

Calamagrostis epigeios Roth.

(Pl. 105.)

C.2. Only primary and secondary V.Bs. girdered. About half the bundles not girdered. Blade 235-300 μ thick. V.Bs. not exceeding 20. Upper surface with low but definite square ribs. Girders to V.Bs. in primary side-ribs very strong; they broaden slightly towards both surfaces. Girders to penultimate primary bundles in each leaf half broader than those of other laterals.

Bromus erectus Huds.

(Pls. 107a, b.)

B.2. Stereome girders to primary side-rib bundles not exceeding width of bundles.

E.1. Leaf bearing long hairs.

F.1. Numerous hairs even in thin sections (10 u thick) not exceeding 200 u thick. Keel wedge-shaped.

G.1. Keel wedge-shaped with rounded base. Upper surface with low, wide, rounded ribs of three orders. Mid-rib contains solitary bundle. Mesophyll cells with characteristic infolded walls. Motor-cells inconspicuous. Long hairs abundant on both sides.

Bromus sterilis L.
(Pl. 108.)

G.2. Keel wedge-shaped and not rounded. Upper surface with rather narrower higher ribs - the primary ribs tending to be squarish. Mid-rib contains three V.Bs. Motor-cells conspicuous. Asperities and long hairs on both sides. Transfusion tissue well developed over mid-rib bundle and to a lesser extent over the subsidiary bundles of mid-rib.

Holcus lanatus L.
(Pl. 109.)

F.2. Occasional hairs only, in thin sections (10 u thick).

H.1. Lower surface strongly cutinised. Keel rounded; wide but not deep. Motor-cells very prominent.

Practically all the V.Bs. girdered. Leaf margins acute. Leaf 150-180 u thick.

Hierochloe odorata Wahl.
(Pl. 110.)

H.2. Lower surface feebly cutinised.

J.1. Motor-cells inconspicuous. Only one V.B. in mid-rib. Bundles not exceeding 15 in number. Only the primary V.Bs. girdered. Leaf 176-190 u thick.

No asperities. Bromus hordeaceus L.
(Pl. 111.)

- J.2. Motor-cells well defined. Usually two subsidiary V.Bs. in mid-rib in addition to principal bundle. Bundles exceed 15 in number. Asperities present.
- K.1. Ridges on lower surface opposite V.Bs. All the V.Bs. have at least stereome bands; (some of the tertiaries may be girdered). Ribs on upper surface always low; leaf 4-8 mm. wide.
- L.1. Leaf 130-190 μ thick. Ridges on lower surface less marked. Ribs on upper surface higher. Motor-cell groups narrower, deeper and conspicuous. Stereome less abundant. Lower epidermal cells cutinised. A few asperities on the ribs.
Agropyron repens Beauv.
(Pl. 112.)
- L.2. Leaf 102-132 μ thick. Ridges on lower surface more marked. Ribs lower and motor-cell groups wider, shallower and less conspicuous. Stereome more abundant and stronger. Lower epidermal cells arching and feebly cutinised. Hooked asperities prominent on lower surface.
Agropyron caninum Beauv.
(Pl. 113.)
- K.2. No ridges on lower surface opposite the V.Bs. Some of the tertiary bundles have not even stereome bands associated with them. Tertiaries never girdered. Ribs on upper surface sometimes fairly prominent; V.Bs. 16-23. Leaf 120-150 μ thick and 3-5 mm. wide.
Hordeum murinum L. (Pl. 114.)
- E.2. Leaf bearing asperities but not long hairs.
- M.1. Stereome of mid-rib bundle definitely projecting beyond the lower epidermis. Green sphaerocrystals of phlein present in mesophyll. Lower surface outwards curving opposite the furrows, giving a sinuous outline. Large cell or cells on lower epidermis opposite the motor-cells. Phleum pratense L.
(Pl. 115.)

- M.2. Stereome of mid-rib bundle not projecting beyond the lower epidermis. Phlein crystals never present. Lower epidermal outline never so conspicuously sinuous.
- N.1. Asperities abundant on upper surface. Leaf thin, about 130 u thick. All the bundles girdered, the latter being wider on adaxial side than on abaxial in the side rib bundles. Lower epidermal cells strongly cutinised. Stomata on upper surface only. Motor-cell groups rather wide. V.Bs. 13-20.
Melica nutans L. (Pl.116.)
- N.2. Asperities not abundant on upper surface. Leaf 130-250 u thick. Side rib bundle girders not wider on adaxial side than on abaxial. All V.Bs. not girdered. Stomata on both surfaces. Motor-cell groups narrower and deeply seated.
- O.1. Upper surface with fairly prominent ribs; primary ribs squarish. Lower surface not ribbed opposite the bundles but on the contrary rather depressed. Leaf 3 mm. wide and 130-150 u thick. V.Bs. c.15 in number.
Briza media L. (Pl. 117.)
- O.2. Ribs obsolete or low and rounded. Lower surface with ridges opposite the V.Bs.
- P.1. Upper surface with low undulating ribs. Short asperities on both surfaces. V.Bs. c.15 in number - mainly of third order. Stereome scanty. Stomatal air-spaces very conspicuous. Stomata unusually large and abundant. Cells of lower epidermis large, irregular, but the cells opposite the furrows not unusually large. Margins sub-acute. Avena fatua L.
(Pl. 118.)
- P.2. Upper surface with almost obsolete ribs. A few asperities on lower surface and at margins. V.Bs. (25)-40-52 in number. Stereome abundant. Frequently two or four subsidiary bundles in mid-rib, in addition to principal bundle. Cells of lower epidermis small but three or four opposite the motor-cells considerably larger than the rest. Margins acute.
Phalaris arundinacea L. (pl.119.)

SECTION IV.

DISCUSSION.

We have seen that grasses such as Ammophila arenaria, Elymus arenarius, Agropyron junceum and Festuca juncifolia are markedly xerophytic, and that the 'adaptive' responses are very similar in each case. In all four, the lower epidermis is markedly cutinised, the upper surface strongly ribbed and bearing hairs, and the stereome well developed on the adaxial side.

The moor grasses, Nardus stricta, Molinia coerulea, Festuca ovina and Sieglingia decumbens are also xerophytic. Festuca ovina and Nardus stricta have evolved on similar lines - constant enrolment giving a more or less circular outline to the leaf. The abaxial surface is strongly cutinised in both cases, and stereome is distributed on the columnar principle. Molinia and Sieglingia are linear but have the lower epidermis very strongly cutinised and have motor-cell arrangement to permit of enrolment when required. The aquatics, Glyceria aquatica, G. fluitans et vars. and Catabrosa aquatica have feeble stereome development and large air chambers. The wood species, Poa nemoralis, Brachypodium sylvaticum, Melica uniflora, and M. nutans have extremely thin, broad, expanded leaves, little cuticular development and stomata on both sides. This form of leaf affords an expansive area of chlorophyll tissue which is required by the curtailment of light. Water supplies are seldom deficient and transpiration not high under the shade of the trees. They do not require therefore, to adopt any special devices for transpiration control.

The xerophytes of sand-dune and moor, the aquatics and moor grasses, ^{each} afford excellent examples of parallel development/

development, in leaf structure. These facts are in keeping with the general principle well recognised by ecologists that plants occupying the same habitat tend to be alike, at least to some extent, in their growth forms.

The other groups of grasses live under less exacting conditions, and special development in any special direction is not so necessary.

In the genus Poa, of which there are eleven British species, and of which there are representatives in all the chief habitats, we find a great similarity of leaf structure. The leaves of Poa alpina and P. chaixii are larger than the others but their generic position is evident in cross sections.

Spartina spp., Holcus spp. and Agrostis spp. also exhibit congeneric similarity, with the exception of A. setacea in the genus Agrostis. In Phleum spp., we have representatives of meadow habitat, in P. pratense, alpine, in P. alpinum and halophyte, in P. arenarium. This is surprising at first sight but can be explained to some extent. P. alpinum grows in wet situations in sheltered corries, so that moisture is probably not a problem except when the ground is frozen. P. arenarium is an annual and they, as a rule, do not exhibit marked xerophytic development. The leaves have, however, a wax covering, a device which is quite effective in a species which requires a very short vegetative period.

In connexion with this investigation a collection of growing grasses has been made on a loam soil. The species grown include halophytes, aquatics and wood grasses. Sections of the leaves of most of these species have been made, and it is surprising to find no evidence of alteration in anatomical detail in grasses such as Ammophila arenaria (Pl. 33a), A. baltica (Pl. 34c), Corynephorus canescens, Glyceria aquatica, G. Borreri, Sesleria coerulea etc. The specimens were in most cases more luxuriant than those growing in their native habitats/

habitats, and in some cases the number of vascular bundles was greater. No difference in cutinisation or hairiness could be detected. In this connexion it is interesting to note the experience of Clements, that "Gardens of the usual mesophytic type have proved more or less neutral in effect with respect to changes of form, and consequently to afford slight or misleading evidence as to fixity."

Arrangement of Tribes and Genera in the Gramineae
(after Bews)

1. Subfamily: Pooideae.
2. Subfamily: Panicoideae.

subfamily Pooideae.

Tribes. -

1. Bambuseae.
2. Phareae.
3. Festuceae.

Arundo.
Phragmites.
Bromus.
Triodia (Sieglingia).
Glyceria.
Puccinellia.
Sclerochloa.
Poa.
Brachypodium.
Catapodium.
Vulpia.

Festuca.
Cynosurus.
Brisa.
Dactylis.
Desmazeria.
Sesleria.
Melica.
Triodia.
Molinea.
Koeleria.
Catabrosa.

4. Aveneae.

Anthoxanthum.
Arrhenatherum.
Koeleria.
Avena.
Avenastrum.
Deschampsia.

Corynephorus.
Trisetum.
Holcus.
Airopsis.
Aira.

5. Chlorideae.

Spartina.
Cynodon.

6./

6. Hordeae.

Hordeum.	Triticum.
Elymus.	Secale.
Nardus.	Lolium.
Agropyron.	Lepturus.

7. Agrostideae.

Polypogon.	Agrostis.
Lagurus.	Mibora.
Gastridium.	Alopecurus.
Apera.	Phleum.
Calamagrostis.	Milium.
Ammophila.	Stipa.

8. Zoysieae.

Tragus.

9. Phalarideae.

Hierochloa.
Anthoxanthum.
Phalaris.

10. Arundinelleae.

11. Oryzeae.

Leersia.

Subfamily Panicoideae.

Tribes.

12. Melinideae.

13. Paniceae.

Digitaria.	Echinochloa.
Panicum.	Setaria.

14. Andropogonae.

15. Maydeae.

Reference to the arrangement of tribes and genera in the Gramineae shows that the xerophytic adaptation is not the attribute of any one tribe. In the Festuceae, which is the lowest in the evolutionary series as represented in Britain (Pl. 121), we have Sesleria coerulea, Sieglingia decumbens and Molinea coerulea; in Aveneae, Deschampsia caespitosa, Deschampsia flexuosa and Corynephorus canescens; in Hordeae, a relatively advanced group, Elymus arenarius, Nardus stricta, Agropyron junceum; A. pungens; in Agrostideae, Ammophila arenaria.

The/

The anatomical evidence is in accord with the phylogenetic relationships based on floristic and morphological characters as far as the xerophytic species are concerned. Ammophila which has markedly xerophytic leaves belongs to Agrostideae - an advanced tribe, while Elymus, Nardus, A. junceum and A. pungens, belong to the Hordeae, a relatively advanced tribe. The aquatics, Glyceria fluitans, G. aquatica and Catabrosa aquatica belong to the primitive tribe Festuceae. It must be noted, however, that the leaves of Festuca ovina and F. capillata belonging to this tribe, are well adapted to a xerophytic existence.

Lastly, it must be added, that the anatomical differentiation of the leaves of grasses follows in a remarkable manner the systematic arrangement based upon floristic characters.

CONCLUSIONS.

(1) Cross sections of the leaves present a valuable means of identification of grasses in non-flowering condition in most cases. Even, when inflorescence is present, this method will prove of material assistance in making a determination. There is sometimes considerable differences anatomically, between culm and basal leaves. It is important, therefore, that basal leaves only be utilised for purposes of diagnosis.

(2) The anatomical structure does not appear to undergo change with alteration of habitat, though the leaves themselves may be smaller or larger according to the suitability of the habitat, and leaves which are as a rule permanently enrolled exhibit a tendency to remain partly expanded.

(3)/

(3) It is suggested, contrary to what is generally believed, that the true function of the motor-cells in grasses is that of creating 'accommodation gaps' to permit of enrolment. The actual mechanism which brings about the movement is differential turgor on the adaxial and abaxial sides. The lower surface is usually strongly cutinised. in enrolling types, and the stomata are principally situated on the upper surface. The upper mesophyll cells lose moisture more rapidly therefore, and cause the upper surface to shrink. The motor-cells lose their water content to the mesophyll cells and by providing longitudinal lines of weakness facilitate enrolment.

In conclusion, grateful acknowledgement is made to the Carnegie Trustees for the travelling grants which have made this investigation possible.

A P P E N D I X.

TECHNIQUE.

Killing and Fixing. For the most part, specimens were collected during somewhat prolonged absence from the laboratory. Form-acetic-alcohol (5 ccs: 5 ccs: 90 ccs. of 5% Ethyl Alcohol) - a combined mordant and fixative - in which the materials may be left for several months if required, was found satisfactory. This combination has long given satisfaction where the materials are required for microtoming. It does produce a certain amount of brittleness, however, as is noticeable in hand sectioning. It may be that a new mixture containing n-butyl alcohol would give the desired toughness without any of the brittleness. In practice, however, the specimens were removed on returning to the laboratory, to a mixture of equal parts glycerine and 50% ethyl alcohol, and thus stored until required. This, it was found, prevented any tendency to harden, and the specimens were in excellent condition when required for embedding.

Washing. At this stage it may be said that the specimens were carried singly through all subsequent stages, including wax in hollow tubes - two inches in length and one inch in diameter, with a silk gauze cap at one end. After removal from the glycerine-alcohol mixture, each half inch segment of leaf was rinsed in 25% ethyl alcohol. Thereafter they were placed in the tubes, each of which bore a serial number inscribed by means of a diamond pencil. The tubes were stoppered with a slightly perforated cork and placed in a rotary photographic print washer, which latter was connected to a high pressure water tap. The specimens were allowed to wash over night. The corks were finally removed and the water allowed/

allowed to drain from the tubes.

The n-butyl alcohol was utilised in an ascending and well graduated series of ten different concentrations. Each strength was kept in a large ground glass covered petri dish (6 ins. diam x 3 ins. high). Each dish accommodated fifteen tubes, but as two parallel sets were employed it was possible to pass thirty specimens through at a time. The specimens were left for approximately one hour in each of the following stages:

STAGE.	1	2	3	4	5	6	7	8	9	10	11
PERCENTAGE OF SOLUTION.	5	10	20	30	50	70	85	95	95	100	100
WATER.	95	90	80	70	50	30	15	5	0	0	0
ETHYL ALCOHOL.	5	10	20	30	40	50	50	40	25	0	0
N-BUTYL ALCOHOL.	0	0	0	0	10	20	35	55	75	100	100.

It was found that the addition of a little safranin powder to the last stage was of great assistance in finding the smaller setaceous leaves later in the wax. The specimens were removed from the pure n-butyl alcohol to the preliminary wax stage which consisted of equal parts n-butyl alcohol and wax with melting point 115° F. They were then incubated for two days at the very lowest temperature at which the wax remained in the melted condition. Thereafter, the tubes were placed in wax of melting point 125° F. for one hour. They were then placed for twenty minutes in 135° - 140° F. wax, in which they were finally embedded. The wax blocks were cooled as rapidly as possible first by blowing upon them and then by immersion in water. They were stored in water until required. No difficulty was experienced in obtaining sections 10 u in thickness - at which setting most of the cutting has been/

been done. In the case of grass leaves, anyone experienced in the use of a bench microtome will secure with it as good, if not better sections than with any of the more expensive types. The shape of the grass leaf presents specific problems to the microtome. For example, it is not always possible to embed these rather extensive objects without the inclusion of a few air bubbles. Even the tiniest bubble will cause difficulties. They can be eradicated, however, by the use of a hot needle and a lens. It is of value to study the anatomy of the leaf in the first section cut in order to determine whether the leaf will respond best to the knife, if placed with adaxial or abaxial side towards it.

The further operations were those in common use. Preparations were stained in safrannin and counterstained with anilin blue for a time. The latter however even if sparingly used tended to obliterate the mesophyll of many species, by reason of the avidity of chlorophyll for the stain. Moreover, anilin blue has a tendency to stain the fixative, viz. egg albumen. Bismark brown has none of these defects and combines very successfully with safrannin for photographic purposes. Throughout this investigation, terpeneol, which successfully follows even 80% alcohol, has been used as a clearing agent. Its use saves a considerable amount of time and has exhibited no tendency to cause fading in the preparations.

The sections have all been recorded by photography. It might be held that drawing, affording the opportunity of presenting a composite record of the cross section, would be preferable. Variability in most grass leaves, if attention is confined to the basal ones, is not great, not more than can be adequately described in the accompanying legends. Photography affords an accuracy of delineation and a relative thickness of cell walls which cannot be achieved by the artist. In addition, the reproduction of chlorophyll in the photomicrographs

is of considerable diagnostic value.

Phleum spp.

Gregor has pointed out that there are two distinct forms of Phleum pratense L., one with diploid chromosome number = (14), associated with drier situations, and the other hexaploid (2 n = 42), associated with moist situations. He finds in the case of Phleum alpinum, that Scottish plants are tetraploid (2 n = 28). Plants of continental origin are diploid with 14 chromosomes. Gregor and Sansome, in the light of hybridization experiments carried out by them, suggest that the hexaploid form of Phleum pratense may have originated through natural hybridization of P. pratense (2 n = 14) and P. alpinum (2 n = 28). In this connection it is interesting to note that the leaves of the hexaploid P. pratense are thicker than in the diploid form and in this respect approximate more nearly to those of P. alpinum. Moreover, the lower girder to the mid-rib bundle is wedge-shaped as in P. alpinum, not rounded as in diploid P. pratense. Other characters, however, are similar to those of diploid P. pratense.

Turesson considers that P. pratense and P. alpinum constitute a natural group, a 'coenospecies' comprising several groups of lesser magnitude, 'ecospecies', and that these latter contain still smaller units of ecological significance - 'ecotypes'. The anatomical differences, it must be admitted, are of a relative rather than an absolute nature. And this also applies to P. arenarium which shows little or no adaptation to its environment. P. phleoides on the other hand is quite distinctive.

The following plants from the Scottish Plant Breeding Station, of known chromosome constitution were examined:

Diploid/

	Width mm.	Thickness u	V.Bs.
Diploid	3-3.5	130-150.	13-17.
Diploid (broad leaved type)	5.0	182	24.
Diploid (narrow leaved type)	1.5	118	9.
Hexaploid	7.0	221	24.

The diploid forms have smaller, thinner leaves than the hexaploid. The lower keel girder in the former protrudes from the lower epidermis in rounded fashion, while in the latter it protrudes less and is more wedge-shaped.

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PLANT DISEASES OF THE GARDEN

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PREFACE

THIS booklet is written in response to a request for a concise presentation of the symptoms of the chief diseases of horticultural crops caused by fungi, bacteria, etc., and the preventive and remedial measures applicable in each case. It is beyond the scope of this work to consider the multitude of maladies affecting flowers: one or two of the more prominent diseases, however, are discussed. The structural details of causal organisms have been purposely omitted, as these do not concern the practical man.

The number of control measures available is strictly limited, and the majority are referred to; thus it is hoped that a clue will be afforded to the preventive and remedial measures which should be taken to cope with pests not specifically mentioned.

Thanks are due to Dr. Malcolm Wilson and Mrs. N. L. Alcock, and acknowledgement gratefully made.

DAVID CLOUSTON.

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INTRODUCTION

WHEREAS insect pests are on the whole fairly well understood, disease-causing fungi, because of their minute size, are less comprehensible to the layman. The gardener, however, if he is to reap the full reward of his labours, must sooner or later take cognisance of them.

The Characteristics of Fungi.—Fungi and bacteria differ markedly from flowering plants, in so far as they possess no green colouring matter or chlorophyll. They are in consequence unable to utilise the carbonic acid gas of the air for manufacturing starch, and have to rely for sustenance on dead or living organisms. Those which obtain their food from other living organisms are termed parasites; it is with them that we are concerned.

A fungus consists of a thread-like vegetative body—the mycelium—and spores which are comparable with the seeds of the higher plants. These spores are extremely minute dust-like bodies, and they are produced in myriads. They are dispersed by wind, rain, or insects, and are responsible for epidemics of disease.

Method of Attack, Habit and Control.—Fungi vary considerably in respect of the degree of parasitism manifested by them. Some, e.g. *Nectria cinnabarina*, the Coral Spot fungus, are weak parasites, living on dead twigs, but are capable under certain conditions of passing on to living tissues and of causing disease. Others, e.g. *Stereum purpureum*, the Silver Leaf fungus, enter the tree by way of a snag or wound but quickly move on to healthy tissues. Rusts and mildews are entirely parasitic. Certain fungi are superficial, but extract nutriment from the host plant by means of suckers; others, for example the Wart Disease organism, take up their abode actually within the tissues of the plant and cannot be dislodged.

For successful control of fungi, an intimate knowledge of the mode of attack and subsequent development is of paramount importance. Remedial and preventive measures are based

upon a knowledge of the life-history. The latter is excluded from the purview of this work, on the ground that it does not concern the practical man directly, provided he will follow accurately the control measures based upon this knowledge. Leaf-attacking fungi can usually be effectively controlled by the application of a fungicidal dust or spray. The saying that 'Prevention is better than cure,' applies with unusual aptitude in the war against fungal parasites. In the main, therefore, spraying is designed to ward off attack; less frequently it aims at the immediate destruction of the fungus. When the fungus hibernates on the tree, the affected parts may be cut out, e.g. 'tipping' of gooseberry bushes against American Gooseberry Mildew. In most leaf-attacking fungi, the resting spores pass the winter on fallen leaves and, to some extent, on the twigs, e.g. the Apple Scab fungus. Both diseased leaves and twigs must therefore be burnt. Fruit-attacking types, in whatever other way they hibernate, do so on the fruit; the latter forms a potent source of infection in spring, if not previously gathered and destroyed. For control of wood-infecting fungi, it is important to remove and burn all dead wood, whether on the tree or on the ground. Affected parts should be cut out well below the seat of attack, and the pruned surfaces, together with other wounds, dressed with white-lead paint.

Importance of Good Cultivation.—Good cultivation is of prime importance in restraining disease-causing organisms; conversely, careless cultivation and a disregard for the rules of plant hygiene lay the grower open to the full blast of the ever-present agents of disease. Moreover, care expended on economic plants will prove of little avail, if weed or other host plants are allowed to act as centres of infection, or if the disease organisms are allowed to propagate freely on plant debris. Under glass, attention to ventilation and the judicious use of water are matters of cardinal importance. Growers in their desire to catch the cream of the market must refrain from the use of too great quantities of nitrogenous manures, since excessive nitrogen encourages a rank growth, peculiarly susceptible to fungal and insect ravages. On the other hand, reasonable use of phosphates, and especially potash, leads to sturdy growth, of immense value in resisting attack. It may be said that disease symptoms directly due to lack of

potash are commonly manifest in orchards, the leaves assuming a red tint around the margins.

In the choice of varieties immune or resistant to specific parasites lies the most hopeful method of combating disease. But for the timely advent of types immune to Wart Disease, the culture of potatoes in many parts of this country must have ceased. Despite rigid adherence to the most approved practices of cultivation, and after the fullest exploitation of suitable varieties, disease will yet occur. In this connection, the results accruing from scientific experiment are of immense value. It is the aim of this work to supply an answer to 'How do I know?' and 'How can I prevent or cure?' certain of the more frequently occurring diseases for selected crops. The number of control measures available is strictly limited, and the majority are referred to; thus it is hoped that preventive and remedial measures may suggest themselves for diseases not included.

FRUIT

APPLE

CANKER (*Nectria galligena*, Bres.).

This fungus is one of the most formidable pests occurring in the orchard. It attacks apple trees most frequently, but occurs also on the pear.

Symptoms.—Commonly the disease starts at the junction of a small branch with a larger one. Where attacked, the stem exhibits a small, dark, depressed area. Later, the bark becomes puckered, cracks, and peels off. The wood is laid bare in the centre of the affected part, and is surrounded by much raised, gnarled bark; the wound is referred to as 'canker.' The canker may partially surround the stem or completely 'ring' it. In the latter event the branch is frequently severed by wind; if not, it dies as the result of the interruption of the flow of sap. The fruiting bodies of the fungus are characteristic. In spring, little white pustules make their appearance on infected branches. During autumn, pear-shaped bodies develop, about the size of a pin-head, but red in colour. These become conspicuous, however, only in spring. In those pustules are the spores which are dispersed by the agency of wind, rain, or insects. This fungus is essentially a 'wound parasite,' and entrance to a host can be gained only through a wounded surface. A leaf scar, an insect puncture, the fissure caused by the Apple Scab fungus or inefficient pruning, offer ingress.

Control.—1. Cut out diseased parts, taking care to cut well down into the sound wood, to remove every trace of the fungus.

2. Protect all wounds or cut surfaces by painting with thick white-lead paint.

3. Certain varieties of apple are resistant, e.g. Bramley's Seedling, Blenheim Orange, Newton Wonder, Beauty of Bath, etc., while Warner's King, Ecklinville Seedling, Lord Grosvenor are very susceptible. In cases where the disease has gone too far for treatment to be effective, consideration may be given to grafting a resistant variety on to the susceptible stock.

4. Prevent attack of Woolly Aphis, which is often the forerunner of canker.

5. Avoid bad drainage. Root pruning should be resorted to in heavy soils.

All diseased prunings should be scrupulously burnt to curtail infection. Spraying is not of much direct use against the canker fungus, but lessens the risk of 'scab,' which favours a subsequent attack of canker.

'The sale of any trees that are substantially attacked by this disease is prohibited by the Sale of Diseased Plants Order, 1927.'

CORAL SPOT (*Nectria cinnabarina* (Tode) Fr.).

See under **BLACK CURRANT** (p. 22.)

SCAB (*Venturia inaequalis*, Aderh.).

Scab is one of the most widely distributed diseases of apples. The unsightly scabs greatly depreciate the market value of the fruit, and frequently render it unsaleable. Moreover, keeping quality is very seriously impaired.

Symptoms.—The disease is usually first detected on the young fruit by the presence of black spots or scabs, which are irregular in outline and slightly depressed. The margin of the scab has often a silvery frill of broken skin; individual scabs may coalesce, forming large black patches. On some varieties the scabbed area becomes deeply cracked.

Young fruit becomes distorted in shape and is frequently shed. The disease may be observed in spring, commonly at the base of the previous year's shoots, where the bark ruptures lengthwise and tends to peel off. In this stage, it is not uncommonly mistaken for Apple Canker. On the young leaves, especially those surrounding the flower trusses, small dark spots appear, later developing into larger star-like blotches covered by a dark-brown sooty layer. The entire leaf may be involved, or the blotches may be confined mainly to the veins; one or both surfaces may be affected. Throughout winter, the fungus persists in a dormant state in the young wood. It becomes active in spring, and causes the new season's outbreak. Fallen leaves and fruit are also sources of infection.

Control.—1. As far as possible, all diseased leaves and fruit should be collected and burnt before the end of March.

2. Cut out all infected wood before the end of March. Winter spraying with a powerful fungicide, such as tar oil, copper sulphate or strong lime sulphur, has been tried in an attempt to kill the fungus on the young wood, with varying results.

3. Certain varieties of apple, including Bramley's Seedling, Lord Derby, and Grenadier, are fairly resistant, while Warner's King and Ecklinville Seedling are highly susceptible.

Amongst pears, Conference and Dr. Jules Guyot are somewhat resistant.

4. **Spraying.**—Bordeaux Mixture and lime sulphur solution are commonly employed as preventives. The former, however, sometimes occasions scorching of the leaves and russetting of the fruit of some varieties. Lime sulphur may also cause scorching and defoliation and fruit shedding, but is to be preferred in the case of sensitive varieties. On no account should fear of damage lead growers to shirk spraying. The operation should be performed on a calm day, but not in strong sunshine. For ordinary sized trees, about 1 gall. of the spray fluid should suffice. The addition of lead arsenate increases the efficiency of the fungicide, and is valuable in checking the ravages of caterpillars and biting insects. Three applications as under are advisable—the first and second are particularly important :—

A. *First application*—before flowering, i.e. in the ‘pink bud’ stage.

Bordeaux Mixture (4 lbs. copper sulphate ; 4 lbs. quicklime ; 50 galls. water) ; or lime sulphur (1 gall. to 29 galls. water).

In either case add 1 lb. of lead arsenate to 25 galls. of spray fluid.

B. *Second application*—soon after petal fall.

Lime sulphur (1 gall to 59 galls. water).

If necessary, 1 lb. of lead arsenate per 25 galls. of spray may be added. With Cox’s Orange Pippin, James Grieve, and Rival, use lime sulphur at strength 1 to 99.

C. *Third application*—about three weeks after the second. Apply as in B.

Bordeaux Mixture should be used in the case of Stirling Castle and Lane’s Prince Albert, as they are very susceptible to injury from lime sulphur.

MILDEW (*Podosphaera leucotricha* (Ell. et Everh.) Salm.).

Mildew is a very common disease of apples, but fortunately one which can readily be controlled.

Symptoms.—The leaves and tips of the shoots are covered with a dense growth of the fungal threads—presenting a ‘mealy’ appearance, which is very conspicuous in the early part of the season. The fungus hibernates in the buds during winter, and attack commences each year with the unfolding of flower and leaf buds in spring ; this is the ‘primary infection.’ Flower buds may be so seriously damaged as to occasion a considerable reduction in the crop. ‘Secondary infection’ results from the myriads of spores blown by the wind from those early infected leaves. In cases of severe

attack, serious defoliation occurs, and the tree presents a very naked appearance with but a few tufts of leaves at the growing tips. Though the flower buds are attacked in the early phase of the disease, the fruit is seldom affected. Varieties exhibit considerable differences in susceptibility.

Control.—1. Prune out before the New Year all shoots which were affected during the growing season. (They can be readily recognised by the whitish colour of the young wood.)

2. Prune out during spring and early summer any shoots missed in winter. If recommendations (1) and (2) are carefully carried out, little trouble need be feared.

3. Should there be a risk of secondary infection from outside sources, spraying with lime sulphur shortly after the blossoms set, and again later if occasion demands, with the strength recommended under Apple Scab, will do much to prevent an outbreak.

BROWN ROT (*Sclerotinia fructigena*, Schroet.).

Brown Rot is a well-known disease of apples which attacks both growing and stored fruit, and is responsible for much damage each year. Pears, plums, and cherries also suffer from this disease.

Symptoms.—Little brown patches on the fruit are the first indication of the disease. Those patches increase in size until the entire apple is affected. From the surface of the apple appear small yellowish or buff-coloured pustules, the fruiting bodies of the fungus, usually arranged in concentric circles. As the fungus uses up the inside of the apple, the skin becomes puckered. Such fruits are readily detached by wind, and fall to the ground. Fungus fructifications continue to be formed on those 'windfalls,' which constitute a source of further infection. If the affected apple is in contact with a branch or other apple, it frequently becomes firmly attached to this support by adhesion of the fungus pustules. The apple generally remains in this position during the winter and becomes small, shrunken, and dry, forming the well-known mummied apples.

On certain soft-wooded varieties of apple a canker is frequently formed round the base of the spur. In this case symptoms not unlike those of 'Blossom Wilt' canker are presented. The causal organisms, however, are quite distinct. In the case of Blossom Wilt, infection takes place through the open flower, while in Brown Rot it occurs only through the fruit.

Control.—1. All mummies must be collected and burnt during winter.

2. Trees should be examined during the growing season and all fruit showing signs of the disease removed and burnt.

3. Cankered spurs are evident in summer and should then be cut out and burnt.

4. Care should be exercised not to injure apples in any way in picking, as Brown Rot is liable to set in wherever there is a wound. It is advisable to pick apples with their stalks still attached.

5. All apples showing any trace of Brown Rot should be discarded when storing; otherwise the disease will spread by contact.

6. Spray the trees with a tar-distillate wash, such as Mortegg or Carbokrimp, in winter.

BLOSSOM WILT (*Sclerotinia cinerea*, Schroet.).

This disease has been recognised only in comparatively recent years. The blossoms, spurs, and shoots are affected and the yield of fruit considerably reduced. The fungus causing Blossom Wilt is nearly related to *S. fructigena* Schroet., which causes Apple Brown Rot, but the buff-brown pustules of the latter distinguish it readily from the Blossom Wilt fungus, in which they are pale grey. Blossom Wilt of plums is caused by a distinct form of the same fungus.

Symptoms.—The leaves on some of the spurs will be noticed to wilt about a fortnight after blossoming commences, and a day or two later they are brown, withered, and inrolled. Flowers of affected trusses are found to be brown and dead. Many trusses may be involved, and ultimately the spur itself is killed. The spur frequently becomes cankered. Sometimes the fungus penetrates beyond the spur and affects considerable portions of the branch. About December, the light grey spore pustules may be observed bursting through newly killed spurs and shoots. They continue to develop during the winter months and appear powdery in spring when the spores are being liberated. The new season's outbreak is caused by wind-borne spores gaining entrance to the open flowers.

Control.—1. Bramley's Seedling is the only variety of apple which is resistant to any degree.

2. It is important that all dead spurs and cankers should be cut out in *summer*, when they contrast with the green foliage, the cut being made well beyond the lowest region of infection.

3. Spraying with a solution containing 1 lb. of caustic soda and 1 lb. of soft soap in 10 galls. of water, just before the buds swell, has been recommended as a winter wash.

PEAR

SCAB (*Venturia pirina*, Aderh.).

Symptoms.—Similar to those of Apple Scab (p. 12).

Control.—Spray with Bordeaux Mixture (4—4—50), adding 25 lbs. of lead arsenate per 25 galls. of spray fluid.

First application—immediately after petal fall.

Second application—three weeks later.

CANKER (*Nectria galligena*, Bres.).

Symptoms and Control as for **APPLE CANKER** (p. 11).

BLOSSOM WILT (*Sclerotinia cinerea*, Schroet.).

Symptoms and Control as for **BLOSSOM WILT OF APPLE** (p. 15).

PLUM

SILVER LEAF (*Stereum purpureum*, Pers.).

Silver Leaf disease does most damage to plums, especially the Victoria variety, but it occurs quite commonly on other members of the *Rosaceae*, including the apple, almond, cherry, peach, wild sloe, etc. It also attacks currant, gooseberry, horse chestnut, laburnum, etc. Fortunately, however, this serious disease is not common in Scotland.

Symptoms.—Leaves of affected trees take on a silvery sheen in summer. At first only one branch may be concerned, but later others become affected. Branches die from the top and ultimately the whole tree may succumb. Fructifications of the fungus appear on dead wood of the branches or stem—sometimes only after the whole tree has been killed—as flat, firmly-attached incrustations or as bracket-like projections $\frac{1}{4}$ –1 inch wide, the latter usually in tiers, one above the other. These fruit bodies of the fungus, which are *annual*, may break through the wood at any season, provided that the weather is moist and mild, but most frequently they are to be observed after the early autumn rains. The upper surface of the flat form is characteristically purple; the top of the bracket form is greyish-white, the bottom purple. The fructifications shrivel in dry weather, but resume their normal shape with the advent of moisture. Spores are formed in these fruit bodies and are wind-borne. This is a 'wound parasite,' and infection cannot take place on sound tissues. The lower part of a diseased stem on being cut across reveals a dark brown or blackish discoloration. It must be noted that a silvery sheen occurs naturally on the plum St. Julien and on other varieties, when

attacked by red spider, thrips, or a physiological disease called 'chlorosis,' and must not be confused with Silver Leaf disease.

Control.—1. Badly affected and dead trees should be uprooted without delay and burnt. (*N.B.*—The disease may occur on dead trees of various kinds; they, too, must receive attention.) Others may safely be planted in their places.

2. An attack if not severe may be arrested by cutting out the 'silvered' portion and healthy tissues for some distance beyond.

3. All pruning wounds and the broken ends of branches must be coated with white-lead paint.

4. The 'Silver Leaf Order' requires that, in the case of Plums and Apples, all dead wood be removed and burnt before 15th July each year, and where such dead wood is in the trunk and extends to the soil, the whole tree, including the roots, must be burnt.

5. *Resistant Varieties.*—Yellow Pershore, River's Early Prolific, Blaisdon Red, and Damascene.

BROWN ROT, BLOSSOM WILT, and WITHER TIP (*Sclerotinia cinerea f. pruni*, Schroet.).

BROWN ROT of ripe plums is a familiar disease, and one which occasions great loss both on the tree and in market consignments. The same fungus causes considerable damage to the blossoms and young shoots. In addition to plums, cherries are attacked in like manner.

BLOSSOM WILT.—In spring flowers are infected by spores from mummied plums on the branches, and from spore-pustules on infected wood. The flowers soon die, and the fungus passes on through the stalk into the wood. Trees which have had Blossom Wilt can be detected by the dead brown leaves which remain in position. Muggy weather and low temperature are predisposing factors.

WITHER TIP.—The fungus causes a die-back of the young shoots—referred to as Wither Tip. A number of weak shoots take the place of the fruit buds. Infection is caused by spores from mummied fruit, wood of the previous season which has been attacked, and from blossoms killed by Blossom Wilt. Entry of the fungus is through a leaf or node, and the disease generally commences some little distance from the tip. The leaves become limp to begin with, but later dry up and become brown. They do not fall off but remain in position during the winter. The shoot is characteristically curved at the top. Occasionally spurs become cankered. Grey fructifications appear on the dead twigs about December, and increase progressively until about March. The fungus may remain alive for two seasons in dead twigs. Cold weather predisposes to

attack by the fungus. Aphides are also regarded with suspicion, it being held that the leaf punctures resulting from their attack facilitate entry of the fungus.

BROWN ROT OF FRUIT.—Fruit is most frequently attacked just prior to maturity; the smallest bruise lays the fruit open to attack. The fruit shrinks until it becomes finally hard, when it is known as a mummy. The mummies generally remain on the tree, frequently two or three adhering together. Very young fruit is sometimes attacked. The familiar grey pustules on the mummies harbour the spores, which may attack flowers, shoots, or fruits.

Control.—1. Decayed and mummied fruit should be collected and burnt before the buds break in spring.

2. Diseased wood should be cut out and burnt.

3. Spray during winter—not later than the end of January—with a tar-distillate wash.

4. Seedling and River's Early are fairly resistant.

RUST (*Puccinia Pruni-spinosae*, Pers.).

Rust of plums is not of any great economic importance. The same fungus attacks *Anemone coronaria*. In this country it is probable that the parasite must have both hosts in order to persist.

Symptoms.—Yellow spore pustules occur on the lower surface of the plum leaf in spring and summer. Occasionally, defoliation may occur. Later, darker pustules appear bearing spores which infect *Anemone coronaria*. Infection may occur in spring from either the plum or anemone.

Control.—It is advisable to eradicate diseased specimens of *Anemone coronaria* which may be growing in the neighbourhood of the plantation.

BLADDER or POCKET PLUMS (*Taphrina Pruni* (Fckl.) Tul.).

The common name refers to the fact that affected plums are somewhat hollow and possess no stone; they are often flattened and elongated. If no action be taken the disease becomes progressively worse each year. It is not common in Scotland.

Symptoms.—Young plums, when affected, are yellowish, elastic, and wrinkled. Later they become tough and are covered with a greyish or dingy yellow powder—the spores. Finally the diseased plums become black and fall off. The fungus is also present in the shoots, where it spends the winter and whence it passes into the buds and fruit each season. Affected shoots are thickened and contorted.

Control.—1. Collect and burn all 'bladder plums.'

2. Prune out all diseased shoots and burn.

CHERRY

BROWN ROT, BLOSSOM WILT, and WITHER TIP
(*Sclerotinia cinerea f. pruni*, Schroet.).

See under **PLUM** for Symptoms and Control (p. 16).

WITCHES' BROOM (*Taphrina Cerasi* (Fckl.) Sadeb.).

Symptoms.—The densely-crowded branches popularly called 'Witches' Brooms' are due to attack by the above fungus. The brooms increase in size each year and the tree becomes gradually weakened.

Control.—Cut out all brooms and burn.

PEACH

PEACH LEAF CURL (*Taphrina deformans* (Berk.) Tul.).

Leaf Curl also attacks nectarines and almonds.

Symptoms.—The leaf blade becomes thickened and markedly puckered. It is yellowish in colour with a tinge of red. The redness becomes intensified with the progress of the disease, and the upper surfaces of diseased leaves become covered with a delicate bloom—the spores. Ultimately the leaves brown and die. Serious defoliation may occur. Generally, however, new leaves replace the fallen ones.

Young shoots and sometimes flowers and fruit may be affected. Attacked shoots become swollen and contorted, and generally bear a tuft of diseased leaves at their tips. The damage to the tree consists in premature defoliation and dropping of fruit. Three or four consecutive attacks generally kill the tree.

Control.—1. Remove and burn all diseased leaves prior to spore formation.

2. Remove and burn all dead twigs.

3. Spray with Burgundy Mixture before the buds begin to swell, and again a few days later ($2\frac{1}{2}$ — $2\frac{3}{4}$ —12).

MILDEW (*Sphaerotheca pannosa* (Wallr.) Lév.).

Symptoms.—The young stems and fruits are covered with a felt of white fungal threads.

Control.—1. Paint the hot-water pipes with a mixture of sulphur and lime—the sulphur is gradually vaporised.

2. Flowers of sulphur may be sprinkled over the tree as an alternative.

3. A weak solution of carbolic also greatly checks mildew (one dessertspoonful in a gallon of water—add 2 ozs. of soft soap).

ALMOND

LEAF CURL (*Taphrina deformans* (Berk.) Tul.).

As for PEACH LEAF CURL (p. 19).

GOOSEBERRY

AMERICAN GOOSEBERRY MILDEW (*Sphaerotheca mors-uvae* (Schw.) Berk.).

This is the most serious fungal disease of gooseberries. The fungus occurs on the shoots and fruit—occasionally on the leaves. In its earliest stage it appears on the fruit, and affected parts look as if they are dusted with flour. Still later, those patches turn dingy brown and merge together, forming large areas covered by the felt-like interwoven fungal threads, especially on the fruits. More or less buried in this brown felt-like mass are little black dots (spores), quite apparent to the naked eye. Similar patches occur on young wood; the tips of affected shoots appear brown and shrivelled. Berries are generally attacked on one side only, and because of the interruption in growth they become lop-sided; they frequently crack and decay.

Spread of the disease in summer is due to the millions of spores liberated during the powdery stage. The little black objects, visible to the naked eye amongst the brown felt of fungal tissue, are the 'winter' spores. They fall to the ground with the leaves, and overwinter in the soil or debris at the base of the bush. They germinate during May and June and cause the new seasons's outbreak.

Control.—1. Obtain a guarantee with new stocks that they are free from the disease.

2. Keep introduced bushes under observation for a time—preferably away from the others.

3. A certain number of varieties resistant to the disease are available; e.g. Lancer, Crown Bob, White Smith.

4. Spray with ammonium polysulphide 1 in 199, adding 4 lbs. of soft soap per 100 galls. Where protection against Gooseberry Sawfly larvae is required—ammonium polysulphide 1 in 199, plus 2½ lbs. lead arsenate paste (poisonous) plus 5 lbs. freshly slaked lime per 199 galls.

Lime sulphur 1 in 99 may be substituted for the ammonium polysulphide, but it is not quite so good, often causing leaf drop. In either case, *at least two (and preferably three) sprayings are desirable.* The first should be applied just before the flowers open, and the second and third at 3–4 week intervals.

Certain varieties (Sulphur or Amber varieties mainly) cannot be safely sprayed with any of the above, owing to the defoliation which occurs. For those and indeed all varieties washing soda and soft soap (p. 49) provides very efficient control. The first application should be made once the flowers have set, and subsequently at fortnightly intervals as long as occasion demands. This is necessary, as this spray is readily washed off by rain. The efficacy of washing soda is enhanced by spraying with a tar-distillate wash during winter (not later than the end of January) or with 2 per cent. caustic soda (not later than the end of February). This spray commends itself to many growers on account of its cheapness and easy preparation.

5. *Tipping*.—Where disease is actually present, cut out infected wood and burn; this is best done in September, after which no new growth is likely to take place.

6. Excessive doses of nitrogen make bushes more susceptible to the disease.

Under the Sale of Diseased Plants Order, 1927, the sale of infected bushes is prohibited. For Scotland, note, however, that under the American Gooseberry Mildew (Scotland) Order, 1920, an outbreak or suspected outbreak on any premises on which gooseberries or fruit are grown for sale must be reported forthwith to the Department of Agriculture for Scotland or the local authority.

EUROPEAN GOOSEBERRY MILDEW (*Microsphaera Grossulariae* (Wallr.) Lév.).

This mildew is comparatively innocuous but occasionally causes premature defoliation. It occurs particularly on bushes which are in partial shade. The fungal threads occur *principally on the leaves*, and when on the stems they never become felted as in American Gooseberry Mildew. *The fruit is rarely affected*. The winter spores appear as black dots *superficially* on the fungal tissue.

The control measures recommended for American Gooseberry Mildew are applicable in this case.

GOOSEBERRY LEAF CLUSTER CUP (*Puccinia Pringsheimiana*, Kleb.).

Leaves and berries frequently bear bright orange-coloured patches due to this Rust fungus. The disease occurs only when gooseberries are grown in the vicinity of sedges. This is because an essential stage in the life history of the fungus is passed on the sedge. Sedges in the neighbourhood of gooseberry bushes should be cut and burnt before autumn. Sedges should not be used for mulching purposes. The sprays

recommended for use against the mildews will prove beneficial. Cut out all affected parts and burn.

LEAF SPOT (*Pseudopeziza Ribis*, Kleb.).

See under RED CURRANT (p. 23).

BLACK CURRANT

REVERSION (Virus disease).

This disease of black currants, sometimes called 'Nettle-head,' which causes immense damage every year, is little understood, but is generally believed to belong to what is termed the 'virus' group of plant diseases. It is contagious, but no causal organism is known. There is abundant evidence, however, that it is closely associated with 'Big Bud,' and it is believed that the mite is actually concerned in the transmission of the disease.

Symptoms.—When black currant bushes are in flower, the presence of Reversion may be noted by the blossoms appearing more reddish than those in normal health. Dropping of any fruit formed is a marked feature of the disease.

The leaves of reverted bushes are so abnormal in shape that it is comparatively simple to detect affected plants. The best time to examine a plantation is in June. The characteristic nettle-shaped leaves and absence of fruit—on mature bushes—are sure signs of Reversion. On drawing the hands over an affected shoot, a very strong 'black curranty' smell provides a further simple aid to reliable diagnosis.

These symptoms, considered together, will enable any observant person to distinguish Reversion from another condition termed False Reversion, which sometimes follows severe pruning or accidental damage. This condition, however, does not cause any serious injury, as the bushes usually resume normal growth the following season.

Control.—1. Careful selection of cuttings, which should be taken only from vigorous *fruiting* bushes.

2. Skilful cultivation. The black currant requires a deep fertile soil, and must be severely pruned to be maintained in vigorous condition.

3. In spite of the greatest care, however, a few bushes may revert. These should be promptly eradicated. Others can be planted in the gaps without danger.

4. Incidence of the disease is closely bound up with the prevalence of 'Big Bud'; spray the bushes, therefore, with lime sulphur, 1 part in 12 of water, when the young leaves are about the size of a shilling. Some scorching will occur, but no permanent injury need be feared.

AMERICAN MILDEW (*Sphaerotheca mors-uvae* (Schw.) Berk.).

See under **GOOSEBERRY** (p. 20).

LEAF SPOT (*Pseudopeziza Ribis*, Kleb.).

See under **RED CURRANT** (p. 23).

CORAL SPOT (*Nectria cinnabarina* (Tode) Fr.).

Though in general this fungus is found on dead wood, it frequently becomes parasitic and attacks, amongst others, the apple, gooseberry, and especially currants. The fungus commonly becomes established on 'snags,' and thereafter invades the living tissues; as a result, the branches above the seat of infection wilt and ultimately die. No canker is formed (cf. Apple Canker). The pustules in this case are respectively coral and brownish red in colour.

Control.—Avoid leaving dead wood or snags on the trees, or prunings on the ground. Diseased branches and affected material on the ground should be removed and burnt. The fungus grows freely on dead wood of many kinds, and must be eradicated from these sources, otherwise care taken with growing trees will prove of little avail.

RED CURRANT

LEAF SPOT (*Pseudopeziza Ribis*, Kleb.).

Red currants, and to a lesser extent black currants and gooseberries, suffer premature defoliation from this fungus. Affected plants are characterised by numerous small brown spots on the leaves. August is an important month for the building up of food reserves, and defoliation at this period reacts very unfavourably on the subsequent crop.

Control.—An application of Bordeaux Mixture (2 lbs. copper sulphate, 4 lbs. lime, and 50 galls. water) *immediately after picking* provides effective control.

CORAL SPOT (*Nectria cinnabarina* (Tode) Fr.).

See under **BLACK CURRANT** (p. 22).

BLACK PUSTULE (*Plowrightia ribesia* (Pers.) Sacc.).

Symptoms.—A slow die-back of branches of old black and red currants, and occasionally of gooseberries, is caused by this fungus. Black Pustule is sometimes associated with Coral Spot. It is a wound parasite, and gains entrance to the bushes principally through snags left on pruning. Thence the fungus gradually works its way downwards. The progress of the fungus is occasionally arrested by the formation of a cork barrier by the branch. Small, black, oval pustules (the

fruiting bodies of the fungus) erupt through the bark as the branches die.

Control.—Prune out and burn affected branches. Treat cut surfaces with white-lead paint.

RASPBERRY

BLUE STRIPE WILT (*Verticillium Dahliae*, Kleb.).

Symptoms.—In the spring or early summer the fruiting canes of affected subjects may entirely fail to expand their buds and produce foliage, or they may do so very feebly. During the summer the lower leaves of newly-affected canes show a yellow or reddish-brown discoloration between the main veins. Those mottled leaves fall prematurely. About midsummer, on new canes, a dark blue stripe occurs near ground level, gradually extending upwards. The canes frequently die at the end of the fruiting season, or during winter. On the dead canes small black hard bodies, 'sclerotia' or 'resting spores,' can be observed. The fungus lives particularly in the water-conducting channels which it chokes. Bath's Perfection and Red Antwerp B are very susceptible.

Control.—Diseased stools should be scrupulously weeded out and burnt.

MOSAIC (Virus disease).

Symptoms.—The causal organism is reputed to be a virus. The virus extends throughout the plant. Accordingly canes propagated from diseased stocks exhibit the infection. The disease is characterised by the familiar yellow mottling and turning downwards of the leaves. The canes are dwarfed and yield but little fruit.

Control.—Insects probably transmit the disease from infected plants. Diseased canes should therefore be destroyed and only healthy stools utilised for propagating purposes. Varieties differ in their susceptibility to the disease.

RUST (*Phragmidium Rubi-Idaei* (Pers.) Karst.).

This Rust is of widespread occurrence and in some seasons causes defoliation both of the raspberry and the loganberry. Though prevalent, it is seldom serious.

Symptoms.—Yellowish orange-coloured spores of the fungus, occurring on the upper surface of the leaves, are the first indication of the disease. A subsequent spore stage occurs on the lower surface of the leaf as orange-coloured 'dust.' Still later, black dots appearing generally on the lower surface, represent the resting spores which are responsible for the new season's outbreak.

Control.—Collection and burning of diseased leaves reduces the infection. Weak Bordeaux Mixture or lime sulphur solution (1 in 50) can be usefully applied after the diseased leaves have been gathered. Lime sulphur applied in early spring materially reduces infection.

STRAWBERRY

MILDEW (*Sphaerotheca Humuli* (DC.) Burr.).

This fungus also occurs on the hop and on a variety of common plants, such as roses, meadow-sweet, avens, groundsel, and others.

The disease generally appears on the foliage of the strawberry after the fruit has been picked. It may, however, occur earlier, when the ripening fruit may suffer and be rendered unsaleable. The under surfaces of the leaves are covered with the white mycelium and affected leaves tend to roll inwards.

Control.—As soon as the disease appears the plants should be dusted with flowers of sulphur. At the end of the season, at least two-thirds of the leaves should be cut down and, with the addition of straw if necessary, set on fire.

LEAF SPOT (*Mycosphaerella Fragariae* (Tul.) Lindau).

Strawberry leaves frequently exhibit reddish spots caused by this fungus. The spot gradually becomes greyish towards the centre, but continues to be bounded by a reddish border. Flowers of sulphur should be applied as soon as the disease is noticed. Burning the leaves at the end of the season, as recommended above, will do much towards holding the disease in check. The soil surrounding the plants should also be turned over if possible.

RED CORE DISEASE (LANARKSHIRE DISEASE) (*Phytophthora* sp. Alcock).

This serious disease of strawberries, at first confined to certain areas, is now found in several of the principal strawberry growing areas. The causal organism is nearly related to that causing blight in potatoes, but unlike that disease it is the roots which are affected in the case of the strawberry. The disease is first apparent as brown areas in the field, frequently coincident with ill-drained spots; this often leads to an incorrect diagnosis of the trouble. Affected plants are diminutive and generally unthrifty. Growth stops and the outer leaves die, but characteristically remain stiff and in position. The affected area gradually enlarges, but no fungus or causal agent is discernible on the parts above ground.

On lifting a diseased plant, there will be noted a very marked

absence of lateral and fibrous roots. The larger roots often present the appearance of black cords, while later roots exhibit a progressive browning from the tip upwards. The outer surface of the root is easily detached from the internal core, which is *red* in contrast to the white of normal roots. The 'red core' is a useful diagnostic character, and has earned for the disease its common name. New rootlets are put out in spring, and the plants temporarily appear to have thrown off the disease until the roots make contact with the infected regions of the soil. The spores which, it is believed, transmit the disease, are probably long lived, and as no curative treatment is known, diseased plants should be burnt and the field abandoned for strawberry culture for a number of years.

It is possible that certain varieties are more resistant than others, e.g. The Duke and Madame Kooi are possibly more resistant than Ruskin, Overton, Seedling 17, and Royal Sovereign, which are apparently highly susceptible.

GRAPE VINE

POWDERY MILDEW (*Uncinula necator* (Schw.) Burr.).

This mildew, familiar to all vine growers, gives trouble both under glass and in the open. Under glass the disease can be effectively controlled, while in the open it can be held in check.

Symptoms.—A white felt of fungus threads appears on leaves, shoots, and fruits. The fungus is superficial, and derives its nourishment by way of suckers sent into the host tissues. Despite this, however, the leaves may be severely injured and sometimes killed. The fungus may also attack the flowers, which fall off. When fruits are attacked in the young stage they are frequently shed. Older fruits when attacked, crack and become malformed. Once ripening commences, the fruits are not affected. The fungus overwinters in the buds, and the epidemic starts about flowering time.

Control.—1. *Outside.* Avoid damp areas: the situation should be sunny, and overcrowding prevented by thinning out. Apply flowers of sulphur when the leaves are damp.

2. *Under glass.* Proper ventilation is of the utmost importance. Vents should be opened wide as the temperature rises. During damp weather, raise the temperature to effect buoyancy of the atmosphere and maintain circulation. Cut out the laterals to prevent overcrowding. Maintain an equable temperature, and do not allow the roots to dry out. Immediately signs of mildew are apparent, start applying sulphur either by means of a sulphur vaporiser, which is most effective, or by a sulphurator. If the vaporising method is adopted, remove all delicate plants prior to commencing the operation.

GREY MOULD (*Botrytis cinerea*, Pers.).

This disease is confined to vines under glass.

Symptoms.—The familiar greyish or brownish mould occurs on rotting areas of the leaves and fruit. Myriads of spores are liberated, and are carried by air currents to infect new tissues. The germinating spores penetrate any area with a poorly developed protective layer—such as young growths and older leaves of low vitality that may have been induced by high temperature and moist atmosphere. The fungus may live on dead matter and become parasitic at a future date. Small black bodies—sclerotia—appear on the dead tissues which previously have shown the mould. These sclerotia may act as resting bodies, or germinate and cause the ‘mould stage.’

Control.—1. A warm, damp atmosphere is conducive to the spread of the disease; warmth, ventilation, and moisture such as favour the plant and not the fungus should be aimed at.

2. After an outbreak, the house and dormant vines should be brushed with a solution of iron sulphate. (Add as much ferrous sulphate to warm water as will dissolve.)

VEGETABLES**B E E T****RUST** (*Uromyces Betae* (Pers.) Tul.).

Symptoms.—‘Rusty’ specks occur on the leaves. The disease is seed-borne.

Control.—1. Potash is said to aggravate the disease.

2. Immediately a plant displays the symptoms, it should be uprooted and burnt.

3. Special care should be taken to rogue out rusted plants from those set aside for seed. Growers should be careful to obtain only disease-free seed.

4. Do not use rusted plants for compost.

B E A N S**CHOCOLATE SPOT.**

Symptoms.—This disease is characterised by the appearance of dark brown spots on the foliage, stems, and pods. In damp weather it may become epidemic and reduce the yield considerably. A bacterium—*Bacillus Lathyri*—has been named

as the causal organism, but there appears to be doubt on this point.

Control.—1. Nothing can be done once a crop is attacked, but it is helpful to apply potash prior to taking another crop of beans.

2. The disease can be transmitted by the seed, and affected plants should not be seeded.

RUST (*Uromyces Fabae* (Pers.) de Bary).

This fungus occasionally attacks broad beans, causing rusty spots on the foliage. Little damage is done as a rule. No remedial measures are available or required.

ANTHRACNOSE or **BEAN POD SCAB** (*Colletotrichum Lindemuthianum* (Sacc. et Magn.) Bri. et Cav.).

Symptoms.—Dwarf and Runner beans are attacked by this fungus. The pods are chiefly involved, but leaves and stems may also be affected. Small dark spots appear at first; later, the infected areas increase in size, the centre being rust-coloured and the margin red. In bad attacks the fungus may invade the seeds. The spore pustules are pink.

Control.—This disease is seed-borne, and care should be exercised to obtain disease-free seed.

PEAS

POWDERY MILDEW (*Erysiphe Polygoni* (DC.)).

Almost every season this mildew appears, but it is not generally of much importance. Seldom are any remedial measures adopted, therefore, but should it prove unusually severe, dusting with flowers of sulphur would doubtless give some relief.

SPOT (*Ascochyta Pisi*, Lib.).

This is a seed-borne disease which occurs in wet seasons on peas and other legumes. Grey or brown sunken areas—'spots'—occur on leaves, stems, and pods. The fungus grows through the pod into the seed, which thus transmits the disease. Seed should be obtained which is free from disease.

ROOT ROT (*Aphanomyces euteiches*, Drechsl.).

This is a comparatively new disease. Infection comes from the soil. So far, no control measure has been devised.

STREAK.

Streak affects a number of plants, including the pea. The stems bear brown 'streaks.' The leaves at first exhibit yellow

blotches, which later become brown, dry, and shrivelled. The disease is seed-borne and is attributed to *Bacillus Lathyri*. Potash at the rate of 1 oz. to the square yard is helpful in combating the disease. Seed should be obtained from healthy stocks.

CABBAGES, CAULIFLOWERS, TURNIPS, and other members of the CRUCIFERAE

FINGER-AND-TOE (*Plasmodiophora Brassicae*, Woron.).

This disease is widespread and has increased since the advent of acid artificial manures and with the decline in the use of lime. On lifting a young cabbage or other Crucifer for transplanting, the roots may be observed to possess irregular knob-like swellings. At first small, these swellings increase in size as the plants age. Affected seedlings do not grow normally, the leaves being small and soon turning yellow. During bright sunlight diseased plants wilt and may thus be recognised. In the case of cabbages, cauliflowers, etc., no head is formed. The root is deformed and exhibits a fanciful resemblance to 'fingers and toes'—hence the popular name. When the diseased portion is cut across the swollen part is solid and of greyish colour, with small white opaque areas dispersed throughout; at a later stage the affected parts turn brown. In dry soil the affected parts crumble into brown dust; in wet soils the roots become decayed and have an offensive odour. The causal organism remains alive in the soil for many years and affects cruciferous crops when they recur in the rotation. Cruciferous weeds, e.g. Charlock, also support the disease in the intervening period.

Control.—Certain varieties of turnips, e.g. The Bruce and The Wallace, are highly resistant, and the same probably applies to other cruciferous crops. Never transplant diseased seedlings. Burn diseased plants. Lime corrects the acidity which the disease revels in, and kills the spores. Apply quicklime at the rate of 1 lb. per square yard, or 2 tons per acre, after lifting the crop, and work well into the soil. It is advisable to repeat the dressing prior to taking another cruciferous crop. Alkaline manures such as basic slag and nitrate of soda should be used in preference to acid manures.

If for any reason liming is inadvisable, corrosive sublimate (1 in 1000, i.e. 1 oz. in $6\frac{1}{4}$ galls. of water) is useful. Mix the corrosive sublimate with an approximately equal quantity of common salt before adding the water. This has the effect of rendering the chemical more soluble. Pour a cupful round the

base of each plant. Corrosive sublimate¹ can also be usefully applied to the seed bed at sowing time—1 pint of the solution per 5 feet of drill. It may be obtained in tabloid form, so that one tablet makes 1 gallon of the solution. Corrosive sublimate possesses the added advantage of being a control for Cabbage Root Fly.

WHITE RUST OF TURNIPS, CABBAGES, and other CRUCIFERS (*Cystopus candidus* (Pers.) de Bary).

This disease affects many plants belonging to the turnip family, causing swelling and malformation of the affected parts. White porcelain patches are formed on the surface of the host in the early stages of the disease. These give way later to a powdery stage—thus the name White Rust. Infection takes place by way of the seed-leaves, seedlings, or through delicate growing tissue such as the flower buds. By securing a fairly dry and open situation for the seed bed the disease can be reduced. Diseased plants, including affected weeds, should be burnt.

POWDERY MILDEW OF TURNIP (*Erysiphe Polygoni* (DC.)).

Turnips and swedes commonly suffer in dry seasons. The upper surface of the leaves are covered with the fungal threads which are superficial. The spores give a mealy appearance to the leaves. This disease is not generally of importance, but if action is required, flowers of sulphur or half-strength Bordeaux Mixture will give relief.

CABBAGE MILDEW (*Peronospora parasitica* (Pers.) Tul.).

This mildew is confined to members of the cabbage family. Affected leaves become yellowish-green and the white fungal felt may be observed on the under surface of the leaf. Only where plants are crowded, as in seed beds and under glass, etc., is the disease destructive. Half-strength Bordeaux Mixture, if sprayed on the under surfaces of the leaves, will give control. Diseased materials should be burnt.

CELERY

LEAF SPOT (*Septoria Apii*, Chester).

Symptoms.—Leaf Spot attacks both seedling and adult celery plants, and must be regarded as the most formidable difficulty in the growing of celery. The disease is seed-borne. When slightly diseased seedlings are planted out, the disease spreads epidemically if damp weather supervenes. Small

¹ Great care should be exercised in the handling of this material, as it is highly poisonous to animals and man.

brown spots occur on the leaves; these may increase until the entire foliage is killed. Spore pustules occur on the dead tissues and on the young fruits of seeded plants.

Control.—1. Clean seed is of prime importance. This can be obtained by soaking the seed for about twenty-four hours in formalin, 1 part to 300 parts of water (1 tablespoonful to 1 gall. of water).

2. Disinfect seed boxes with 2 per cent. formalin.

3. The soil also should be treated with this solution. Allow about a fortnight to elapse before seed is sown in the treated soil, to avoid injury to the seedlings from the formalin.

4. The growing crop should be sprayed with Bordeaux Mixture—

(a) Immediately after planting out in the beds.

(b) Twice or thrice subsequently in the field.

Bordeaux Mixture :—

Copper sulphate	8 lbs.
Quicklime	8 lbs.
Water	100 galls.

LETTUCE

GREY MOULD (*Botrytis cinerea*, Pers.).

Lettuce grown under glass is frequently attacked by *Botrytis* on leaf and stem. In the field crops do not generally suffer greatly, and little can be done for them. A wilt commences on the outer leaves, working progressively inwards. The greyish fungal threads may be found especially on the under surfaces of the leaves; at the leaf bases small black sclerotia (resting spores) will be found.

Control.—1. Remove and burn all affected plants.

2. After an outbreak the soil should be sterilised by steam, preferably, or with formalin (1 pint 40 per cent. formaldehyde to 12 galls. water).

3. If sterilising be not adopted, remove the infected soil to grass-land and replace with fresh soil mixed with a little quicklime.

4. Ventilation is very important.

RING SPOT (*Marssonina panattoniana*, Berl.).

Both under glass and in the open this is a serious disease, but more especially in the latter case.

Symptoms.—Brown, water-soaked areas appear on the leaves. With the formation of spores these spots become white. Later the central portion falls out, leaving a hole with a white margin. Outer leaves are first attacked and

infection continues inwards until the heart is affected, when the plant dies.

Control.—1. Collect and burn all diseased plants.

2. Whether outside or under glass, lettuce should not be grown on soil which has borne a diseased crop.

3. Affected soil under glass may be sterilised by steam.

DOWNY MILDEW (*Bremia Lactucae*, Regel).

This is a disease which is not at all common in Scotland. Lettuce grown under glass is often affected by it—more rarely when grown out of doors. Affected leaves become yellowish or sometimes brown. By avoiding too high temperatures and excessive moisture it can generally be controlled. Varieties differ in respect of their susceptibility to Mildew.

TOMATO

'**DAMPING-OFF**' (*Phytophthora cryptogea* Peth. et Laff., *P. parasitica* Dastur, and *Rhizoctonia Solani* Kuhn.).

Symptoms.—Seedlings, especially summer sowings, are susceptible to this disease. Affected plants become brown and constricted at soil level, and ultimately topple over. Crowding, excessive moisture, and high temperature predispose to attack.

The soil and contaminated water present the chief sources of infection, but seed-boxes and pots are also capable of carrying the disease.

Control.—1. Sterilise the infected soil by steam, dry heat, or with a 2 per cent. solution of formalin (1 gall. commercial formaldehyde in 49 galls. of water).

2. Pots and boxes should also be treated, and formalin is probably best for this purpose.

3. Water the seedlings with *sterilised* water.

4. Cheshunt Compound—1 oz. to 2 galls. water—applied to the seedlings provides an excellent means of prevention.

FOOT ROT (*Phytophthora spp.*).

Foot Rots are caused by the two species of *Phytophthora* previously referred to as causes of 'damping-off.'

Symptoms.—The symptoms are the same as in 'damping off,' but older plants are affected. Affected stems become brown or black at the seat of attack, shrink and ultimately collapse—generally at about soil level. Root Rots are also caused by the same parasites.

Control.—As for 'damping-off' of tomato.

Foot Rot may also be caused by *Botrytis spp.*

Symptoms.—Smooth, slightly depressed grey patches occur on the stem at about soil level. The affected area increases in size, turns brown, and gradually surrounds the stem. The plant wilts and frequently topples over. The surface of the diseased part bears a grey felt of fungal threads. When cut across, the diseased portion exhibits a dark reddish-brown colour. Small, hard, black bodies, the sclerotia, which are particularly resistant to adverse conditions, enable the fungus to live from season to season.

Control.—1. Avoid warm, moist conditions.

2. Affected plants should be uprooted and burnt—nothing will save them.

3. A 2 per cent. solution of calcium bisulphite will kill the fungus on the surface of the soil and at the base of the plant.

GREY MOULD.

A stem rot also is caused by *Botrytis*, especially when the houses are maintained at a high humidity. The half-dead snags left in careless pruning and the petals of flowers, when damp and adhering to the stem, provide suitable stepping-stones to the host tissues.

Symptoms.—Grey, sunken patches around a wound, or where some dead vegetable matter has been lodged, provide the first indication of the disease. The lesions extend and the stem breaks over. The formation of spores on the affected area gives rise to the familiar grey mould.

Control.—Nothing will save the affected portion, which should be carefully cut out and burnt. The cut surface should be rubbed with a crystal of blue-stone or with a lump of liver of sulphur. Prevention lies in maintaining a buoyant atmosphere and in regulating carefully the moisture supply. When pruning, the cuts should be clean and preferably rubbed with blue-stone. White lead paint applied to the cut surfaces is also excellent. Clammy conditions in general predispose to *Botrytis* attack, and thus, ventilation is of the utmost importance. To aid the circulation of air, plants should be defoliated up to the lowest unpicked truss.

If the disease is epidemic, spraying the stems with a 2 per cent. solution of calcium bisulphite will arrest its spread.

LEAF MOULD (*Cladosporium fulvum* Cke.).

Symptoms.—The first symptoms of the disease is the development of localised patches of pale olive-buff fungal mycelium on the under surface of the leaf. This is followed by the appearance of pale yellow blotches on the upper surface opposite the infected areas below. With time, those patches become more intensely yellow and ultimately reddish-

brown. The fungal cushions below become darker, and finally assume a purple coloration once the leaf tissues die. The fungus spreads quickly over the surface, and myriads of spores are liberated to cause new infections. The lower leaves are first affected, but the disease gradually passes on to the younger leaves. Flowers are sometimes destroyed and the fruit is also attacked, but little harm results except to the very youngest berries.

The toll which the disease exacts is largely dependent upon the atmospheric and general conditions obtaining in the house. A moist atmosphere and a temperature of 68°-77° F. favours the disease. In severe attacks the effective leaf surface is appreciably curtailed with resultant reduction in fruit yield.

Control.—Maintain a dry atmosphere and provide ample ventilation. Vaporisation of sulphur has been practised in the past with variable results. In the Annual Report of the Cheshunt Experimental Station, Bewley and Orchard report success with the following mixture :—

Shirlan Paste	$\frac{1}{8}$ oz.
Agral I.	$\frac{1}{4}$ oz.
Water	1 gall.

The Agral I. powder is sprinkled into the water and mixed by stirring vigorously. The Shirlan Paste is then added and similarly treated.

Two sprayings, with an interval of a week between, were found most satisfactory. If the disease is not arrested with two sprayings, another application should be made.

This spray was found to provide effective control for the mildews of rose, cucumber, and chrysanthemum.

MOSAIC.

This disease is due to a *virus*. Leaves, flowers, and fruit become abnormal, mottled, and often much changed in appearance. Irregular green or yellow blotches develop on the leaves. In *Aucuba Mosaic*, the blotches are bright yellow and with clearly defined margins. In other forms the leaves are mottled, or generally light in colour. Sometimes the leaves are markedly blistered and the margins distorted, this abnormality increasing with age. In one type the leaf-blade is considerably reduced and assumes a tendril-like appearance. When infection occurs at an early stage in the plant's life, growth suffers considerably and the plant is stunted. On the other hand, when plants develop the disease at a later date, the symptoms are more or less restricted to the parts developing after the infection has been acquired. The symptoms

tend to become accentuated after 'stopping' has been performed. In general, the vitality of the plants is lowered and the yield of fruit materially reduced.

Control.—It must be remembered that the disease is highly infectious. All affected plants should be removed and burnt, and a dressing of dried blood given to the remainder. Insects, especially white fly and aphides, are active agents in the transmission of the disease and must therefore be controlled.

Pruning knives should be disinfected in lysol or other disinfectant after treating each plant.

Seed should be saved from healthy stocks.

STRIPE.

Though occasionally seedlings are attacked, this disease in the main is one associated with older plants, especially such as have made soft growth. The cause of the disease is obscure, but it is now believed to be a *virus* and to be associated with potash deficiency.

Symptoms.—Dark, longitudinal stripes, frequently sunken, occur on the stem, and occasionally on the leaf and flower stalks. Yellow patches develop near the mid-rib and the main veins of the leaf, later turning brown and becoming shrivelled. Irregular, brown, sunken blotches occur on the fruit. In bad attacks the plant succumbs.

Control.—It is important to obtain seed which has been collected from healthy plants, as there is reason to believe that the disease is sometimes seed-borne. Insects should be kept down. Pruning knives should be dipped in lysol or other suitable disinfectant after each operation, in order to prevent transmission of the disease from one plant to another. Healthy plants should be pruned first, and all prunings from affected plants burnt. In general, a soft growth should be avoided.

Potash encourages a hard growth particularly valuable against disease. For stripe, 1 pint per week to each plant of a solution made from 1 lb. potassium sulphate per 100 galls. water is valuable, if the disease has not been allowed to progress too far.

BUCK EYE ROT (*Phytophthora parasitica* Dastur.) or WATER ROT.

The fruit on the lower trusses are affected chiefly.

Symptoms.—Discoloured patches occur on the fruit, varying from grey to reddish-brown; the colours frequently alternate, and are disposed in roughly circular outline.

Control.—The fungus lives in the soil and the fruits become

infected by touching the ground or by soil being splashed up through careless watering.

Mulching the soil with straw keeps down infection. The lower trusses should be tied up to keep them off the ground. Infected soil should be watered at planting time with Cheshunt Compound—4 to 8 pints per square yard. It is also well to remove leaves which are too near the soil. All affected fruit must be burnt.

ONION

ONION MILDEW (*Peronospora Schleideni*, Unger).

Symptoms.—This disease is common on onion and related species. It appears about the end of June. The characteristic symptoms are yellowing of affected leaves, which die from the tips, and the elongation of the 'neck.' The bulb is not attacked, but suffers from the reduced efficiency of the leaves and is generally poorly developed. The spots on the leaves are at first covered with the white fungal spores which later become dingy violet. Diseased areas are characteristically rough, and in the later phases of attack become black owing to the presence of a mould which often supervenes. The disease makes little headway during dry periods, but may become epidemic when dull damp weather prevails.

Control.—1. Maintain vigour by deep cultivation, complete manuring, and constant hoeing.

2. Spray with Bordeaux or Burgundy Mixture, or apply flowers of sulphur, when the foliage is moist, at the end of June if the weather is damp. Repeat at ten-day intervals.

3. Remove and burn all diseased plants.

4. Onions should not be grown on infected soil until a period of at least three years has elapsed; alternatively, sterilise the soil.

NECK ROT or GREY MOULD (*Botrytis Allii*, Munn).

Symptoms.—Neck Rot attacks the onion at harvest or during storage. The fungus penetrates the bulb at the neck and gradually works downwards into the bulb itself, causing what has been aptly termed a 'cooked appearance.' The characteristic grey felt of fungal tissue of the parasite develops on affected tissues, while later the small, round, black sclerotia (resting spores) become apparent on the surface. White varieties are more susceptible than coloured ones. Damp weather at harvest, and immaturity of the bulbs, are predisposing causes.

Control.—1. Dry the harvested bulbs artificially.

2. Maintain dry storage conditions.

WHITE ROT (*Sclerotium cepivorum*, Berk.).

Symptoms.—White Rot generally becomes apparent about the beginning of June through the wilting and yellowing of affected leaves. Collapse of the leaves occurs, commencing with the oldest ones and progressively working inwards. If a diseased bulb be lifted it will be found to have a very poor root hold, the roots being almost entirely destroyed. The disease is favoured by warm weather, and it spreads rapidly through the beds. A characteristic white felt develops at the base of the bulbs—a distinctive feature. With age the fungal web becomes more firmly attached to the bulb, and tiny black sclerotia—resting spores—which perpetuate the disease in the soil—become apparent. This disease must not be confused with that resulting from Onion Fly attack, the foliage symptoms of which are not dissimilar to those of White Rot. The latter, however, generally causes a wet rot, and the maggots may be found in the bulb. White Rot may be distinguished from Neck Rot by the fact that the mould is white, not grey, and further, by the fact that it is the base of the bulb and roots which suffer in the former, the leaves and the top of the bulb in the latter.

Control.—The disease is conveyed to the plants by means of contaminated soil containing the resistant sclerotia (resting bodies). So far, soil fungicides have not proved efficacious, so that the disease must be starved out. Allow eight to ten years to elapse before onions are again planted in soil which has borne a diseased crop. All diseased plants should be removed and burnt immediately they are noticed.

SMUT (*Urocystis Cepulae*, Frost).

This dreaded disease of seedlings and young plants of onions and leeks is on a par with Wart Disease of potatoes in its seriousness. Shallots, chives, and garlic are occasionally affected. Growers are under obligation to report outbreaks or suspected cases forthwith to the Department of Agriculture. Failure to comply renders growers liable to a penalty of £10.

Symptoms.—Careful observation will reveal, on the first and subsequent leaves, and occasionally on the scales of young bulbs, dark spots or streaks just under the skin. The leaves become malformed, thickened, twisted and curled, and bend downwards. The dark spots erupt, and the dark spore balls are liberated into the soil. Not infrequently, considerable numbers of seedlings succumb to the disease, and those which persist through 'flaking off' the disease bear stunted bulbs. The disease is perpetuated in the soil by the long-lived spores; there are records of contaminated soil having so remained for

at least twelve years. Infection of seedlings, fortunately, can take place only through the first leaf, and the period of susceptibility runs from the second or third day of the seedling's life until it is about 3 inches high; this period is dependent upon vigour of growth, but is on average about two to three weeks.

Control.—1. Collect and burn all infected plants and exercise vigilance in order that no infected soil is transported to new areas by implements or by adherence to plants from 'infected areas.'

2. Neither onions nor leeks may be grown upon contaminated soil without licence. Only crops which are not liable to spread the disease ought to be grown, if the wiser course of relegation of infected land from cultivation altogether be not adopted.

3. Watering the seeds in the unclosed drills at sowing time with formalin will ward off attack in considerable measure, even in contaminated soil. Formula: Formalin (40 per cent. formaldehyde), 1 pint to 16 galls. of water; apply with watering-can without rose, or other suitable machine, to 800 yards of drill. Such treatment is advantageous apart from risk of Smut.

SHALLOT

Any or all of the diseases listed for onions may affect shallots, and what has been said in that section applies equally here.

LEEK

WHITE TIP (*Phytophthora Porri*, Foister).

Described but recently by Foister, this disease would nevertheless appear to have been present for a number of years.

Symptoms.—The disease begins to appear in Scotland about September—in England, about August. Affected leaves become yellow and die at the tips. Subsequently, the affected portion, which may be from $\frac{1}{2}$ inch to 6 inches in extent, becomes white, and generally bends backwards. Some leaves, however, harden and do not topple over. Though the tip is generally affected, infection may occur along the edge of the leaf in its top half. Large plants, if heavily attacked, decay, and the top comes away at soil level, leaving the base behind.

Control.—None has been devised so far. After an attack it would be well to grow the subsequent crop away from the affected centre.

WHITE ROT (*Sclerotium cepivorum*, Berk.).

See under **ONION** (p. 37).

SMUT (*Urocystis Cepulae*, Frost).

See under **ONION** (p. 37).

RUST (*Puccinia Porri* (Sow.) Wint.).

This disease is of general occurrence. It is particularly common on plants set aside for seed. Yellow spore pustules occur in the early part of the season, while darker ones replace them toward the end of the year.

Infected plants should not be used for seed.

MINT

RUST (*Puccinia Menthae*, Pers.).

Mint Rust is widespread, and in addition to mint, attacks peppermint. Leaves and underground stems are affected. Invaded shoots become contorted and the leaves small and yellowish. Yellow pustules appear on the under surface early in the season; later, dark brown spots occur on the upper surface of the leaves.

Control.—Establish fresh mint beds each year from healthy stocks. In old beds, cover with straw and burn the mint tops in autumn.

RHUBARB

CROWN ROT (*Bacterium Rhaponticum*, Millard).

This is said to be caused by bacteria, and is a serious disease in some areas.

Symptoms.—The disease has generally been present for some time before symptoms become manifest. In young plants a soft brown area at the region of infection (generally at the shoulder of the set near the soil level and just immediately below a bud) is a sure indication. This feature is not so readily observed in older plants. In the latter, no external symptoms may be evident unless the disease is actually in the buds. The sheathing leaves will then appear fleshy and exhibit discoloration, when the rhubarb sticks are pulled. The leaves of affected plants growing in the open are duller than those of healthy plants, and ultimately become brownish-purple—a very characteristic symptom of this disease. (This root symptom should not, however, be confused with the natural red tints of healthy plants in autumn.) When the disease approaches its final stages, the crown of the plant rots and a great number of small spindly shoots take the place of the normal stalks. The whole crown of the plant is readily detached and frequently comes away on pulling the 'sticks.'

Control.—Watering the ground, a fortnight prior to planting the sets, with ammonia (2 tablespoonfuls per gall.) at the rate of 1 gall. per square yard has proved beneficial.

POTATO

THE POTATO DISEASE or LATE BLIGHT (*Phytophthora infestans* (Mont.) de Bary).

Blight is by far the most important disease of the potato.

The disease generally makes its first appearance in Scotland during July, in the form of spots or patches on the leaves—at first pale and water sodden. Later these patches become brown or black with greyish edging. The tips or edges of the leaves generally exhibit the first symptoms of attack. A white mould will generally be found on the lower surface of the leaf, emanating from the border of the diseased patch. Dry weather checks the onslaught of the disease; wet or muggy weather causes its rapid spread.

Tubers of affected plants frequently exhibit sunken areas of leaden hue. When such a tuber is cut across the diseased tissue shows a rusty red appearance. The tubers are infected by spores from the leaves, which are washed down through the soil. Affected tubers may rot in the soil, or later in the pit. *Phytophthora* itself causes a 'dry rot,' but if bacteria subsequently supervene a 'wet rot' ensues. In the event of an attacked crop having to be pitted, care should be exercised to allow the tubers to dry thoroughly before being clamped, and to provide ample ventilation in the pit itself. Tubers containing the fungus cause the new season's outbreak.

Control.—Plant only healthy sets; earth up the potatoes well; protect the plants against wind-borne spores by spraying (see below); cut and burn blighted tops a week before lifting; lift a diseased crop as soon as practicable; dry off tubers before storing.

Spraying. This provides a complete control, if properly carried out, and in addition prolongs growth of the foliage with resultant greater yield. The object of spraying is the coating of the entire surface of the leaves (under and upper) so as to kill the germinating spores.

Burgundy Mixture, 2 per cent. at the rate of 40 galls. per acre and put on with a knapsack sprayer, is most convenient for small areas on account of the ease of preparation. (8 lbs. copper sulphate, 10 lbs. washing soda and 40 galls. water.) Dissolve the bluestone in 35 galls. of water in a 40-gall. wooden barrel and the soda in 5 galls. of water. Pour the latter into the former, stirring constantly. If the mixture

causes a bright coloured wire nail to be coppered, add soda until no deposit of copper is discernible on a bright nail. Apply immediately after making up.

Bordeaux Mixture : copper sulphate, 8 lbs. ; lime, 8 lbs. to 100 galls. water, made up as for Burgundy, is used for larger areas.

COMMON SCAB (*Actinomyces scabies* (Thaxt.) Güssow).

Scab is prevalent particularly on light soils and in dry seasons. Table quality is not affected materially, but the appearance of the tuber is spoiled.

The disease takes the form of irregular brown scabs, with wrinkled edges arranged more or less concentrically around the central core. The scab is merely skin deep, and the surface presents a rough, broken, corky tissue. Scabs may coalesce, but 'cankers' are never formed (cf. Corky Scab).

Control.—Incorporate grass cuttings or other organic matter with the tubers at planting. Lime and ashes which deplete the soil of organic matter increase the amount of Scab on potatoes.

CORKY or POWDERY SCAB (*Spongospora subterranea* (Wallr.) Lagerh.).

This disease is caused by a lowly type of fungus which requires abundant moisture to complete its cycle of life. Corky Scab is prevalent, therefore, in the wetter parts of the country and in ill-drained soils. Tubers are principally affected, and exhibit in the early stages of the disease white pimples. With the development of the parasite the swelling increases in size, and the covering skin is ruptured, so forming a 'scab' with a frill of surrounding skin. A number of scabs, when situated closely together, give a 'honey-comb' appearance. If the scabs be scraped, the olive brown spore-balls appear as dust-like particles. They are liberated into the soil, leaving crater-like cavities with a layer of wrinkled cork at the base. (*Note that the malformation is much deeper than in Common Scab, which is only skin deep.*)

Sometimes large diseased excrescences occur on affected tubers, and in such cases may be mistaken for Wart Disease. (*Note, however, that a Warted tuber has a crinkled or cauliflower appearance.*) If in doubt, consult a specialist. The spores are reputed to live in the soil for eight years.

Control.—Flowers of sulphur applied to the soil at the rate of $2\frac{1}{2}$ ozs. per square yard destroys the fungus without detriment to the potato. Remember, however, that sulphur will render the soil sour and uncongenial for crops other than potatoes. If crops other than potatoes are grown for at least

eight years on affected soil, the disease will die out of its own accord. When seed tubers are suspected, they should be steeped in a 1 per cent. solution of copper sulphate for thirty minutes before planting. Lime aggravates the disease. No varieties are known to be immune.

WART DISEASE or BLACK SCAB (*Synchytrium endobioticum* (Schilb.) Perc.).

Wart Disease is notifiable to the Department of Agriculture, which makes orders controlling the purchase, sale, and growth of varieties in 'affected areas.'

The disease appears as irregular warty protuberances from the eyes of tubers or from stem buds above soil level. In the early stage of the disease, white pimples are evident. These develop during the growing period and the warts from neighbouring eyes often run together forming large 'cauliflower'-like excrescences which are to be regarded as the characteristic symptom. On cutting through a diseased tuber the spores can often be seen with a pocket lens as brown specks in the cut tissue—just beneath the surface. The spores may remain alive in the soil for ten years at least, so that no reasonable rotation is of any avail in disposing of the disease; nor has any substance been found of fungicidal value. Great care should be exercised that spread of the disease is not carried by implements, boots, or diseased tubers to non-affected areas. As stated above, any outbreak of the disease must be reported immediately to the Department of Agriculture. When the disease is suspected, an expert should be consulted in the first instance.

Certain varieties are immune, and as a fairly wide selection of immunes is available, no hardship is imposed upon growers who are obliged to utilise them.

Immune Varieties :

Early Varieties—Edzell Blue ; Snowdrop ; Immune Ashleaf.

Maincrop—Great Scot ; Golden Wonder ; Abundance ; Ally ; Majestic ; Arran Comrade ; Arran Banner ; Kerr's Pink.

PINK ROT (*Phytophthora erythroseptica* Peth.).

Pink Rot is of importance only in wet districts where potatoes are repeatedly taken from the same soil.

Symptoms.—The cut surfaces of affected tubers become pink in a few minutes, when they are exposed to the air. At first faintly pink, the colour intensifies to salmon-pink after about half an hour. With continued exposure, the colour darkens gradually through purplish-brown to almost black. The fungus is present in stem and roots also, and causes an unhealthy appearance in the foliage.

This disease is carried from year to year by resistant spores which remain in the soil. The spores germinate and the fungus effects entry generally at the heel end of the tuber. The rot, which is firm, advances towards the 'sprout' end.

Control.—No variety is known to be immune. Diseased plants should be burnt. A lapse of at least four years is advisable between potato crops where the disease is prevalent.

WINTER or DRY ROT (*Fusarium caeruleum* (Lib.) Sacc.).

This is a disease which appears during the later months of storage. Darkened sunken patches gradually increasing in size mark the early phase of attack. The skin later becomes puckered and the pustules of fungus—usually white on the exterior, bluish-green within—are formed. On cutting the tuber, the tissue beneath the seat of infection is observed to be brown. As the rot advances the tuber becomes lighter and lighter owing to loss of moisture and may ultimately become a hard, dry, shrivelled mass. If bacteria and saprophytes (decay organisms) join in the attack, a wet rot supervenes.

Damaged potatoes are particularly susceptible, while sweating in the pit also encourages attack. Badly diseased tubers will usually be entirely destroyed by planting time. Partially diseased tubers used as 'sets' may either rot, or if they grow, yield but little.

Control.—Allow tubers to dry before storing; maintain the storage place well ventilated and cool; sprinkle powdered sulphur over the tubers as they are being pitted, at the rate of 2 lbs. per ton. Plant only healthy seed.

BLACKLEG (*Bacillus atrosepticus*, van Hall).

The haulm blackens and rots at the 'collar' or soil level. The underground portion of the stem becomes brown, and the heel end of the tuber may also be affected. Blackleg is favoured by warm moist weather. It appears from June onwards and, owing to the early death of the haulm, few tubers are formed. Infected tubers may rot in the soil or under storage conditions. The disease is regarded as being seed-borne.

Control.—The value of roguing out diseased plants is a controversial point, but if the attack is small it can do no harm and conceivably much good. It is recommended that about $\frac{1}{2}$ lb. Paris green be included in every 100 galls. of the spray mixture, if spraying be done after the removal of Blackleg plants. Dry, well-ventilated conditions during storage reduce the possibility of decay of affected tubers. Plant only healthy seed.

SKIN SPOT (*Oospora pustulans*, Owen et Wakef.).

Shallow circular depressions occur on the tuber with a slightly raised centre. The tuber may become very unsightly. The disease develops during storage. The fungus commonly kills the young sprouts and is a common cause of 'blanking.' Do not plant dubious sets. Arran Chief, King Edward, and British Queen are most susceptible.

MOSAIC and LEAF CURL.

These diseases belong to the virus group. The former is characterised by a mottling of the leaves, the latter by the leaf curling inwards towards the mid-rib. The leaves are generally crisp and break across if pressed between the fingers.

In both cases greenflies are active in the spread of the virus, and the infection is transmitted from year to year by tubers. Control lies in roguing out affected plants and their tubers during the growing season. If the majority are affected, purchase a healthy stock.

FLOWERS

While diseases of fruit-trees and vegetables have been fairly fully dealt with, it is not possible to give, in the compass of a work such as this, an account of more than a very few of the more important fungal diseases occurring on flowers.

HOLLYHOCK**RUST** (*Puccinia Malvacearum*, Mont.).

Complete defoliation as the result of attack by this rust is not uncommon. The familiar brown pustules occur on the under surfaces of the leaves. Particularly do specimens in sheltered parts of the garden suffer; those planted in open situations are not so strongly attacked. The virulence of attack may be reduced by collecting and burning leaves exhibiting the symptoms before the attack is widespread. In general, encourage hardy growth.

SWEET PEA**STREAK.**

Symptoms and Control as for **CULINARY PEA** (p. 28).

ROOT ROT (*Aphanomyces euteiches*, Drechsl.).

Symptoms and Control as for **CULINARY PEA** (p. 28).

ROSE

BLACK SPOT (*Diplocarpon Rosae*, Wolf).

Black Spot is of general occurrence and may cause considerable leaf-fall and associated loss of vitality.

Symptoms.—Irregular purplish-black spots are produced on the upper surfaces of the leaves, less often on the young wood, and occasionally on the petals. Bad attacks result in premature leaf-fall, and the plant is thereby much weakened. Thick-leaved varieties are seldom attacked.

Control.—Collect and burn from the plant and the ground all diseased leaves. Cut out affected wood. Apply 1—1—10 Bordeaux with the addition of $\frac{1}{2}$ lb. lead arsenate during June, July, and August.

MILDEW (*Sphaerotheca pannosa* (Wallr.) Lév.).

Mildew constitutes one of the chief fungal troubles of the rose grower. Young stems, thorns, leaves, and fruits are covered with the white powdery fungus, especially in a dry season. Ramblers, including Dorothy Perkins and Crimson Rambler, are particularly susceptible. Badly-infected plants may suffer from premature leaf-fall.

Control.—Flowers of sulphur constitutes a convenient and efficacious remedy, both outside and under glass, applied preferably when the leaves are damp. As a spray, lime sulphur 1—59 is an effective control.

RUST (*Phragmidium mucronatum* (Pers.) Schlecht.).

The under surfaces of the leaves exhibit orange-yellow pustules in the early part of the year; in the latter part black pustules are formed. Defoliation often results from severe attacks, and ultimately the plant may die.

Control.—Collect and burn infected leaves. Affected stems should be cut out and burnt.

VIOLA

RUST (*Puccinia aegra*, Grove).

The shoots of violas are often deformed as a result of Rust attack. Stems and the under surfaces of the leaves may be covered with the yellow pustules of the fungus. Lift and burn affected specimens to reduce centres of infection.

BULB DISEASES

SCLEROTIAL DISEASES

TULIP—

FIRE (*Botrytis Tulipae* (Lib.) Lind.).

GREY BULB ROT (*Rhizoctonia Tuliparum* (Kleb.) Whetz.
et Arth.).

SNOWDROP—

(*Botrytis galanthina*, Berk.).

NARCISSUS—

(*Ramularia vallisumbrosae*, Cav.).

(*Penicillium* sp.).

Small black fungal bodies—sclerotia—will be found on bulb scales, on the base of the old flowering stem, or in the tissues of the bulb or corm. The sclerotia of the different fungi range from the size of a poppy seed to that of a cabbage seed in some of the larger types. The resting bodies of *Penicillium* are pink in the case of narcissus and creamy-yellow in gladioli.

ROTS

TULIP—

SHANKING DISEASE (*Phytophthora cryptogea*, Peth. et Laff.).

Bulb somewhat wet and with a sweet smell.

YELLOW S (*Bacterium Hyacinthi*, Wakk.).

Bulbs have a bad smell and, if cut through, yellow stripes are apparent in the flesh.

Control.—Great care should be exercised in the selection of bulbs, and any diseased ones should be rejected. Store the bulbs in a cool, dry atmosphere. If disease is suspected, apply Kainit and basic slag—2 ozs. per square yard—at planting time. Dig up and burn all diseased bulbs, and apply quicklime or Cheshunt Compound to the infected soil under outdoor conditions. Sterilise, by steam or dry heat, soil under glass. Spraying of diseased plants is of little avail.

FOOT AND ROOT ROTTS

Foot and Root Rots frequently cause damage amongst herbaceous plants, including aster, calceolaria, petunia, phlox, stock, etc. While various fungi are concerned in those troubles, they are alike in that the resistant spores of the fungus overwinter in or on the soil where the diseased plants have grown. Unless the soil be sterilised by steam, formalin, or Cheshunt Compound, the next crop will again suffer. Once the disease has broken out, nothing will save affected plants, which should be removed and burnt. To prevent spread of the disease, those still healthy should be watered with Cheshunt Compound, at the rate of 1 pint of the solution per square foot.

DAMPING-OFF

All kinds of seedlings growing under unnatural conditions often succumb to this disease. Amongst the more common causes are overcrowding, excessive moisture, lack of air and sunlight, and the use of a contaminated water supply. Attack is caused by various fungi, the chief of which are *Phytophthora cryptogea*, *Pythium de Baryanum*, and *Rhizoctonia* spp. The stems become discoloured and constricted at soil level, and finally topple over.

Control.—Sterilise the soil by means of dry heat or steam where practicable, failing which one of the following may be used: formalin, Cheshunt Compound, or permanganate of potash. Add some potassium permanganate crystals to the water storage tanks just in sufficient quantity to give a pale pink colour to the water.

FUNGICIDES

(Their Preparation and Application)

Fungicides are substances designed to destroy the fungal threads or to prevent the germination of the spores. As such, they are frequently substances of a poisonous nature, and care should be taken to guard against harm to human beings and animals. For instance, hens or grazing animals should be excluded from the orchard after spraying, until rain has washed

away the fungicide. Utensils used for mixing the sprays should be reserved for that purpose alone, and on no account must water be given to animals, in tubs used in this connection. It must be remembered that spraying flowering plants during blossoming may have a deleterious effect upon bees and other agents of pollination, with associated reduction in yield of fruit. Summer sprays should be applied with a *fine nozzle*, to ensure a thin but uniform coating to all parts of the plant. Winter sprays frequently need to be applied with considerable force, when a coarser nozzle is indicated. The sprayer should be tinned internally. Though fungicides are in the main applied 'wet,' some are put on dry, e.g. flowers of sulphur.

BURGUNDY MIXTURE.—Burgundy Mixture is a trifle more expensive than Bordeaux, but on account of its easiness to make up it is generally to be preferred to Bordeaux, made with quicklime, for small jobs. It is commonly used as a 2 per cent. solution, and contains: copper sulphate, 8 lbs., washing soda, 10 lbs., and water to make 40 gallons. This quantity is sufficient for one acre of potatoes. The copper sulphate (bluestone) should be finely ground. It is dissolved in 35 galls. of water in a *wooden vessel*; the soda is dissolved in the remaining 5 galls. of water and the latter added slowly through a strainer to the former—stirring all the while. If a bright wire nail is coloured brown, this indicates that more soda is required. The mixture must not be allowed to stand, but should be applied forthwith.

BORDEAUX MIXTURE.—Bordeaux Mixture is made up in the same manner, but quicklime or hydrated lime replaces the soda. In the controls under the various subjects, the first figure refers to copper sulphate (lbs.), the second to quicklime (lbs.), and the third to water (galls.). The second figure in all controls where Bordeaux is mentioned, refers to quicklime, but should hydrated lime be employed, the amount must be increased by 50 per cent. *Hydrated lime* is not so variable in quality as quicklime; it is more easily made up and less liable to choke the spray nozzles. In addition, it is more readily visible on the plants and adheres more strongly. It causes less scorching than quicklime Bordeaux. Hydrated lime deteriorates unless kept in airtight containers. Though slightly more expensive, the advantages more than compensate for the additional cost.

LIME SULPHUR.—Since this spray is not easy to prepare it is usually bought as a concentrated solution to be diluted with water. It is a useful spray against mildews. By adding

lead arsenate or nicotine to the prepared spray a combined fungicide and insecticide is obtained. For Golden Drop and other sulphur varieties of gooseberry, it cannot be employed. Copper sprayers, unless tinned, should not be used for this spray or for ammonium polysulphide.

AMMONIUM POLYSULPHIDE.—Ammonium polysulphide is best bought ready for dilution. It is sold in various strengths, so that the amount of water recommended by the maker should be used. The spray fluid should contain 0.11 per cent. of polysulphide. The addition of *soft soap*—5 lbs. per 100 galls.—is sometimes advantageous. Ammonium polysulphide should be made up in a wooden vessel. The soft soap is made up *separately* in a little hot water, and added later. This spray is very useful in controlling mildews. It causes no discoloration of foliage or fruit. For this reason it is in favour for late application to gooseberry bushes.

SULPHUR.—Either as flowers of sulphur or finely-ground sulphur, this is one of the most easily manipulated and best fungicides for mildews. It should be applied when the leaves are damp. In greenhouses it is often vaporised for control of mildews.

WASHING SODA.—

Washing soda	. 1 lb.
Soft soap	. 2 ozs., or skimmed milk— $\frac{1}{2}$ pint.
Water	. 4 galls.

The water should be boiling and should preferably be rain water. Easy to make and cheap, this spray is much used against American Gooseberry Mildew. Its efficiency is much enhanced by the application of 2 per cent. caustic soda before the end of February, or a tar-distillate wash before the end of January. Such winter washes must on no account be used except during winter.

CALCIUM BISULPHITE.—A 2 per cent. solution (3 table-spoonfuls of the concentrated solution to 1 gall. water) is very effective for spraying the soil and the bases of plants affected with *Botrytis*.

TAR OILS.—Tar oils or tar distillates are now widely used as winter washes for the control of aphides and other insects by killing their eggs. They are undoubtedly of value too as fungicides. Applications must be made in December or January, when the buds are dormant, at a strength of 5-6 per cent.

COPPER SULPHATE.—A 0.5 per cent. solution (5 lbs. in 100 galls. of water) is sometimes applied to dormant trees to kill hibernating fungi. The addition of a little milk of lime to the solution is helpful in indicating what parts of the tree have been treated.

CAUSTIC SODA.—This used to be applied as a spray fluid on dormant trees and bushes to remove lichens and algae from the bark and also to kill certain forms of insect life. *Tar Oils*, however, have now largely replaced the caustic wash and serve both as fungicide and insecticide.

WHITE-LEAD PAINT.—Pruned surfaces and wounds in trees should be coated with the above to exclude wound parasites such as *Stereum purpureum*—the causal agent in Silver Leaf Disease. While in general, for woody tissues, white-lead paint is very serviceable in dressing wounds in certain soft-tissued plants, such as tomatoes, to prevent the entry of *Botrytis*. Formula for making :—

Mix together—White lead paste . . .	2 lbs. ;
Paste driers	2 teaspoonfuls ;
Linseed oil	2 tablespoonfuls ;
Add—Turpentine	2 tablespoonfuls,

and mix thoroughly.

SOIL STERILISATION

The chemicals referred to below accomplish what is scientifically designated 'partial sterilisation' of the soil. The aim of soil sterilisation is to kill bacteria and fungi present in the soil, capable of causing disease in plants. Sterilisation is practicable only under very intensive systems of culture such as in greenhouses and small areas in gardens.

Pots and boxes may be sterilised in steam or dry heat (2-3 hours). Seed-beds and potting soil can be sterilised by steam at a pressure of 80-100 lbs. Results more than compensate for the trouble and cost, if sterilisation be done thoroughly. If patches are left untreated or if contaminated soil is reintroduced, infection spreads more rapidly than ever through treated soil.

Various chemicals are in use for this purpose—**Formalin** being the most commonly used. A satisfactory strength is 1 pint of 40 per cent. formaldehyde to 12 galls. of water. The beds are first thoroughly broken up and then saturated with the formalin at the rate of 4 galls. per square yard. The treated soil is then covered with a tarpaulin for forty-eight hours in order to retain the vapours. About a fortnight should

elapse before the soil is planted. To sterilise pots, seed-boxes, etc., immerse in formalin (2 pints of formalin to 5 galls. of water) for about fifteen minutes; then cover with a tarpaulin for two days. Expose the pots or boxes for a day or two before using.

Permanganate of Potash is an old-time remedy for 'damping-off' and similar troubles. It is very effective and readily handled. As a preventive, spray the beds with a solution containing 1 oz. of Permanganate of Potash to 4 galls. of water. Double strength may be required if the attack has become bad. Permanganate of Potash is frequently added to water tanks used as the source of water for plants in order to kill water-borne organisms. Sufficient of the chemical should be added to give a slightly red coloration.

Cheshunt Compound has found great favour, of recent years, as a means of combating damping-off and foot rots—especially for tomatoes and seedlings. Formula for making:—

Copper sulphate . . .	2 lbs.
Ammonium carbonate . . .	11 lbs.

Both chemicals should be bought in finely-powdered form and mixed together in the above proportion. The mixture should be placed in an air-tight container and allowed to stand for twenty-four hours before using. One ounce of this powder is added to 2 galls. of water and applied direct to plants and boxes. This is a very effective soil fungicide and is not inimical to the plants. Plants already diseased will not be cured, but those still free of disease will be prevented from acquiring infection.

Corrosive Sublimate.¹—A 0.1 per cent. solution of corrosive sublimate or mercuric chloride—1 oz. to $6\frac{1}{4}$ galls. of water—is a useful control against Finger-and-toe in plants of the cabbage tribe. The chemical is somewhat difficult to dissolve, but the addition of an equal quantity of common salt renders it more readily soluble.

¹ Great care should be exercised in the handling of this material as it is highly poisonous to animals and man.

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THE USE OF CHLORATES IN
WEED CONTROL

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THE USE OF CHLORATES IN WEED CONTROL.

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AVOIDABLE losses of great magnitude are occasioned each year by weeds. As a result of age-long selection, weeds are better adapted to their respective environments than crop plants, which, to a considerable extent, are alien to the areas on which they grow. Unless the balance is constantly thrown against them by tillage operations, weeds gain the ascendancy. They cannot be exterminated altogether, but their numbers should be maintained at a minimum. Ordinary tillage operations incidental to cropping prove totally inadequate for the control of certain weeds. In former times bare fallowing was commonly resorted to, in order to rid land of such persistent weeds. It is still practised, but is very costly, especially when to the cost of cleaning operations is added the loss of a crop. Root crops offer an opportunity of extended intercultivation throughout the growing season, and are therefore valuable in repressing weeds. Smother crops are also useful in this respect. The potato crop combines the advantages of both these methods and is unsurpassed as a means of clearing land of weeds. It is not always expedient to employ any of the foregoing methods of control. Fouling crops may be dictated because of market considerations, or cleaning operations may be curtailed through bad weather.

In recent years, therefore, resort has been had to chemicals in the suppression of weeds, where orthodox cultural methods were not practicable. Copper sulphate, iron sulphate, kainit, calcium cyanamide and sulphuric acid have been used with success, particularly against annual weeds of corn crops. The efficacy of the herbicide depends on the fact that it adheres more readily to the rough broad leaves of the weed than to the smooth narrow leaves of the cereal. The latter may suffer initial check but they soon make recovery. The utilisation of selective weed-killers in corn crops has been attended with marked success, but heretofore no chemical has been available to render similar service against perennial weeds such as coltsfoot, couch, &c., without interfering seriously with the continuity of cropping. The experiments herein described were especially designed with the object of discovering to

what extent certain chlorates would meet this requirement. The scope of the experiment, however, was widened so as to include certain of the more important annual weeds.

The chief chlorates on the British market are those of sodium and potassium. They are obtainable either as powder or as crystals. When the weed-killer is broadcast, it is imperative that the powder be used, but even for applying as a solution it is preferable, since it dissolves so much more rapidly than does the crystalline form. Chlorates are marketed in 1 cwt. drums. The lid is generally screwed down, and the insertion of a rubber washer between the drum and its lid ensures that the container is airtight. This is a matter of considerable importance, since exposure to the atmosphere impairs the quality of the chemical.

Against chlorates it must be emphasised that there is a very definite risk of fire, if they are not handled with care. When admixed with finely divided organic matter (such as may be present in dust) or with sulphur, there is a risk of spontaneous ignition. The metal containers should on no account be dropped. It is almost impossible to spray weeds without wetting the clothing with the solution. Unless clothes so damped are washed immediately, before they dry, there is a serious risk of fire. Friction alone is sufficient to ignite such clothing once it has dried. It is advisable to wear rubber boots and raincoat during spraying operations, and the garments should be washed before the chemical becomes dry. It is possible to reduce the fire hazard of chlorates by the addition to them of certain inert substances; the efficacy of the chlorate is, however, diminished thereby.

Chlorates are generally represented as being non-poisonous. In these experiments animals have grazed in fields during and after spraying with chlorate, without harm. There is reason to believe that if animals are given access to the dry salt, they may eat sufficient to do themselves harm. Pails used during spraying operations should be washed before being used in connection with animals. A case of a horse being given water in a pail in which chlorates had been dissolved was reported to us; the urinary system of the horse was upset for several days. Compared with many other weed-killers, such as arsenic preparations, chlorates are practically innocuous.

Both sodium and potassium chlorates were used in the earlier trials. Early supplies were obtained in wooden barrels. The potassium salt especially tended to harden, and was much less soluble than the sodium salt. It was also rather more expensive, and since there appeared to be no difference in the potency of the salts, only sodium chlorate was used in later trials. Both on grounds of economy and efficacy, it was preferable to apply the chlorate in solution. It is difficult to effect uniform distribution of the powder, and a greater amount of the chemical

per acre is required to give equivalent results. The dry method of application is dependent for its success on a subsequent shower of rain. For widely scattered weeds in pasture the dry method may commend itself. Concentrations from 15 per cent downwards have been employed in the case of sodium chlorate. Potassium chlorate on the other hand is not so readily soluble, and a 2½ per cent solution was generally used. The amount of water does not appear to be an all-important factor provided that there is sufficient water to wet the foliage of growing weeds, or in the case of dormant perennials sufficient water to carry the chlorate to the underground organs. Experimenting with thistles on pasture, better results were obtained from spraying the foliage than from applications to the base of the stem. It was found easier to kill thistles in stubble than in pasture; in general, the less vegetation surrounding the weeds treated the more successful the treatment. It was found to be a decided advantage, in the case of weeds with strong underground organs, if the land were ploughed prior to spraying.

TIME TO APPLY.

Annuals and biennials can be treated at any time of the year, but where the land requiring treatment is to be cropped it is well to have as long a period as possible intervening between the time of application of the chlorate and subsequent utilisation of the land for crops. Chlorates will not kill weed seeds. For perennials, distinctly better results have been obtained when the chlorate was applied in September or October than when applied earlier or later. Moreover, since heavy dressings are required for weeds with well-developed underground stems or roots, a proportionately longer time is required for the land to be freed of residual effects of the chlorate. The time taken for the chlorate to decompose depends on the season. Heavy dressings made about mid-December were found to cause considerable damage to turnips sown on 21st May. The braird was decidedly thinner and the leaves pale. September dressings of equal amount, in another experiment, were effective against the weed treated and were in no wise harmful to the subsequent turnip crop. Potatoes and cereals are much more tolerant of the residual effect of chlorate.

It will be observed from the table that the lethal dose of chlorate varies within rather wide limits, depending on the type of weed. Early experiments were designed to afford only a rough guidance as to the amount of chlorate necessary for extermination of each species. Further trials were conducted for each weed at as many centres as possible in order to find the lowest effective dressing. All figures quoted in the table relate to the 'wet' method of application. In most cases the chlorate was applied as a 5 per cent solution by means of a watering-can with rose attachment. The

figures refer in almost all cases to experiments carried out on Aberdeenshire soils—in these experiments the soils varied from light to heavy loam.

TABLE.

Species.	Sodium chlorate. Lbs. per acre. Minimum effective dressing.	Remarks.
COMMON CHICKWEED. <i>Stellaria media</i> . L.	15	Action somewhat slow but ultimately successful.
SPEEDWELLS. <i>Veronica</i> spp.	20	—
CRESS. <i>Lepidium</i> spp.	20	—
GROUNDSEL. <i>Senecio vulgaris</i> . L.	30	Action slow but ultimately successful.
WILLOWHERBS. <i>Epilobium</i> spp.	50	—
CREEPING BUTTERCUP. <i>Ranunculus repens</i> . L.	50	Not subject to special experiment but occurred in some plots.
KNOTGRASS. <i>Polygonum aviculare</i> . L.	100	—
COMFREY. <i>Symphytum officinale</i> . L.	110	—
COLTSFOOT. <i>Tussilago farfara</i> . L.	150	100 lb. kills greater part of coltsfoot.
COUCH. <i>Agropyron repens</i> . Beauv.	150-200	Amount of chlorate required varied rather widely at different centres.
COMMON NETTLE. <i>Urtica dioica</i> . L.	150	—
CHERVIL. <i>Anthriscus cerefolium</i> . Hoffm.	150	—
CREEPING THISTLE. <i>Cirsium arvense</i> . Scop. <i>In pasture.</i>	250-350	Dressing required depends on type of soil, size of plants and amount of grass.
<i>Land ploughed prior to application.</i>	200	Note much reduced dressing required after ploughing.

Species.	Sodium chlorate. Lbs. per acre. Minimum effective dressing.	Remarks.
LESSER CELANDINE. <i>Ranunculus Ficaria</i>	270	—
SHEEP'S SORREL. <i>Rumex acetosella</i> . L.	400	Very resistant. Apply 200 lb. per acre, then 2nd and 3rd dressings of 100 lb. each at monthly intervals.
DOCKS. <i>Rumex spp.</i>	400	do.
BISHOP'S WEED. <i>Agopodium podagraria</i> . L.	500	Very resistant. Even this very high dress- ing did not entirely kill out the weed.

Where there is an admixture of weeds it is probably wise to make a light preliminary application to thin out the vegetation in order that the chlorate can afterwards be concentrated on the areas bearing the more resistant weeds. The trials on comfrey were probably the most spectacular of the series. The experiments were conducted on two separate fields. Preliminary trials were carried out on a six-acre field which the comfrey had so completely fouled that the proprietor, a nurseryman, had given up the idea of cropping altogether. The results were so promising that about an acre of the field was given up to experimentation the following year. The owner was so impressed with the preliminary results that he embarked on a spraying programme for the remaining five acres without awaiting the fuller results. Both sodium and potassium chlorates were used on the experimental area, on separate plots, and dressings of 110 lb. per acre of both chlorates entirely eradicated the weed. The major part of the field received 130 lb. per acre and complete control was secured. The applications were made in November and the field was planted with potatoes about the beginning of April. The chlorate was applied at a date which in the light of later experience was too late; notwithstanding this, however, the potatoes were unaffected by any residual effects from the chlorate. A more comprehensive account of these experiments appears elsewhere.¹

¹ See Reference—page 8.

DISCUSSION OF RESULTS.

The potency of both sodium and potassium chlorate against weeds has been clearly demonstrated. Chlorates disappear from the soil in a reasonably short time, and, provided that application is made in September or October, decomposition of the salt takes place during the dormant period, so that there need be no interference with the continuity of cropping. This represents a great advance on eradication by arsenical weed-killers, the effect of which lingers in the soil for a much longer period, not to mention much greater danger of poisoning. It appears that price alone will determine the future rôle of chlorates in weed control. When the experiments were commenced the price of sodium and potassium chlorates was 30s. and 33s. per cwt. respectively. The price is now in the neighbourhood of 40s. per cwt. for both chlorates. Autumn applications have proved to be distinctly superior to those made in spring or summer, both on grounds of efficacy and expediency. Chlorates are much more effective applied as a solution than in the dry form, and the amount required per acre to kill any given weed is considerably less. They can be used to free weed-dumps, in market gardens and on farms, of noxious weeds which prevent the utilisation of large quantities of soil. Because of their relatively harmless nature when applied in solution they present a ready means of ridding edges of fields and other inaccessible places of weeds. On the Continent and in America extensive use has been made of chlorates by railway companies in the control of weeds along permanent ways. The London Midland and Scottish Railway Company has recently been experimenting with this method of weed control along the track. Municipal authorities will probably also find chlorates of value in suppressing weeds on sand and cinder paths. Chlorate provides a simple yet effective means of removing weed herbage from areas intended for lawns. If the treatment is made in autumn, the seeds can be sown without risk the following spring. The seeds of the weeds, of course, will not have been killed, but removal of the resultant weed seedlings is an easy matter if this is done before they grow too large.

A potato sprayer, temporarily converted to give a coarse and downward spray, provides a satisfactory means of application. For small areas an ordinary watering-can with rose attachment is suitable. An application of $1\frac{1}{2}$ -2 cwt. per acre (in solution) is a good general dressing. For convenience of application it may be stated that 1 lb. of sodium chlorate dissolved in 2 galls. of water constitutes a 5 per cent solution. If this amount of solution is applied to 24 square yards a dress-

ing of about 200 lb. per acre will have been given. Lesser or greater applications can readily be calculated from these figures. For example, if it is desired to apply 100 lb. per acre, only $\frac{1}{2}$ lb. of chlorate will be dissolved in each 2 galls. of water and applied to 24 square yards. Risk to animals grazing in fields where weeds have been sprayed is negligible. At the same time, if it is convenient, it is better to remove them until the herbage has been washed by rain.

There is a very definite fire risk with chlorates: calcium chlorate is less subject to fire risk than the sodium or potassium salts, but was not readily obtainable when required for these trials. It is not, therefore, possible to give first-hand facts relating to its potency as a weed-killer. With the exercise of reasonable care, no trouble need be experienced in using chlorates. Having apprised an intelligent worker of the precautions required in handling these substances, it is wise to vest control of spraying operations in him, in order to avoid mistakes by the uninitiated.

SUMMARY.

1. The value of sodium and potassium chlorates as weed-killers has been demonstrated for a number of annual and perennial weeds.

2. Application in the form of a solution is most effective. The amount of water is not a matter of great importance provided uniform distribution is secured. A 5 per cent solution (5 lb. to 10 galls. water) is a convenient strength for sodium chlorate and half that concentration for potassium chlorate.

3. There is a definite fire hazard in the use of chlorates. Instructions as to handling are given, and if these are followed no trouble need be experienced.

4. For perennials, autumn (September and October) applications give decidedly better results than those made in spring or summer.

5. The efficacy of the chlorates is much enhanced in the case of perennial weeds if the soil is ploughed prior to making the application.

6. The chlorates decompose during the winter, and it is possible to proceed with normal cropping in spring. If application be made too late, there is a risk of the subsequent crop suffering from residual effect of the chlorate.

7. Chlorates are generally regarded as non-poisonous. This statement should not be taken too literally, however, and drinking pails should not be put before animals, if they have contained chlorate, until they have been thoroughly washed out. There is probably no danger in leaving the animals

on a pasture which has been sprayed. At the same time it is better to remove them, if possible, until rain has fallen.

8. The future rôle of chlorates in weed control must ultimately be governed by their price.

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WILD WHITE CLOVER VARIETIES.

By S. P. MERCER, B.Sc. AND D. CLOUSTON, M.A., B.Sc.

Since the latter part of last century, when the use of white clover seed harvested from long established plants first found favour in Great Britain, two questions have formed the basis of lively controversy; what is the difference between wild white and cultivated white clover, and: how may plants or seeds of the two sorts be distinguished? More recently a third has been added; do wild white clovers from different seed producing centres differ in value? These three questions are, in fact, all forms of the same question.

Everyone recognises that wild white clover is more “ permanent ” than the cultivated form and that it makes a better “ bottom ” to a turf, but it is perhaps not generally realized that these two things are really the same thing, or two manifestations of the same character. The good bottom is the result of strong “ stooling ” or “ tillering ”—that is, the short central stem develops side branches strongly and these, creeping like strawberry runners, take fresh root at intervals and thus give rise to daughter plants. It is also this strong development of runners which gives “ permanence ” for it is the daughters which carry on the life of the plant and in their turn produce grand-daughters to carry it still further. The major branches may separate off as independent plants (a process promoted by the commendable practice of rolling) but the original central roots and primary stem do not themselves persist indefinitely. The tendency to tiller is a matter of genetical constitution—a matter of variety, as oat growers well know.

Wild white and cultivated white clovers are thus only varieties of the same plant, exhibiting similar characters but having these developed to different degrees. Botanically, there are no absolute characters by which one may distinguish either the seeds or the plants. Consequently, attempts to diagnose single seeds or single plants are hazardous. In bulk, it is possible to classify a crop or a seed sample with fair accuracy by observing the *average* development of the varietal characters. The most prominent of these may be summarized as follows:—

	<i>Ordinary White "Dutch" Clover.</i>	<i>Wild White Clover.</i>
<i>Habit.</i>	Less creeping. More upstanding. Less hardy and shorter lived.	Extensively creeping. Hardier and longer lived.
<i>Leaves.</i>	Lighter coloured. Larger. Stalks longer and more erect.	Darker. Smaller. Stalks shorter and more prostrate.
<i>Main stem.</i>	Thicker. Occasionally bearing flowers.	Thinner. Seldom bearing flowers.
<i>Branches.</i>	Fewer. Rooting sparingly.	Numerous. Rooting very freely.
<i>Flowers.</i>	Earlier. More numerous. Larger. Stalks longer.	About a fortnight later. Fewer. Smaller. Stalks shorter.
<i>Seeds.</i>	Larger. Flatter. Brighter coloured. Less "hard" seeds. Characteristic weed seed impurities.	Smaller. Plumper. Lighter. Duller colour. More "hard" seeds. Characteristic weed seed impurities.
<i>Seedlings.</i>	Seedlings of wild white usually evolve prussic acid gas more readily than those of Dutch white. We have found this a useful confirmatory test for seed in bulk, but too unreliable to be regarded as diagnostic.	

It is clear that the average development of wild characters in a crop (and we may for this purpose group the various characters together as one, and call it "wildness") depends upon the *proportion* in which individuals with much wildness and individuals with little wildness are mixed. The difference, then, between our two varieties, is that wild white contains a *high proportion* of individuals with much wildness and Dutch a *small proportion* of such individuals. And this leads to another vexed question—the difference in value, if any, between "old pasture" and "once grown" wild white.

Now one of the characteristics of "wildness" is shyness in seed production. The cultivated plant seeds more freely than the wild plant. Hence, if a mixture of wild and cultivated types be sown, harvested while still young, re-sown, again harvested, and so on, the proportion of seed of the "cultivated" type will gradually increase. It has been pointed out that true wild white is a mixture of such types, but with a very high proportion of the "wild" individuals. By repeated sowing and harvesting while young, it will, therefore, be caused to lose its wild character—that is to say, the proportion of wild individuals will be decreased. This is, in fact, what has happened in the development of "Dutch" white itself; its original parents were, of course, truly wild. White clover is practically self sterile, and since the wild and Dutch types have been found to cross freely under experimental conditions, it is inevitable that on arable land, a proportion of the plants in a wild white crop will be pollinated by Dutch white plants growing in the vicinity. If, however,

the stock sown in the first place was harvested from an old sward, from which the short lived plants had largely died out, the proportion of "wild" individuals would be very high, and by simply growing and harvesting this mixture *once*, the resultant seed would still be mainly wild.

Influence of Country of Origin.

It will be clear from the foregoing that the farming practice in a given area may, in the course of years, materially influence the character of a stock of seed. A familiar instance is to be found in the short-lived character of East Anglian sainfoin compared with the much more permanent Hampshire type. The latter has been "automatically selected" for longevity by the practice current in Hampshire of leaving it down for some half-dozen years before harvesting it for seed. It is, therefore, necessary to test produce from a new country of origin, before accepting it as the equivalent of the native strain; it may easily be different in character from the agricultural point of view—it may be more useful, or less. Wild white clover harvested in New Zealand has of recent years appeared on British markets at a tempting retail price, and the trials here described have been carried out to compare its value, for Northern Ireland farming purposes, with English and county Down stocks.

Method of Trial.

For several seasons the wild white samples received for routine testing by the Seed Testing Station were sown in pots and in garden plots. Ample evidence of material variation in character of produce was shown. Preliminary field tests were made in 1924, at two centres, to compare the performance of three brands of seed: Kentish, New Zealand seed obtained through official channels, and New Zealand seed obtained direct from a New Zealand farmer. In this instance the three samples were tested for purity, germination and weight, and the amounts sown were carefully adjusted to provide the same number of germinating seeds per acre from each sample. The differences observed on these plots in 1925 were relatively small, but it was considered that they were sufficient to justify the laying-out of a more extensive series of trials. In 1926, 1927 and 1928, therefore, plots were sown at centres distributed widely over Northern Ireland, as great a variety of soils, aspects and elevations as possible being used. The sources of the seed used are indicated in the table of results. In each case the clover was sown down in spring with a grass mixture known to be sound for the district concerned. All plots were half-acre in size and the clover was sown at a rate of one pound per statute acre. When the ger-

mination capacities of the stocks used in a given year differed materially, the poorer quality was compensated by sowing at an increased rate. No notice was taken of small differences.

The seed was tested in the official seed testing station, and weighed amounts issued thence to county instructors in agriculture and to agricultural overseers,* who kindly undertook the supervision of the sowing and the subsequent management of the trials. The treatment given in each case was that in ordinary use in the district. The common practice in most areas is to take one hay crop from new "seeds," followed by two or three years' pasture. In a few instances two hay crops were taken.

Judgment of Results.

Visits were paid in the summer or autumn and the plots judged by three or four observers—the county instructor and in the case of an overseer's plot, the overseer, and the authors. Each plot was awarded marks out of a maximum possible of 10. In judging, an attempt was made to award marks for wild character, that is to say, attention was chiefly paid to profusion and vigour of tillering, to sole forming capacity and winter hardiness, rather than to such characters as herbage productivity, since the latter would be more pronounced in any strain having a tendency towards the Dutch character. Judging of the pasture *as* pasture was avoided for this reason, and in point of fact many plots received high marks, which were not first class pasture because they had too much clover in them. Longevity was considered to be covered by profusion in the later years. Small errors might arise through self-seeding in the early years, but it is believed that any such errors were negligible, and that judgments agreed upon by the observers are, within narrow latitudes, reliable. It was not, in practice, found that mark assessments often differed by any material figure—differences between plots were usually clear and distinct. Details of the trials are collated in the tables (pp. 5-6). The plots have there been grouped so as to bring together, respectively, those sown in the same years, and those sown with seed from similar sources. It was recognised by the authors that seed of several distinct types was produced in New Zealand, but for the purpose of this trial no attempt was made to use only seed known to be of the best type, since the intention was to test the suitability of the produce ordinarily met with on our own market.

* We wish to acknowledge, gratefully, the help of the Itinerant Instructors in Agriculture and the Agricultural Overseers in each county, without which these trials could not have been conducted.

TABLE I.

PLOTS SOWN 1927 (" OFFICIAL " NEW ZEALAND SEED.)

In the Marks Column, E=Kentish, I=County Down,
NZ=New Zealand.

District.	County.	Soil.	Marks.			Remarks.
			E.	I.	NZ	
Aghacully	Antrim	Light Loam	7	9	2	Other clovers not succeeding in mixture.
Portnelligan	Armagh	"	10	6	4	NZ patchy. Larger in leaf than E. or I.
Ballynure	Antrim	Wet	0	0	0	Oats lodged badly. No hay crop. Clover total failure.
Larne	Antrim	Strong	5	-	5	No Irish sown; E and NZ both patchy. Field badly poached.
Dungiven	Derry		9	7	4	Rest of field, sown with Dutch clover, given 3 marks.
Park	Derry	Poor	7	6	4	All plots patchy through lodging of oats.
Loughgilley	Armagh	Loam with stones	6	2	0	Weedy. Much ox-eye daisy.
Tullyearnett	Down	Wet	8	6	2	Much suckling clover in Irish plot. Much horsetail.
Portnelligan	Armagh	Friable stony	8	7	4	Hayed two years. Irish plot poorer land.
Tullyvallen	Armagh	Blackish friable	6	6	2	Second year hay. English patchy.
Plumbridge	Tyrone		8	7	3	Weedy. Only ryegrass sown with clover.
Broughshane	Antrim	Poor	6½	6½	3	Clover on NZ plot only around droppings.
"	"	Light Poor	6	5	1	Weedy. Poached in spring of second year.
"	"	Poor	6	7	4	Second year hay.
"	"	Poor	6	6	4	Second year hay.
Rostrevor	Down	Poor stony	6	4	1	All plots weedy. Much bent and hair grass.
Hilltown	"	Rich	7	9	4	Rest of field (sown with English W.W.C.) not so good as Irish.
Dromore	"	Stony loam	8	6	2	Gravelly subsoil.
Banbridge	"	Medium on Clay	-	-	-	Grazed one year and ploughed up. Grower reports only English good. Now in oats. Only English plot lodged.
		AVERAGE	6.6	5.9	2.7	

TABLE II.

**PLOTS SOWN 1926 AND 1928 (COMMERCIAL
NEW ZEALAND SEED.)**

In the Marks Column, E—Kentish, I—County Down,
NZ—New Zealand.

District.	County.	Soil.	Marks.			Remarks.
			E.	I.	NZ	
Sown 1926						
Strabane	Tyrone	Shallow on Clay	6	7	2	NZ plot wettest. Irish driest and best grazed. Bird's foot trefoil prominent on NZ plot in early stages.
Aughacessy	„	Clay Loam	7	7	3	Conditions very uniform. NZ distinctly larger in leaf.
Ballynagor	Antrim	Retentive	2	2	2	Field very wet.
Finvoy	Antrim	Medium loam	8	7	1	Little difference in early stages. NZ failed badly in second year.
Killylea	Antrim	Stony loam	7	4	2	Irish plot very wet. Indigenous white clover common here.
Coleraine	Derry	Medium loam	8	7	2	Summer grazing estimated worth £1 p.a. less on NZ than on E or I. Irish slightly smaller in leaf than English.
Limavady	Derry	Heavy	8	7½	2½	NZ disappearing. Difference very slight between E & I.
Mullabawn	Armagh	Good potato soil	10	7	4	Whole field rather weedy but evenly grazed.
Park	Derry		10	9	—	No NZ sown. English slightly superior at south end of plot.
Dunadry	Antrim	Heavy	10	10	10	If any difference NZ slightly best. Heavy oat and hay crops on I plot lodged. (Soil deeper than other two plots).
Markethill	Armagh	Heavy retentive	7	6	5½	Differences slight. Irish plot much damaged by carting.
Killyleagh	Down	Light loam	8	7	3	Marked effect on grass development in E and I plots.
Newtownhamilton	Armagh	Poor	6	4½	—	Badly infested with ragwort.
„	„	„	6	5	—	Clover poor on both plots in 1st and 2nd years.
Glenarm	Antrim	Poor stony	8	8	—	Never grazed. Weedy. Clover somewhat irregular in both plots.
Carnalbanagh	Antrim	Poor	4	4	0	Two years hay, one pasture. NZ reported strongest in first year's hay.
Broughshane	Antrim	Fairly strong	9	9	—	Three years' hay.
		AVERAGE	7.3	6.5	3.1	
Sown 1928.						
Killinchy	Down	Light	½	—	½	Nearly pure ryegrass.
Killinchy	Down	Poor	3	—	0	Whole field badly infested with suckling clover.
Tandragee	Armagh		9	—	2	Grass distinctly yellow on NZ plot.
Hilltown	Down	Shallow stony	8	—	3½	No Irish sown. Both plots weedy. Mixture mainly perennial. Rest of field sown with Dutch, marked 2½.
Hilltown	Down		9	—	5	In early stages NZ appeared better, but has fallen off. Now irregular. Bigger leaved type.
Katesbridge	Down		8	—	4	NZ distinctly bigger in leaf and flowerhead.
		AVERAGE	6.3	—	2.5	
TWO YEAR AVERAGE, 1926 & 1928			7.0	6.5	2.9	
GENERAL AVERAGE 1926, '27, '28			6.9	6.2	2.8	

It was pointed out by Stapledon in 1927 that bulking of produce likely to be long-lived, and produce likely to be short-lived, was frequently practised in the preparation of New Zealand seed, and it is probable that the commercial seed used by us was of this

mixed character. The examination of weights for standard numbers of seeds, and of the cyanophoric (prussic acid forming) capacity gave inconclusive results. As they stand, the figures seem to call for little comment. It will be borne in mind that in this country wild white very seldom produces any appreciable bulk of herbage in the first year, and that an added difficulty crops up in judging first year plots by reason of the rather heavier herbage production in the early stages from plants of a Dutch type. For these reasons the marking of plots during their first year was found less satisfactory and less definite than markings in later years when distinctions became much more obvious. It did not appear that any vitiation of results arose from the development of voluntary wild white plants from seed already in the land, as will be seen from the figures below (p. 8) where a comparison is made of the average marks given to one year, two year, three year and four year old swards, respectively. In this connection, the probable tendency for all strains to level up as a turf ages, must be borne in mind. This would be the natural result of the fact that the various strains are mixtures of long-lived and short-lived types. As the years proceed, the few long-lived plants produced by the poorer strains would have an increasing chance of covering the ground. It is perhaps for this cause that the marks earned by four year old swards show rather less advantage to the British strains than those awarded to second and third year leys, although the average difference between British and Antipodean is still wide.

Soil and Climate.

From an examination of the groups assembled in the tables it will be seen that soil and season appear to affect the general relative values of the three types little, and that, in the enormous majority of cases New Zealand seed produced, at no stage, results comparable with British. The topographical aspect of the plot was noted in each case but it was not found that any definite relation was shown between aspect and clover development, nor did the question of northerly or southerly slope appear to influence winter hardiness. No statement of aspect is, therefore, included in the tables.

Source of Seed.

The English seed was, in all cases, of Kentish origin, and was purchased on the Belfast market. The Irish seed was obtained direct from growers in the Ards district of the county Down. The New Zealand seed sown in 1927, was obtained from an official source in New Zealand, while in 1926 and 1928 commercial New Zealand seed was purchased on the market. In any one year, all seed used of the same strain was from the same actual

bulk. Inspection of the partial and general averages shown in the tables makes it clear that the value of "official" New Zealand seed and that of the commercial New Zealand produce was much the same by comparison with British strains.

Assembling the appropriate averages shown in the main tables, so as to compare official and commercial New Zealand seed, respectively, with the British strains, the following figures are obtained :—

- 1927 *Sowing*. (Official New Zealand seed)—First, second and third year inspections grouped together—Average marks out of 10 :
 Kentish, 6.6. Co. Down, 5.9. New Zealand, 2.7.
- 1926 *Sowing*. (Commercial New Zealand seed)—First, second, third and fourth years grouped together :
 Kentish, 7.3. Co. Down, 6.5. New Zealand, 3.4.
- 1928 *Sowing*. (Commercial New Zealand seed)—First and second years grouped together :
 Kentish, 6.3. New Zealand, 2.5.

Development with age.

If the figures be grouped in another way, so as to bring together the results shown at various ages, as below, it will be seen that the relative positions of the three brands under trial remain much the same throughout, and that, at least up to the fourth year, the two British types remain well ahead of the Antipodean.

TABLE III.

Year of Inspection.	Approximate Age.	Marks out of 10.		
		English.	Co. Down	N.Z.
First	15 months	5½	5½	2½
Second	28 months	7½	6½	3
Third	40 months	7	6¼	2¼
Fourth	52 months	8	8	4½

It will be observed that a slight drop in average marks was quite unconsciously recorded during the third year and that in all other cases a steady advance in average marks was registered by each strain, the advance in the fourth years being most marked in the New Zealand plots. We think that in view of the points previously mentioned, these facts lend support to the validity of the system of judging.

General.

In view of the uniformity of relative position from the various

view points examined, it is only to be expected that if all figures are grouped together, irrespective of age and source, a similar relative position will result. Treated in this way the marks scored are as follows :—

Kentish, 6.9. County Down, 6.2. New Zealand, 2.8.

In view then, of all these considerations there seems little doubt that British strains are distinctly superior to the New Zealand strains at present on the market, for use in Northern Ireland, and that there is little to choose between Kentish and county Down types in those years when the latter is available. It may be noted that when obtainable, Irish seed is usually cheaper than English, but commonly contains a somewhat higher proportion of "hard" seeds and is frequently of rather lower germination. Usually, however, the difference in price in favour of Irish seed more than covers the discrepancy in germination value.

Summary.

1. Trials have been conducted on a variety of soils and in situations widely distributed over the six counties, for the purpose of assessing the relative merits of Kentish, County Down and New Zealand strains of wild white clover, when grown under Northern Ireland conditions.
2. The Kentish and Northern Ireland (county Down) strains have given materially better results in practically every case than the New Zealand produce. On the average there was little to choose between English and Irish types. Average marks awarded out of a maximum ten : Kentish, 6.9 ; Co. Down, 6.2 ; New Zealand, 2.8.
3. In growth, a tendency towards a "Dutch" character was frequently noted among the New Zealand clover. Similar evidence was obtained from pot and garden trials on routine samples received at the Seed Testing Station.
4. Soil, altitude and aspect seem to affect the relative values of the three types tried, very little.

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THE USE OF CHLORATES AS WEED ERADICATORS

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It is not necessary to emphasise the importance of weeds. The nation loses each year millions of pounds through "the plant which grows out of place." Crop plants are in the main alien to the areas on which they grow, and are not well equipped to withstand the vigorous competition of weeds which, as a result of long selection, are peculiarly well adapted to their respective environments. Indeed, it is only by maintaining eternal vigilance and exercising all his ingenuity that the cultivator can prevent weeds from gaining the ascendancy.

While absolute extermination is impossible, it is essential that their numbers should be kept at a minimum. Cultural operations, since time immemorial, have been the chief means of holding weeds in check. Annuals and biennials are readily killed by mere reversal of the sod; so too are some perennials. Many of the latter, however, by reason of strong development of underground organs and associated food reserves, are capable of withstanding the most drastic cultural methods of eradication. Indeed, far from reducing infestation, many of the modern implements devised for extreme pulverisation of the soil, lend themselves to dissemination of perennial weeds, since each part detached is capable of becoming an independent plant. Bare fallowing was commonly resorted to in the past to rid land of weeds. This method is still practised but is very costly, especially when to the cost of extermination is added the loss of a crop.

It is not always expedient to employ the foregoing methods of control against weeds because of economic, rotational or climatic considerations. Harrowing, hoeing or other operations involving the movement of soil and the employment of much labour are necessarily expensive. The growing of crops with an innate tendency to foul may be dictated by situation and markets. Yet again, the weather may not permit of the usual cleaning operations at the proper time. For these and other reasons, resort has been had in recent years to chemicals which are particularly useful for the destruction of weeds growing amongst cereals where the orthodox cultural methods are of limited use. Copper sulphate, iron sulphate, kainit, calcium cyanamide and sulphuric acid are probably the best-known herbicides. These chemicals are referable to two groups: (a) those such as kainit, which in addition to being herbicides possess a manurial value; (b) those such as sulphuric acid,

which are solely weed-killers and a dead loss apart from any control which they exert over the weeds. Kainit and calcium cyanamide are applied in the form of a very fine dust; the others are sprayed on in solution. The efficacy of these chemicals depends on the fact that they are selective in action. Cereals are narrow-leaved and smooth and, as a result, do not retain much of the chemical, whereas weeds which respond well to this treatment have broad, rough leaves, to which the weed-killer adheres. The weeds are killed while the cereals are not seriously injured. The cereals may suffer initial check but they soon make recovery. Those chemicals have undoubted value for the eradication of weeds like charlock, and have not been exploited to the full.

Though a considerable measure of success has attended the search for chemicals capable of eradicating certain annual and biennial weeds, none has been found heretofore which will destroy coltsfoot, couch and other persistent perennials, without interfering with the continuity of cropping. Such a substance, could it be discovered, would prove of immense value, especially to market gardeners and others practising specialised types of farming prone to fouling. It was with a view to ascertaining how far certain chlorates would meet this requirement that the experiments hereafter described were undertaken in 1930, after certain preliminary work in 1929.

Chlorates are not poisonous in the ordinary sense; nevertheless care should be exercised in handling them, and pails or other utensils which have contained chlorate in the course of spraying operations should be washed carefully. Cattle have grazed without harm in a field in which extensive areas have been sprayed. Moreover, it was observed that the animals concentrated on the sprayed part, and ate considerable quantities of the sprayed weeds. There may be some risk attaching to the use of the chlorate if the chemical is sown in a lumpy state and the animals permitted to eat much of the concentrated salt.

Against the use of chlorate, it must be emphasised that there is a very definite risk of fire, especially when it is admixed with acids, sulphur or finely divided organic matter such as dust. For this reason chlorates must be stored in such a way that no dust gains entry. Manufacturers have recently adopted the commendable practice of putting out chlorates in metal containers. On no account must these be dropped when handling, as there is risk of spontaneous ignition. It is almost impossible to spray weeds without wetting the clothing with the solution. Unless clothes so damped are washed immediately, before they become dry, there is serious risk of fire. Friction alone is sufficient to ignite such clothing once it has dried. It is advisable to wear rubber boots and a raincoat during spraying operations. Certain inert substances, notably calcium, sodium or magnesium chloride, are sometimes added to chlorates to reduce the risk of fire.

In the experiments here outlined, both sodium and potassium chlorate were used in the earlier trials; little difference was noted in their potency as weed-killers. The early supplies of chlorates were obtained in wooden barrels, and trouble was experienced through the chemical hardening to such an extent that it could be dissolved only with difficulty.

The relative advantages of "wet" and "dry" applications were tested. The "wet" method proved superior both on grounds of economy and efficacy. It is very difficult to distribute small quantities of the powder evenly over large areas; moreover, the chlorate must be dissolved before it operates. Dry applications are dependent, therefore, on a subsequent shower of rain. Where widely scattered weeds are being treated in pasture or among other crops, it may be convenient to adopt the "dry" method.

The efficacy of chlorates is directly proportional to the amount of the salt applied per acre. In the experiments described, lethal doses, depending on the weed treated, ranged from 15 to 500 lb. per acre. Concentrations from 15 per cent. downwards have been used with success. It does not appear to be a matter of great importance what concentration is used, provided sufficient water is available to wet the foliage of growing weeds, or to carry the chlorate to the underground parts of dormant perennials.

Spraying has been conducted under diverse weather conditions. It is desirable that at least a short, dry period should follow the spraying, if it is the foliage of the weed that is being sprayed. Rain following spraying, in the case of dormant perennials, is beneficial rather than harmful. It was found, on experimenting with thistles in pasture, that better results followed from wetting the foliage with a fine mist from a sprayer than from applications to the base of the stem. The chlorate applied to foliage is no doubt carried through the vascular (circulatory) system of the plant more economically than that applied at the base of the plant, when some wastage occurs by diffusion in the soil. There is a temptation to burn the dead foliage of the weeds after it has frizzled up. By so doing, however, a certain amount of chlorate is burnt with the stem and is thereby wasted. It was observed that the more vigorous the herbage surrounding the weeds treated, the poorer the results; thus it is easier to kill thistles on fallow or stubble than in pasture. *In spraying perennial weeds, the foliage of which had died down, it was found to be a decided advantage if the land were ploughed prior to spraying.*

Time of Application.—Applications have been made at all times of the year. For annuals of course, treatment must be given when they are in growth; for these, therefore, applications can be made at any time that fits in with the general operations. *Chlorates are not lethal to seeds.*—In the case of perennials, it has been our experience that applications are more successful when made in the autumn than at other times, although on theoretical grounds it

might be expected that better results would be obtained when the weed was at the height of its physiological activity—*i.e.* in summer. Moreover, if the continuity of cropping is to be undisturbed by the eradication of weeds, it is well that winter should follow the application.

The time taken by the chlorate to decompose and disappear from the soil varies with the amount applied, the amount of rainfall, and probably with the type of the soil. If there is little rain during the winter, there is a risk of the residual effect of the chlorate causing harm to the subsequent crop. In the case of an application made on 12th December, followed by a somewhat open winter, it was found that the turnips sown on 20th May suffered rather badly, especially on the plots receiving the heavier dressings. In the case of another experiment where the amount of chlorate ranged from 50 to 300 lb. per acre, no deleterious effect was observed on the subsequent potato crop, planted early in April. Cereals appear to be equally tolerant of the after effects, and grasses recuperate in 2 to 3 months after applications of 200 lb. per acre. Where the dressings are heavier the time of recuperation will be proportionately greater.

As the amount of chlorate necessary to kill different weeds varies within wide limits, it will be convenient to describe the trials with the various weeds separately.

COMMON CHICKWEED (*Stellaria media*, Vill.)

An ideal opportunity of testing the efficacy of chlorates on chickweed was provided in a large garden where a pure crop was flourishing. Five plots, each 48 square yards, were marked out on 25th November 1931, and sprayed by means of a watering-can with a solution of sodium chlorate, at the following rates per acre: 5, 10, 20, 40 and 80 lb. respectively. On the plot receiving 5 lb. per acre the weed was scarcely affected; on the 10 lb. per acre plot a fair proportion of the chickweed was killed; while on the 20 lb. per acre plot not a single plant survived. The plants gradually lost their chlorophyll (green colouring matter) and finally frizzled up and died. The effect of chlorates is apparently cumulative. As might be expected, the weed was entirely exterminated from the plots receiving the higher dressings. An additional plot was laid down on 8th March 1932, at the rate of 15 lb. per acre, to determine whether this reduced dressing would suffice to kill the weed. At first it appeared that the application might prove inadequate. Three weeks after the application was made, however, not a chickweed remained on the plot.

GROUNDSSEL (*Senecio vulgaris*, L.)

In part of the garden above referred to, common chickweed and groundsel were growing together in about equal proportions. Six plots were laid down on this area and were treated as in the

previous experiment in all respects. About 90 per cent. of the weed was killed in the 20 lb. per acre plot, while not a plant survived in the plot receiving 40 lb. per acre. In order to determine more accurately the minimum effective dressing, an additional plot was sprayed at the rate of 30 lb. per acre. This amount gave complete control.

Evidence of the efficacy of chlorates against a variety of annuals was obtained incidentally in experiments concerned with the eradication of perennials, especially in one series where dressings ranged from 10 to 220 lb. per acre by gradations of 10 lb. The lowest application, viz., 10 lb. per acre, killed a proportion of the annuals; 20 lb. per acre eradicated red dead nettle (*Lamium purpureum*, L.), speedwells (*Veronica spp.*), and cress (*Lepidium sp.*). Willowherb (*Epilobium sp.*) was eliminated with a dressing of 50 lb. per acre.

DAISY (*Bellis perennis*, L.)

While a path was being sprayed, it was observed that even wind-borne spray had killed many daisies on the edge of the adjacent lawn. On this being noted, a portion of the lawn was lightly sprayed with a 5 per cent. solution of sodium chlorate. The majority of the daisies was killed, but the lawn remained in an unsightly condition for a considerable period afterwards. It was obvious that chlorates possessed no advantages over the "sulphate of ammonia-calcined iron sulphate method," for killing rosette weeds among lawn grasses.

COLTSFOOT (*Tussilago farfara*, L.)

Several trials were made with coltsfoot, but since results were uniform, reference need be made only to one which is representative of the others. One of the experimental areas selected was a stubble field so fouled with a mixture of coltsfoot and couch that for several years less than half a crop had been secured. Six plots, each 96 square yards, were marked out on 20th November 1931. The arrangement was such that half of each plot was on ploughed land and half on stubble. Sodium chlorate was applied by means of watering-cans with rose attachment, at the rate of 50, 100, 150, 200, 250 and 300 lb. respectively per acre. The results obtained on the ploughed land were superior to those on the stubble and are quoted below. It was estimated that the 50 lb. per acre application resulted in a 50 per cent. kill, whereas on the 100 lb. per acre plot at least 90 per cent. of the weed was destroyed. Next spring, when growth was vigorous on the untreated portion, no trace of coltsfoot was to be found on the 150 lb. per acre plot. The field was planted with Kerr's Pink potatoes about the beginning of April. When the plots were viewed on 16th June the haulms of the potatoes in the treated area were observed to be considerably stronger than those on the untreated area, because of the freedom from weeds.

The untreated area was now heavily infested with couch and coltsfoot. The haulms of the potatoes were slightly paler in colour, especially on the plots receiving the heavier dressings. The yield from the experimental area, however, was considered very satisfactory, despite the fact that the chlorate was applied much too late in the season. Similar results have been obtained for coltsfoot at many centres, but none was probably so striking, in so far as the field in question appeared to have reached the maximum infestation of weeds.

COUCH (*Agropyron repens*, Beauv.)

The data obtained for couch in the experiment described above is fairly typical of autumn applications from other centres; decidedly less satisfactory results followed from summer applications, when the soil proved to be too dry to permit of the chlorate reaching the more deeply situated organs. A dressing of 100 lb. per acre killed the bulk of the couch, while the 150 lb. per acre plot gave complete control. Again, the advantage of ploughing before applying the chlorate was very marked.

COMMON NETTLE (*Urtica dioica*, L.)

A comprehensive trial was made on nettles on ground uniformly covered with this weed, interspersed with a miscellany of other weeds including Bishop's weed, wild chervil, docks and weed grasses. The nettles were reputed to have been six feet high before the ground had been dug for the purpose of sowing down lawn seeds. The nettles along with the other weeds referred to had recovered and were forming a compact braird two or three inches in height, when they came under our notice. Ten plots, each measuring 24 square yards, were treated with a solution of sodium chlorate on 17th April 1932. The dressings applied ranged from 50 to 500 lb. per acre, by gradations of 50 lb. The plots were examined on 24th June, when the top growth on all plots except the 50 lb. per acre plot had been removed. Final observations were postponed until the end of August. It was then found that grass was beginning to establish itself on the 50 lb. per acre plot, as were also dock, wild chervil and nettle. The 100 lb. per acre dressing was almost sufficient for the nettles but inadequate against docks, wild chervil and Bishop's weed. On the other hand, the 150 lb. per acre dressing had completely cleared out all weeds except docks and Bishop's weed. Digging revealed the fact that not only was the surface growth killed but also the underground parts. For wild chervil and nettles, about one cwt. per acre constitutes the minimum effective dressing.

BISHOP'S WEED (*Ægopodium Podagraria*, L.)

Even in the 500 lb. per acre plot, a certain amount of this weed was manifest. Experiments are in progress on an area completely

given up to Bishop's weed, in order to determine whether chlorates offer a possible control of this pernicious weed, but results to date do not engender a feeling of optimism.

COMFREY (*Symphytum officinale*, L.)

A field was obtained for experimental purposes, which was reputed to have failed for some years to yield a return equal to the "seed" sown, so heavy was the infestation of comfrey; in places there were as many as one hundred stems of this weed to the square yard. In addition, there was a goodly representation of other weeds, including docks, sheep's sorrel, couch, creeping buttercup, daisies, groundsel and speedwells. It had been the intention of the proprietor, a market gardener, to take an oat crop from the field and thereafter bare fallow it. A section of the field was laid aside for experimental purposes and sprayed with sodium chlorate during the autumn, at various rates per acre. The concentration was also varied. It was discovered that chlorate provided an effective control, and the proprietor decided to spray the whole field at his own expense the following season. Experiment revealed that the concentration of the solution was not an all-important factor, provided that a certain total amount of the dry chlorate powder was applied per acre, and provided that there was at least sufficient water to distribute the chemical. Rain fell during and after certain of the applications, but it in no wise affected the efficacy of the chlorate.

As a result of the experience gained in 1930 a programme including the spraying of the entire field was arranged for autumn 1931, by which time the field was in stubble. Sodium and potassium chlorate respectively, were applied at the following rates per acre, on the 30th November: 106 lb., 142 lb., 177 lb. and 213 lb. as a solution. Each plot measured one quarter of an acre. The chlorates were applied by means of watering-cans each bearing a rose. The plots were laid off in strips each one yard wide, with garden lines to facilitate the spraying operations. All the weeds previously mentioned were still in evidence with the exception of the comfrey—the foliage of which had died down by this time. The remainder of the field was sprayed with sodium chlorate at a rate of 130 lb. per acre. The results were phenomenal. Next spring there was not a comfrey plant to be seen except on the untreated area.

No difference was observed between the efficacy of the potassium and sodium salts. Potatoes were planted about the beginning of April, and by 1st June the untreated area was covered with comfrey plants about 5 inches tall. Counts were made on this date, when it was discovered that there were from 50 to 100 plants per square yard. The potatoes came away without check, and a much heavier crop than usual was raised. The proprietor considered the amount

of chlorate required per acre, viz., about one cwt., to be a practicable proposition, even at the price of 30s. per cwt. Docks were not killed but severely damaged, and set much less seed than normally. Sheep's sorrel was also very resistant. Wild white clover appeared profusely on the treated area where there were no potatoes. The stimulus afforded to clovers by these two chlorates has been frequently noted in these experiments. It may be, in the case of sodium chlorate, that the sodium renders potash available to the plant.

This experiment confirmed the results obtained from the small trials in the previous year, viz., that a dressing of about one cwt. per acre in autumn will effectively kill that most noxious of weeds, comfrey.

On 1st June 1931 twenty-two plots, each 24 square yards, were laid down on an adjoining field (an old rose bed), which was also overrun with comfrey, to test the effect of a summer dressing. In addition to the comfrey, there were docks, dead nettles, groundsel, *Lepidium sp.*, creeping buttercup, *Epilobium sp.*, bent (*Agrostis sp.*) and speedwell. The dressings of sodium chlorate ranged from 10 lb. per acre to 220 lb. per acre by gradations of 10 lb. The chlorate was applied as a solution by means of watering-cans fitted with rose attachments. This trial, in addition to providing facts relating to comfrey, shed light on the effect of chlorate on the annuals mentioned—which information is noted elsewhere.

The leaves of the comfrey were scorched even in the 10 lb. per acre plot. Scorching became more manifest, however, as the higher dressings were reached. Despite the scorching, the comfrey did not succumb rapidly until the advent of a heavy shower of rain, after which the action of the chemical became more evident. By the end of August, comfrey had disappeared from the plots receiving 110 lb. per acre and upwards. The efficacy of the summer application was better than had been expected, having regard to the results obtained with other perennials treated at this period of the year. The field had been previously planted with roses, and the digging contingent on the lifting of the latter, undoubtedly resulted in a state of the soil amenable to treatment.

CREEPING THISTLE (*Cirsium arvense*, Scop.)

Extensive trials have been conducted on this weed, both on pasture and on arable ground, over a period of three years.

In pasture.—Fields heavily infested with thistles were obtained at two centres. Sodium chlorate was applied at various rates ranging from 50 to 500 lb. per acre. The chemical was applied in the dry state and also in solution by various methods during both autumn and summer. The dry method is easier but not so efficacious as the wet method of application. About a teaspoonful at the base of each plant suffices to kill the weed, and where there are only a few thistles, this method may commend itself.

The chlorate was applied variously as a $2\frac{1}{2}$ per cent. and a 5 per cent. solution. Where equivalent amounts of chlorate were applied, it did not appear to matter what concentration was employed. A fruit sprayer fitted with coarse nozzle was utilized in most of the experiments. A watering-can was used in a certain number of cases. The "spot" method of treatment, that is application of the chlorate to the base of the weed with the aid of a single jet, had been expected to economise material and to place the chlorate where it would prove most effective. This was not borne out by results, however, for what advantage there was lay with spraying of fine mist on to the foliage. It may be added that the thistles numbered about 50 to 60 per square yard, and the leaves caught most of the spray. At one centre, where the soil was almost a pure sand, and the thistles were only some 12 to 14 inches high, a single application of 250 lb. per acre in the middle of August destroyed practically every thistle. At the other centre, this dressing effected a reduction in the number of thistles from 50 to 20 per square yard. The thistles, it must be said, were at least three times the size of the thistles at the other centre, and the soil could be described as a medium loam. At this centre, the thistles required a total dressing at the rate of 350 lb. per acre for total eradication. The grass on the patches receiving this dressing was killed out entirely; regeneration took place after several months from natural sown seed. A first application of 2 cwt. was made, followed by a second of about 1 cwt. six weeks later. Two applications are preferable to one, since the first considerably impairs the vitality of the weed, and in addition kills the surface growth and facilitates penetration of the later dressing. Chlorates cannot therefore be regarded as a practicable method of ridding pasture of thistles on a large scale. Thistles in pasture, moreover, can be readily controlled by cutting three times per year, once in June and twice in July, for two or three consecutive years; but on small patches, and under special circumstances, sodium chlorate might be resorted to for use on thistles in pasture.

On arable land.—Six plots, each measuring 394 square yards, were laid down on 16th December 1931, in a ploughed field. There were from five to six thistles per square yard. Apart from thistles, couch, sheep's sorrel and creeping buttercup were the main weeds. The plots were dressed with sodium chlorate at the following rates: 50, 100, 150, 200, 250 and 300 lb. per acre. Turnips were sown on 20th May 1932. Because of the dry season, brairding was irregular on the field as a whole, but particularly so on the 300 and 250 lb. per acre plots, while the 200 lb. per acre plot was not quite up to the standard of the untreated portion of the field. The 300 and 250 lb. per acre plots yielded poorly, and even the 200 was not so good as the untreated portion of the field. It must be borne in mind, however, as was surmised at the time, that the application was much too late. Had the application been made about mid-September

little residual effects from the chlorate would have been discerned. Thistles were entirely eradicated in the plots receiving 200 lb. per acre and upwards. The 150 lb. per acre plot gave about 90 per cent. control for couch, and destroyed the majority of the thistles. The beneficial effects of ploughing the land prior to the application of chlorates has been emphasised elsewhere. The advantage of turning over the sod is clearly demonstrated if comparison is made of the dressings requisite on pasture and ploughed land.

SHEEP'S SORREL (*Rumex acetosella*, L.)

While no land was found bearing a sufficient amount of this weed to provide a special test, it was frequently represented as a casual in other experiments. It proved to be very resistant to chlorate treatment; an application of 300 lb. per acre did not completely destroy it. About 400 lb. per acre appeared to be necessary.

DOCKS (*Rumex spp.*)

Docks were treated at many centres with sodium chlorate at the following rates per acre: 50, 100, 150, etc., up to 600 lb. The lowest effective dressing at any centre was 400 lb. per acre. This quantity proved inadequate at some centres, especially if the docks were very strongly developed. The best results were obtained when about 200 lb. per acre were watered on with the aid of a watering-can in autumn, and two subsequent applications of 100 lb. per acre given at monthly intervals. This killed most of the docks. A fourth application specially directed to survivors was sometimes found to be necessary. This method of treatment gave better results than when the chlorate was applied in one dressing. It was interesting in one case to note that dock seedlings developed to the number of 230 per square yard on a plot where, two months previous, a dressing at the rate of 400 lb. per acre had been applied. The amount of chlorate required would preclude the use of this chemical in practice except under special circumstances.

RAGWORT (*Senecio Jacobæa*, L.)

New Zealand results (1, 2) have indicated that this weed can be effectively eradicated with as low dressings as 5 lb. per acre. Isolated plants have been sprayed with both a 2½ per cent. and a 5 per cent. solution of sodium chlorate, in the trials under review, but it was difficult to estimate the amount of the chemical required per acre. This weed is certainly readily killed by chlorate, but the amount probably cannot be set at such a low figure for this country, especially having regard to the amount of chlorate required to effect a clearance of certain less robust annuals.

DISCUSSION OF RESULTS

The price of sodium and potassium chlorates was high, viz., 30s. and 33s. per cwt. respectively, when these experiments were

commenced ; now the price is about 40s. per cwt. If it were in the neighbourhood of 10s. per cwt., or less, those chemicals would at once play a very important rôle in weed control. As it is, their use will be more restricted. They will undoubtedly be of service in market gardens, where a much higher capitalisation per acre obtains than on the majority of farms. In particular for coltsfoot and comfrey, for which no very satisfactory control exists, it would appear that chlorates present a practicable means of eradication. If the chlorate is applied in October, and preferably not later than September, eradication will go on apace during the dormant months and the soil will be ready for normal cropping next spring, without causing any rotational inconvenience. The appearance of annuals on the treated area—for chlorates have no effect on seeds—will denote that decomposition of the chlorate has occurred and that the soil may be safely planted. For winter annuals a very light dressing of chlorate may be employed, to prevent seeding at a time when the soil is in an unfit state for mechanical elimination of the weeds. Market gardeners, too, have extensive weed dumps. If these were freed from the superficial growth of weeds, many tons of valuable soil would be liberated. Chlorate applied in autumn, will achieve this end by spring. Chlorate could also be used on the accumulating weed dump to kill the more resistant perennials, thus preventing their flowering and active seed-dispersal. Again, where the condition of a lawn is such as to defy cleaning by ordinary methods, chlorates, if applied in autumn, will kill all the herbage. The lawn can then be sown down with a good seeds mixture in spring. Weed seeds will not, of course, be killed and annual weeds will make their appearance, but if hand picked at an early stage, they can be kept down. Chlorates, because of their relatively harmless nature when applied as solutions, are undoubtedly useful for killing weeds by the edges of fields and other places inaccessible to cultural methods of eradication. In Switzerland, extensive use has been made of chlorates by railway companies in the control of weeds along the permanent way, thus largely dispensing with costly manual labour. In this country, the London, Midland and Scottish Railway Company has recently been experimenting with this method of weed control along the track. No doubt municipal authorities will find chlorates of some use in maintaining, weed-free, sand and cinder paths. But as pointed out earlier, drastic price reductions are required to give a fillip to the use of these chemicals. The cost will prove the vital factor in determining the use made of chlorates.

Wet applications where possible will prove most effective, and are more economical of both labour and chemical. A potato sprayer, temporarily converted to give a coarse and downward spray, is quite an effective mode of application for large areas. For small areas, an ordinary watering-can is suitable. Chlorates are generally regarded as non-poisonous. At the same time, if it is convenient,

it is probably better to remove animals from areas where spraying is contemplated.

Summary.—1. The value of sodium and potassium chlorate respectively as weed eradicators has been demonstrated for a number of annual and perennial weeds.

2. Application in the form of a solution was found to be most effective. The amount of water is not a matter of prime importance, provided there is sufficient to ensure uniform distribution. A 2½ per cent. solution (5 lb. per 20 galls. water) is a convenient strength.

3. *There is a definite fire hazard in the use of chlorates.*—Instructions as to handling are given, and if these are followed no trouble need be experienced.

4. Annuals can be treated at any time, but decidedly better results follow autumn (September or October) applications in the case of perennial weeds having strong underground organs.

5. The efficacy of the chlorate is much enhanced in the case of perennial weeds, if the soil be previously ploughed.

6. The chlorate decomposes during the winter, and it is possible to proceed with normal cropping in spring. If application be made too late, the subsequent crop will suffer from the residual effects of the chlorate.

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THE ESTABLISHMENT OF PASTURE ON VIRGIN PEAT.

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THE trials described in this paper were conducted by the Macaulay Soil Research Institute on the Demonstration Farm in Lewis, and their inception is described in a previous issue of this Journal.¹

Natural Vegetation.—The natural vegetation on the peat is that referred to botanically as *Scirpus* association—a type poor in species and widely distributed over Lewis. The following plants listed in order of importance are representative of the moor:—deer grass, purple moor grass or flying bent, ling or heather, cotton grass, cross-leaved heath, mosses, bog asphodel, carnation grass, heath rush, lesser jointed rush, sundews, &c. Deer grass (50 per cent.), flying bent (20 per cent.) and ling (10 per cent.) together constitute four-fifths of the entire vegetation. The paucity of grasses—a characteristic of deer grass moor—stamps this as poor at once in quality and quantity. This fact is reflected in its low carrying capacity for blackface sheep. Flying bent is the sole representative of the grass family, and the stagnant conditions obtaining are far from conducive to its optimal development. It discards its leaves at the end of the season and is of negligible grazing value during winter, but with the advent of June it develops rapidly and makes a useful contribution during summer and autumn. Deer grass is the dominant species in the vegetation, but as the season advances it browns off and becomes unpalatable. Ling of a diminutive type is widely dispersed among the deer grass. It undoubtedly affords valuable, if not early grazing. Cotton grass occupies the more stagnant areas and performs a useful function in providing keep before the other species come into bearing. Lesser jointed and heath rush are not abundant but valuable for their palatability during winter. Other species apart from cross-leaved heath make no appreciable contribution to the grazing.

Establishment of an Improved Pasture.—The individuals of the association of plants colonising moorland are called upon to make specific adaptation to the existing soil conditions. Aeration is at a minimum. Because of the abundance of water and the associated evaporation the soil is cold; as a result spring sets in late. Moreover, peat is very retentive of water. These factors together with the presence of humic acids greatly depress the functional capacity of the roots, and this renders it difficult for the plant to replace the water lost. Conservation of the limited moisture supply is therefore imperative, and practically

¹ Ogg, W. G., and Macleod, A. "Reclamation and Cultivation of Peat Land in Lewis." *Scot. Journ. Agric.*, vol. xiii, No. 2, April 1930, p. 130.

all species inhabiting the moor are specialised to meet this end. While in general there is a surfeit of unavailable water, during periods of summer drought the peat is liable to excessive baking. Such soils are phenomenally low in bacterial content, while fungal life is negligible. When it is desired to replace the native vegetation, the soil must offer a different and improved set of conditions, since domesticated plants are but ill-equipped for such exacting requirements. Efficient drainage is thus of vital importance in moorland improvement.

Cultural Treatment.—An area extending to about 8 acres of virgin peat was selected for the trials hereafter described. The depth of the peat varied from 3 feet at the top to about 6 feet at the bottom of the field. The ground had been previously drained by wooden pipes. Cultivation was commenced in July 1929 by means of a large rotary cultivator. The surface of the moor was torn into fine shreds to a depth of 9 to 10 inches. Subsequent cultivation proved impossible owing to the nature of the ground, and the tilth obtained from the rotary cultivator formed the seed bed without further treatment. The field was divided into six plots, five of which received lime of some sort, the sixth receiving no lime. A complete dressing of artificial manures was applied over the entire field.

Grass and clover seeds (Table I) were sown on the 16th July with rye as the nurse crop. Owing to the late date of sowing, rye was not an unqualified success, but this defect was more than balanced by the very successful establishment of the herbage species resulting from the reduced competition.

TABLE I.

	MIXTURE.				
	I.	II.	III.	IV.	V.
Perennial rye grass	13	8	12	4	8
Italian rye grass	1 $\frac{1}{2}$	3	4	4	5
Cocksfoot	1 $\frac{1}{2}$	6	8	6	6
Smooth stalked meadow grass	1 $\frac{1}{2}$	4	...	...	...
Rough stalked meadow grass	1 $\frac{1}{2}$	2	1 $\frac{1}{2}$	...	2
Timothy	2 $\frac{1}{2}$	5	5	5	8
Meadow fescue	5 $\frac{1}{2}$	3	...	6	...
Tall fescue ... ..	...	3	...	4	...
Meadow foxtail ... ..	...	...	...	...	4
Red Clover (L.F.)	1 $\frac{1}{2}$	8	...	...	2
Cornish marl ... ..	...	...	2	4	...
Dorset marl ... ..	...	...	2	...	...
Alsike ... ..	...	...	1	...	2
Bird's foot trefoil ... ..	...	1	1	...	2
White clover	5 $\frac{1}{2}$	1	...	...	...
Wild white ... ..	...	1	1	1	1

As the establishment of pasture on peat has received little systematic attention in Britain, the seeds mixtures were necessarily of a tentative nature. At the outset, however, it may

be said that results have far surpassed expectation. Two of the mixtures have yielded herbage not inferior to some of the best on good land. The following marks (Table II) allotted out of a total of 10, awarded by four independent observers and averaged, indicates the relative merits of the plots after 24 months.

TABLE II.

					<i>Marks out of 10.</i>
Mixture I	...	...	...	...	6½
„ II	...	...	...	...	9
„ III	...	...	...	...	9
„ IV	...	...	...	...	4
„ V	...	...	...	...	7½
Unlimed plot	...	...	...	...	2

The Effect of Lime.—The unlimed plots present the most striking feature of the trials. Dominated by a rank growth of ungrazed Yorkshire fog, they stand out in bold relief from the limed plots which are well grazed and green. Yorkshire fog is not represented in the vegetation of the adjoining moorland, except along the edges of the natural waterways. Its presence in the plots is probably due in large measure to wind-borne seeds from this source and to some extent to its inclusion as an impurity in the seeds mixtures. In the absence of lime, the manurial constituents have been rendered ineffective, with the result that of the sown species only timothy has exhibited toleration of the conditions. The meadow grasses, which are excellent “bottom grasses,” are poorly developed. Wild white has suffered from the sourness of the soil and lack of nutrients. Owing to the failure of wild white clover and the meadow grasses the “take” has been very patchy. This has enabled Yorkshire fog, which is neglected by stock when admixed with more palatable species and is a prolific seeder, to gain the ascendancy. Sheep’s sorrel is also prevalent. The plots are also characterised by an abundance of indigenous moorland plants including deer grass, cotton grass, rushes, heather, cross-leaved heath, tormentil, carnation grass, flying bent, mosses, &c. Of the clovers, alsike and wild white are relatively more successful than red clover, but all are diminutive. The paramount importance of lime in reclaiming moorland of this type, even for the establishment of pasture, is emphasised when limed and unlimed plots are compared.

That even a small dressing of lime exerts a beneficial influence is apparent from examination of the plots which received a half ton of lime. The amount of Yorkshire fog, though still plentiful, is insignificant in these plots as compared with the unlimed plots. Marked decrease is evident also in moorland volunteer plants. The clovers generally have responded fairly well—alsike and white preponderating. All the sown species have succeeded with the exception of bird’s foot trefoil and meadow foxtail, which have failed generally. The better tone of these plots is

reflected in their well-grazed condition when compared with plots receiving no lime.

The Seeds Mixtures.—*Mixture I.*—Wild white clover was omitted from this mixture in favour of a heavy seeding of the Dutch variety. The amount of white clover showing after two years is surprisingly high, though bulking rather less than wild white in the other plots. This is interesting and lends support to a belief that is gaining ground, viz. :—that wild white and Dutch white differ only in the proportion of long lived sorts which they contain. The white clover remaining in this plot is probably therefore the residue of longer lived types contained in the ordinary white sown. It should be noted that this mixture is situated on the driest part of the field. Timothy has responded well in relation to the amount seeded. Perennial ryegrass features little in this plot; indeed it has failed uniformly in the second year. Meadow fescue has established itself sparingly. It is more in evidence in “Mixture IV,” where the soil is damper. Present prices, however, prohibit its inclusion on economical grounds. The meadow grasses have responded extremely well in this as in all plots. They form a compact sole of particular value under conditions obtaining on peat soils. A complete covering of herbage prevents the surface from baking, and suppresses native volunteer species and aggressive inferior grasses like Yorkshire fog. The equality of seeding of rough stalked and smooth stalked meadow grass in this mixture affords an opportunity of assessing their relative establishment. Rough stalked represents about 60 per cent. and smooth stalked 40 per cent. of the meadow grasses.

Mixture II.—This mixture and “Mixture III” have yielded the best results. It is characterised by an increased seeding of meadow grasses, timothy and cocksfoot, all of which have been conspicuously successful in the trials. The response of wild white clover is good, but, when compared with “Mixture I” in respect of white clover, its superiority is not so marked as might have been expected. It is possible, however, that the white clover which so far has persisted in “Mixture I” may not withstand the rigorous conditions. Bird’s foot trefoil is entirely absent, as in the other plots where it was included. Late flowering red clover made a fair showing.

Mixture III.—Wild white clover is rather more plentiful than in the previous plot as a result of the reduced seeding of meadow grasses. Red clover features more prominently here than in any of the other plots, which fact, taken in conjunction with data from the other plots, suggests that the increase is due to Dorset marl. Alsike is very plentiful.

Mixture IV.—The exclusion of the meadow grasses has resulted in a poor “bottom,” and, as might be expected, the plot is being invaded by moorland plants and Yorkshire fog. In the wetter parts, meadow and especially tall fescue are in evidence. The increased seeding of Cornish marl is not reflected in the return. This mixture is decidedly inferior to the others.

Mixture V.—Clovers are more strongly in evidence in this plot than in any of the others, due in large measure to the increased seeding of alsike. Timothy is very abundant. This mixture was obtained from a source different from that of the others, and appears to have contained dogstail as an impurity. It is very profuse on the plot, but has been neglected by the stock and is therefore "benty." Under certain conditions, however, its inclusion might be justified.

Discussion of Results.—Efficient drainage is of prime importance in undertaking reclamation whether for pasture or arable crops. If the soil is allowed to remain waterlogged, reversion to moorland vegetation proceeds rapidly. This is well exemplified on an area of wet moor which was cultivated, manured and seeded without previous draining. Establishment was never good and the sward is fast assuming a moorland appearance. Next to drainage lime is important. It is required in order to reduce the acidity of the peat to a point where establishment of the better herbage plants becomes possible. Moreover, without lime, the manurial constituents remain inactive. In the trials under review, the response to even so moderate a dressing as a half ton was conspicuous. An impression is prevalent that heath plants are intolerant of manures. Examination of the unlimed plots unmistakably refutes this idea. Rather is it that, under unfavourable conditions, the sown species are unable to compete successfully with the indigenous flora. Under improved conditions, by nature of their growth habits, the former are able to suppress the heath plants. The absence of lime has proved a limiting factor to the successful establishment of the better herbage types on the unlimed plots, with the result that the soil has been taken up by moorland volunteers and Yorkshire fog. The latter is fairly tolerant of acidity and has a well developed faculty for establishment from seed. It is, moreover, little disturbed by grazing animals, when more palatable herbage is available.

It is important to establish a compact sward as expeditiously as possible to exclude ingress of moorland volunteer and other inferior species. The meadow grasses and wild white clover are especially valuable in this respect, and must be regarded as essential constituents in better class seeds mixtures for peat soils. In "Mixture IV," which contains no meadow grasses, the plots are already being invaded by moorland plants. Moreover, the meadow grasses have demonstrated their ability to check the aggressiveness of wild white clover—a point which can also be observed on mineral soils. Rough stalked meadow grass might be exploited more fully to prevent excessive development of this plant. The success of rough-stalked meadow grass is in accord with Stapledon's¹ findings for poor Welsh soils.

Timothy, of commercial quality, was very successful and displayed a greater degree of toleration of acidity than any other

¹ Stapledon, R. G., and Davies, W. "Some Mixture Problems: Competition." Series H, No. 8, Seasons 1921-1928.

sown species. Cocksfoot contributed liberally to all plots, and it is questionable whether its limit of useful inclusion in the seeds mixture is reached at 8 lb. per acre. Dogstail appears to have been fortuitously included in "Mixture V," where it is prominent in the herbage. It assists materially in securing a close sward, but cannot be recommended unreservedly on account of its aggressiveness and its tendency to become "benty" when uncontrolled. Meadow fescue and meadow foxtail feature prominently in continental mixtures for peat soils.¹ In the present trials, however, they have not so far shown to advantage. In the case of foxtail, establishment is naturally low and it probably warrants further trial. Alsike is vigorous in both plots where it was included. Red clover appears to experience little difficulty in establishment, when the peat is suitably treated. It is premature to state which varieties will prove most suitable.

The trials here discussed are to be regarded as preliminary. Certain facts, however, emerge which are unlikely to be voided by future work. Further trials based upon the experience of those described are in contemplation by the Macaulay Institute, and it is hoped that nearer approximation to the optimum seeds mixture for peat soils will be obtained.

In addition to the "intensive" system of pasture development, there undoubtedly exists scope for marginal improvement under the "extensive" system. Drainage would still be necessary on wet peat, but liming and manuring might be carried out on a less generous scale. In the seeding, use might be made of low fertility grasses, as Gillies² has pointed out, instancing "agrostis." Yorkshire fog, it has been observed, grows luxuriantly on the type of peat described, after drainage, with a little encouragement in the form of manures. Although this species has amply demonstrated its toleration of acidity, lime would be beneficial in rendering effective any manures which might be applied. Yorkshire fog is very leafy, to which must be added its capacity for remaining green throughout winter. It deservedly has a bad reputation on good land, but this is not to say that it is incapable of playing a very useful rôle in the economy of inferior land. In its hairy nature lies its main disability. *Could a non-hairy variety be produced, a place amongst "useful grasses," at least for peat soils, might be secured for this species.*

Summary.—1. A scirpus peat has been converted in less than two years into high grade pasture.

2. Efficient drainage is of prime importance in moorland improvement.

3. Natural fertility is very low and applications of nitrogen, phosphates and potash are necessary.

4. But of no avail unless lime is also applied.

5. Lime is also necessary to counteract acidity.

¹ Ogg, W. G. "Reclamation of Peat Land in Northern Europe." *Scot. Journ. of Agric.*, vol. xii, No. 1, Jan. 1929.

² Gillies, John. "Reclamation of Mossland in Dumfriesshire." *Scot. Journ. of Agric.*, vol. xii, No. 2, April 1929.

6. A compact "bottom" is essential to prevent ingress of moorland volunteers and inferior grasses.

7. The meadow grasses and wild white have proved invaluable in this respect, and must be regarded as essential constituents of better class "seeds mixtures" for peat.

8. Timothy, dogstail, cocksfoot and alsike have responded extremely well.

9. Red clover has persisted into the second year. Inoculation of nodule bacteria has not proved necessary.

10. Attention is directed to the possibility of utilising Yorkshire fog and other "low fertility requirement" species to effect a marginal improvement.

11. Indigenous moorland plants respond to manuring in the absence of competition from aggressive pasture sorts, but this procedure would be of doubtful value in practice.

In conclusion, it must be added that this paper is the outcome of an invitation by Dr. Ogg, Director of the Macaulay Soil Research Institute, who was responsible for the trials, to examine the pasture plots herein described, and the vegetation of the surrounding moor.

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LONGEVITY OF SEEDS.

By D. Clouston, M.A., B.Sc.

The distribution and perpetuation of plants depends largely upon seeds. As far back as anything is known of the human race, man has used seeds for plant propagation. Comparatively few, however, play a direct role in man's economy, and he has chiefly interested himself in that few. The vast remaining flora depends for its reproduction and distribution upon natural agencies. Many plants are equipped with effective devices for disseminating their seed, and the seeds themselves are often endowed with the property of remaining dormant till the advent of favourable conditions.

From earliest times the problem of how long seeds retain their vitality has been of interest alike to scientists and those engaged in husbandry.

Even Theophrastus, about 322 B.C., recorded that most seeds retained their vitality for more than three years, and that at Patra and Cappadonia seed was said to remain fertile and fit for sowing for 40 years.

Popular superstition engendered by the reports of the germination of "Mummy Wheat" attributes a fantastic longevity to seeds. Actual investigation, however, into alleged germination of seed from Egyptian tombs and Roman vaults has discredited these claims. In the case of seeds from such situations which have germinated, it has been proved that they are of later origin—frauds in many cases inserted by the Egyptian felaheen for personal gain. In all other cases where seed of antique origin has been reported to germinate, doubt has been cast on its authenticity.

Such statements and a desire to obtain accurate data induced Ewart to test for viability the seeds of herbarium specimens, and other seeds whose age was accurately known.

His results appear in the *Proceedings of the Royal Society of Victoria* for 1908. Results are given for 4,000 instances, 3,000 being from his own observation. They were mostly made upon a store of seeds of 600 species found in a cupboard at Melbourne, sent out from Kew in 1856 for a projected Botanic garden, and never used.

Some of the seeds included in the experiment succeeded in germinating after the lapse of over a century. Out of 26 *Goodia lotifolia* seed 105 years old, 2 seeds germinated. In the case of *Hovea linearis*, of similar age, no seeds were found to be alive. The results, as a whole, are in close agreement with those of Becquerel, the Leguminosæ furnishing more than half the cases of longevity. *Acacia* seeds, 68 years old, still possessed a germination of 50 per cent. It is possible, therefore, that single seeds would have retained their vitality for a very much longer period. Longevous seeds in the Leguminosæ were generally of the "hard" type, and the coat had generally to receive treatment to induce germination.

In the light of the findings of Ewart and Becquerel with seed of shorter life, the records by Lindley and Des Moulins of germination after 2,000 and 1,400 years collapse. In most cases Ewart

found the seeds to be comparatively short lived—many not retaining their vitality longer than 5 years.

Dorph Petersen, of the Danish Seed Control Station, has conducted very carefully designed experiments with agricultural and horticultural seed to find out how long the various species retain their germination power, and at what rate the power is lost. This is important in deciding to what extent old seeds can be used profitably.

As with other investigators, he found that the Leguminosæ retained their vitality the longest, and of these notably *Trifolium repens*, *T. hybridum*, and *Lotus corniculatus*, were the longest lived. Within these species themselves remarkable differences occurred. Samples containing a high percentage of hard seeds remained viable much longer than similar samples containing a lesser proportion of hard. The germination remained in most instances fairly high until the fourth and fifth year, after which a steady decline set in, until at the tenth year only a few per cent. remained alive. After this the loss in germination was very slow until about the twenty-fifth year, when it was entirely lost. A remarkable fact arising out of these experiments is, that the speed of germination or energy decreases at a much more rapid rate than does germination capacity. This feature is of considerable importance, in that performance in the field is very directly related to speed of germination. With two samples of seed of equal germination capacity, advantage always lies with the one possessing the greater speed.

Gramineæ were shorter lived. *Phalaris canariensis* and *Phleum pratense* were amongst the more longevous, individual grains retaining their vitality for about 16 years. The loss in germination capacity was not appreciable until the 7th or 8th year. After that the loss increased very quickly. Cruciferous forms also retained their vitality for 16 years. Umbelliferæ were, however, short lived, *Carum carvi* remaining viable for only four years. A few tree seeds were included in the experiment, which retained their vitality for a fairly long period, *Pinus montana* only losing its germination entirely after 18 years.

In no case did life extend over anything approaching the period obtained by Ewart and Becquerel. This, however, does not invalidate their findings as their tests included many notably longevous sorts. Climatic conditions during ripening of the seed and during storage and its associated moisture content, also play a very considerable part in determining how long seeds will retain their germinability.

From an agricultural point of view, the most important aspect of seed vitality is that pertaining to survival of weed seeds when buried for prolonged periods. It is generally accepted that certain seeds can lie dormant in the soil for several years, to germinate whenever conditions are favourable. Much discrepancy exists, however, in the actual estimates of the time that seeds can endure burial without losing their germination capacity. As an example of a seed that retains its vitality for a long time in the soil Char-

lock, *Sinapis arvensis*, is probably best known. It is an arable land weed growing particularly luxuriantly among cereals, where its ravages have often rendered the growing of such crops unremunerative. Fields thus badly infected have frequently been laid down to grass with the hope that in the interim the seed would perish. Such extended periods as 25 years have proved insufficient for the purpose. It is certain that in the case of many less conspicuous plants equal, if not greater, longevity obtains.

Shenstone, in the *Journal of Botany*, cites an interesting case of a garden in which a bush of *Ulex Europaeus* had previously grown. The Gorse had been removed nearly a quarter of a century, yet every year, on stirring of the soil, new seedlings continued to appear.

The fact that soil from old forests, at one time cultivated land, often yields seedlings of species peculiar to arable land, has frequently been adduced in support of phenomenal age records for seeds. Peter cites instances of soil from a forest one hundred years old yielding arable land seedlings. From this he concludes that seeds are capable of surviving burial in soil for at least 100 years. Such evidence, however, appears insufficient to warrant such a conclusion, in view of the controlled experiments of Beal, Duvel and others. Moreover, contrary to what might have been expected, Peter found the seeds most plentiful comparatively near the surface. This would seem to indicate that the seeds were of later origin, introduced by birds and other agencies.

The first attempt to obtain specific data on the length of time that seeds retain their vitality in soil was made by Beal in America. He buried twenty inverted open-mouthed bottles, each containing fifty seeds of each of twenty species. One bottle was dug up every five years, and the seeds tested for germination. The experiment extended over a period of 40 years, after which life was still found in seeds of ten of the 20 species.

In 1902 Duvel started a similar experiment with buried seeds, but subjected the seeds to more natural conditions. The test comprised 107 species. The seeds were mixed with a sterilized portion of the soil, and put in ordinary flower-pots covered with porous saucers. Samples were buried at each of the following levels—8, 22, and 42 inches. For comparison sealed tubes of seed were inserted at the lower level.

In almost all cases the seeds from the tubes gave the higher germination. In 1923 it was found that 51 of the 107 species still retained some power of germination. There was no very marked difference in retention of vitality at different depths. On the whole, however, the more deeply buried seeds retained their vitality the longest; this was confirmed in experiments carried out by Dorph Peterson and Waldron. With the Legumes hard seeds retained their vitality longer than other sorts.

Dr. Brenchley, of the Rothamsted Experimental Station, obtained some interesting data from old pastures of known age. Samples of soil 6 inches square were taken inch by inch to a

depth of 12 inches, care being taken to prevent contamination from surrounding soil. One of the fields which was known to have been in pasture for about 300 years yielded all told six seedlings of typical arable weeds. These, however, could easily be accounted for by accidental carriage on the feet of horses, cattle, and human beings. Another field which had been in pasture for 58 years contained germinable seeds of arable weeds in such proportion as to preclude the possibility of accidental infection. As might be expected, as the age of the pasture decreased the percentage of arable weed seed increased. It is, perhaps, significant that the arable weeds were found at progressively greater depths as the age of the pasture increased. From the results it would seem evident that weed seed can remain dormant in the soil for more than half a century. The reason for seeds retaining their germination better at the deeper levels is rather obscure. The answer is probably that the temperature at the lower levels is more equable and a physiological balance is set up—vital changes are inhibited and the seeds are enabled to mark time without becoming desiccated.

It is perhaps worth noting some other conditions under which seeds can retain their vitality. Seeds were kept by Giglioli, in his well known experiment, for a period of 13 years in oxygen, nitrogen, hydrogen and carbon dioxide without losing their power of germination. Laurent maintained seeds in a vacuum for a period of 7 years without loss of germination power.

Indeed Guillaumin has recently advocated the use of a vacuum as a means of prolonging life in seeds, and particularly for the transport of seeds ordinarily short lived.

According to Fischer seeds of *Sagittaria* and similar plants may be kept under water for several years without losing their germination power.

Whether a seed shall be long or short lived is partly a matter of inherent capacity, partly of external conditions. As regards the latter, it is generally agreed that cool, airy, dry conditions preserve seeds best. Some few seeds (Willow, etc.,) are killed by air drying, and according to Poisson seeds of *Cacao* begin to die 36 hours after drying outside the fruit. In the soil seeds last longer in the deeper layers than in the surface layers. Seeds with impermeable coats are less dependent on external conditions, and according to Ewart can resist immersion in poisons and poisonous gases for years, when dry and unswollen. Such seeds are naturally best adapted for survival in the soil, e.g., hard seeds in the Leguminosæ.

Hard seeds are those in which, by some coat restriction, free entrance of water and oxygen is inhibited. The hardness has been variously attributed to impregnation of the testa with mineral matter, the small size of the lumina in the palisade layer of the integument, and the presence of a cuticle. The "Cuticular Theory" was promulgated by Miss White and probably most nearly approximates to the truth. She was able to demonstrate the presence of a cuticle in all seeds which did not swell in the

germinator. Ewart and Crocker believe that dormancy is also caused in most cases by coat restrictions which preclude entry of water and oxygen.

THEORIES OF LONGEVITY.

Loss of vitality has been suggested as due to:—

- (1) Exhaustion of stored food.
- (2) Degeneration of digestive and oxidising enzymes.
- (3) Slow denaturing or coagulation of certain protoplasmic proteins.

With regard to the first, that is the exhaustion of food materials, V. H. Blackman holds that "The loss of germination power after many years is not due to loss of material in respiration. The respiration is so small at low temperatures that a seed in 1,000 years would not lose a considerable part of its material. The loss of it must be due, no doubt, to slow changes in the proteins, probably to denaturing of the protein."

Crocker supports this theory.

Ewart considers that longevity "depends upon how long the inert proteid molecules into which the living protoplasm disintegrates when drying, retain the molecular grouping which permits of their recombination to form the active protoplasmic molecule, when the seed is 'moistened and supplied with oxygen.'" This is just Crocker's theory in different words.

With regard to enzymes, Acton found that the diastatic and proteolytic ferments were absent in old wheat grains. This, Ewart considers concomitant rather than causal, since as long as the power of reconstituting the living protoplasmic molecule is present, the power of reproducing fresh ferments is retained.

Ewart reviewing the available data, and basing his conclusions on the trend of the curves, formed the opinion that the probable extreme duration of vitality for any known seed may be set between 150 and 250 years in the case of the Leguminosæ, 50 and 100 in Malvaceæ and Nymphaeæ; and 50 for Myrtaceæ and other families containing only one or two long lived sorts.

He classed seeds according to their life duration under optimal conditions into 3 groups:—

Microbiotic—Seeds whose duration does not exceed 3 years.

Mesobiotic—Which may last for 3-15 years, and

Macrobiotic—Seeds which may last from 15 to over 100 years.

The first two groups are the more numerous. Macrobiotic seeds are less numerous and are restricted to a few natural families, of which the Leguminosæ greatly surpass all others.

The Macrobiotic families are as follows:—

Leguminosæ.	Iridæ.
Malvaceæ.	Euphorbiaceæ.
Myrtaceæ.	Polygonaceæ.
Nymphaeæ.	Geraniaceæ.
Labiataæ.	Sterculiaceæ.

(Lecture given to the Botanical Society of Northern Ireland.)