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HANDBOOK OF GRASSES

W. HUTCHINSON

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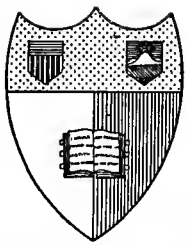

Poa annua, the Annual Meadow-grass ; flowering.

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GEORGE ALLEN & UNWIN, LTD.

Ruskin House,

40, MUSEUM STREET,

LONDON, W.C.

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HANDBOOK OF GRASSES

TREATING OF THEIR

STRUCTURE, CLASSIFICATION, GEOGRAPHICAL DISTRIBUTION AND USES

ALSO DESCRIBING THE

BRITISH SPECIES AND THEIR HABITATS

BY

WILLIAM HUTCHINSON

London

SWAN SONNENSCHEIN & CO., LIM.

NEW YORK: THE MACMILLAN CO.

1910

First Edition, September 1895; Second Edition, March 1899; Third Edition 1906; Fourth Edition, 1910.

PREFACE

GRASSES are in three respects a remarkable family: they possess many structural peculiarities which sharply define them from all other kinds of plants; they are so abundant and widely diffused as to constitute the dominant feature of the landscape, not only in our own, but in most other countries; and lastly, no other Order can at all compare with the Gramineæ in the variety and magnitude of their uses.

Yet the study of grasses, so far from being popular, is shunned by many botanists in the belief that it is beset with unusual difficulties; farmers and graziers, to whom the cereal and forage grasses are all in all, have rarely a scientific acquaintance with them; while those observers of Nature, not particularly interested in either botany or agriculture, are hardly able to recognize two or three among the many species which everywhere abound.

This little handbook is an endeavour to popularize the study of grasses; the peculiarities of the structure of grasses, and the terms employed in describing these plants, are carefully explained; the chapter descriptive of the British species and their habitats is arranged with especial regard to convenience in field-work; and some definite information is given regarding the geographical distribution of grasses and their vast economic importance.

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ILLUSTRATIONS

HANDBOOK OF GRASSES

Field-work

A FEW suggestions about field-work will serve as an introduction to Chapter II., which deals exclusively with the grasses of our own country. The identification of the numerous species may be a difficult matter, or it may be comparatively easy; this will largely depend upon the way in which the tyro applies himself to the task. The first essential is to get a clear understanding of the technical terms employed. Chapter I., on Structure, should be attentively perused, and afterwards referred to in every case of doubt. We purposely omit a glossary, because its meagreness would be likely to mislead.

In describing the British species, we have grouped them according to their habitats, each group consisting of about a dozen species, and these are described in the order of their frequency and abundance (the raritics always last), precisely as one may expect to meet with them on botanical excursions. It is true that some species do not confine themselves to any particular habitat; but these, with few exceptions, are only the grasses of our meadows and pastures, and we start with this group in order that the beginner may familiarize himself with them first and be able to recognise them anywhere. Most of the other groups are perfectly exclusive, *e.g.* the maritime, woodland and alpine grasses. The species to be dealt with in any given habitat are thus restricted to a small number, and still further limitation is afforded by the flowering time of each species, more especially if the study be commenced in spring or early summer. A midsummer meadow bewilders the novice with its wealth of inflorescence, but in early summer only a few flowering species claim notice. *Poa annua* (frontispiece) is the first grass that will be found in flower on every bit of waste ground, in gardens, by roadsides and footpaths; it begins to shoot up its panicles towards the end of March—quite a month in advance of any other species, one or two rare ones excepted. In meadows the spike-like panicles of *Anthoxanthum odoratum* (fig. 13) and *Alopecurus pratensis* (fig. 36) are abundant during the month of May, while the only woodland grasses that

flower in spring are *Milium effusum* and *Melica* (fig. 26). Nearly half our grasses begin to flower in June, an equal number in July, a few not till August; some of the earlier species continue flowering until autumn.

The scientific grouping of grasses, that is, according to their affinities, will be found in Chapter III., to which the student should make frequent reference. The secret of success in the discrimination of grasses lies in being thoroughly conversant with the tribal and generic characters. Suppose, for example, that a specimen of *Poa annua* be gathered; after the student has examined it and satisfied himself about its identity, he should refer to Chapter III. and carefully note the tribal and specially distinctive generic characters there given; he will then be able to recognise, *as belonging to this genus*, all other species of *Poa* that he may meet with.

For the examination of grasses a pocket-lens, preferably a triple one, will suffice; but those who possess a microscope will find it helpful in the examination of extremely minute parts. Tiny one-flowered spikelets are rather troublesome to dissect with needles; if a thin slice be cut off the base of such spikelets, all the parts will then fall asunder. An excellent plan is to make in one's note-book an enlarged drawing of the flower-cluster or spikelet, and its different bracts or glumes (as in some of the illustrations) while examining them with the lens; this will impress the important characters on the mind as nothing else can, and if the name of the species be appended to each sketch, always using the Latin names, as they are more precise, the record thus made will be very convenient for future reference.

Owing to limited space our descriptions of the British species are necessarily brief, and attention is called to the more distinctive characters only. Of the manuals, Hooker's *Student's Flora of the British Islands* gives pretty full delineations; those of Babington's *Manual of Botany* are shorter, but critically precise. Sowerby's *English Botany*, vol. xi., is devoted entirely to grasses, and contains elaborate descriptions of both species and varieties, as well as large coloured illustrations of all the species. We have noticed all the well-marked varieties or sub-species, but the student will bear in mind that in many cases there are transitional forms not usually mentioned by botanical writers, who select the typical or predominant form and the extreme varietal one. Besides these, numerous varieties occur which are too slight for mention. All varieties, however, are of interest as showing the influence of soil and situation in causing variation.

Although in general aspect the leaves of grasses are much alike —"a narrow, sword-shaped strip of fluted green"—close inspection of them, including the sheaths, will reveal many minute characters which, taken collectively, are sufficient for the identification of the species, due regard being paid to habitats. The student should not rest content until he is able to analyze the turf of meadow, pasture and heath with facility, and to assist him in

this, we have taken some pains in describing the leaves of the commoner species. It is necessary to examine and compare the leaves in a fresh state, and as most of our grasses are perennial, this part of agrostological study may be prosecuted at all seasons and when flowering specimens are not obtainable.

A collection of dried specimens is desirable for several reasons, primarily for the purpose of reference and comparison at leisure, and for proof of the identity of rare or local species ; it also affords tangible evidence of one's activity in the pursuit of a favourite science, and recalls to memory many a pleasant ramble. Good examples of average size, and truly representative of the species, are most likely to be obtained in places where the plant grows in abundance ; some grasses vary considerably when growing out of their accustomed habitat. No specimen can be regarded as complete without the root or rootstock, and this part of the plant is sometimes of importance in enabling us to identify the species ; the whole plant should therefore be taken up, and the creeping underground stems, when present, exhumed without being broken off ; the roots should be washed quite clean on arrival home—an apparently large mass can thus be greatly reduced. The flower-clusters or spikelets of some grasses, particularly the Bromes and Barleys, if gathered in full flower, are liable to fall to pieces when dried ; it is better to gather such, and, indeed, nearly all grasses, a few days before the flowers are ready to open, because if the stamens are protruded, they fall off and get scattered throughout the herbarium. The locality and habitat from which each specimen is taken will of course be noted, as well as the date.

The method of preserving plants by drying them between sheets of paper under pressure is so well known that very little need be said on the subject here. Grasses are more easily preserved than most other flowering plants, owing to the dry, chaffy nature of the bracts investing the flowers. Care is required with the leaves, as they are liable to shrink in width and roll up lengthwise ; to obviate this, place the specimens in the drying-sheets immediately they are removed from the vasculum, and in arranging the drying-sheets put narrow slips of blotting paper upon the leaves, or at least upon two or three selected ones, until the thickness equals that of the stems. Some grasses are very brittle when dry ; hence moderately stiff paper is required for mounting. The neatest way to secure them to the mounting-sheet is with strips of tough paper looped over the stem and both ends passed through a perforation in the sheet, then gummed to the back. When the specimen is too large for the sheet, the stem has to be sharply bent upon itself. After being mounted and named, the species may be arranged according to the Manual that the student uses, or the London Catalogue ; failing these, the genera may be arranged and numbered according to the synopsis in Chapter III. Keep the collection in a dry but cool place ; warmth induces brittleness.

Specimens of the fruit, and of the fruiting spikes or panicles, may be gathered and kept in small envelopes.

CHAPTER I

Structure

WHILE perusing this chapter, the student should have before him some flowering specimens of grasses, also some large grains, say wheat, oats or barley, in order that he may verify our statements by his own observation.

We propose to begin with the examination of the tiny grass-plant in the seed, selecting a grain of wheat for the purpose of illustration. Of the grain, regarded as a fruit, we shall speak later, confining our attention at present to the living part or embryo, which is very small in comparison to the mass of floury endosperm stored up for its nourishment and forming the bulk of the grain. The exact position of the embryo is indicated by a minute wrinkled depression of the skin near the base of the grain (the apex is known by its having a crest of short hairs), and on the dorsal side opposite to the grooved or furrowed side. It is not embedded in the endosperm, but lies on the outside of it immediately underneath the skin. Before proceeding to examine the embryo, it is advisable to soften the grain by soaking it in water for a few hours. The embryo can then be easily detached, but the best way to observe it is in a longitudinal section like that represented in the accompanying figure. Such a section is obtained by halving the grain with a sharp knife lengthwise along the furrow. The embryo is now seen to be much longer than broad, and situated rather obliquely in respect to the axis of the grain. With the aid of a lens we can clearly distinguish, in the upper portion, the plumule with several leaf rudiments, the whole enclosed in a sheath known as the cotyledon; in the lower portion we recognise the radicle or young root, invested also by a sheath (coleorhiza); both these sheaths can best be seen in a grain that is germinating. The embryo is completely separated from the endosperm by a broad plate of tissue termed the scutellum (Lat. *scutum*, a shield), which calls for special notice, as it is peculiar to grasses and performs an important function at the time of germination. It is in organic connection with the rudimentary stem, and, by means of various ferments, dissolves the endosperm and then absorbs it for assimilation by the embryo. A better view of the scutellum can be obtained by detaching the embryo from a whole grain.

The phenomenon of germination is very interesting, and in order to observe it, we may experiment with some of the larger grains above-mentioned, also those of *Phalaris canariensis*, the "canary-seed" used for feeding cage-birds. Place the grains in

soil that has been sterilized with boiling water, or in sawdust ; keep very moist and in a warm temperature, say 70°–80° F., and they will germinate in about a week. The first outgrowth is the coleorhiza or root-sheath, from which the slender radicle or primary root soon bursts, followed by two lateral roots ; as these burrow into the soil, they become clothed with absorbent root-hairs. Meanwhile, the plumule appears, completely sheathed by the imperforate cotyledon which thus protects it during early growth. Here we have one of the characters of the *Monocotyledons* (plants having only one cotyledon or seedleaf), as distinguished from the other great class of flowering plants, the *Dicotyledons*, with two or more seedleaves. When the plumule has grown to the height of an inch or two, the first foliage-leaf pierces the apex of the cotyledonary sheath, and emerges. Presuming that we have experimented with the grains of *Phalaris canariensis*, its pink-coloured cotyledon will show in beautiful contrast to the first green leaf. The young plant is now able to provide its own nourishment, though the store of endosperm is not yet exhausted. If the scutellum be examined at this stage, with a high power of the microscope, we shall find that its innermost row of cells, which were at first prismatic in shape, now appear as slender strands, their elongation having taken place in order that they could remain in contact with the diminishing endosperm and absorb it from the remotest parts of the grain. The scutellum affords an absolute distinction between the *Gramineæ* or grasses, and all allied orders or families. Although it never grows out from the seed, it is in view of its function regarded by most botanists as a part, and the chief part, of the cotyledon.

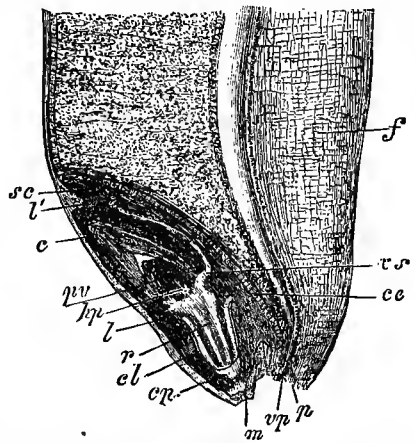

FIG. 1.—Median longitudinal section through the lower part of a grain of wheat (× 14): *f* one side of the furrow ; *sc* scutellum stretching obliquely across the lower part of grain, and separating the embryo below from the endosperm above, and on the right ; *pv* growing point of plumule, and *c* its sheath (cotyledon) ; *r* radicle ; *cp* root-cap ; *cl* root-sheath (coleorhiza) ; *hp* rudimentary stem (hypocotyl) ; *vs* a vascular bundle connecting hypocotyl with scutellum ; *ce* prismatic cells of scutellum ; *m* place where the radicle emerges, corresponding to micropile of ovule.

The primary root does not thicken into a taproot, and is soon indistinguishable from the numerous slender lateral roots which

are successively developed, and which branch very freely. The dense network of fibres thus formed take a remarkably tenacious hold of the surface-soil, and in meadows and pastures the roots of different species interlace; the result is a compact turf-sole, which can be peeled off entire, as in the operation of paring. A characteristic feature of grasses is that the branches of the rootstock, secondary as well as primary, each terminating in a leafy shoot, all originate close to the ground, and are extremely short; this makes the turf short and carpety. Reedlike grasses, on the other hand, have the branches of the rootstock elongated and erect. In many perennials the branches of the rootstock persist for an indefinite time; in others they die off annually; some are barren, the others in due season produce flowering stems; the leafy shoots of annuals are all fertile; those of biennials are barren the first year and flower the next; the rootstock then perishes. Another feature of the branches of the rootstock, and one which explains their remarkable vitality, is that the growing point, with its rudimentary leaves, is not at the apex of the leafy shoots, but near their base, within the cavity formed by the concentric leaf-sheaths, so that when the turf is grazed or trodden, the growing points escape injury, and fresh leaves are quickly produced.

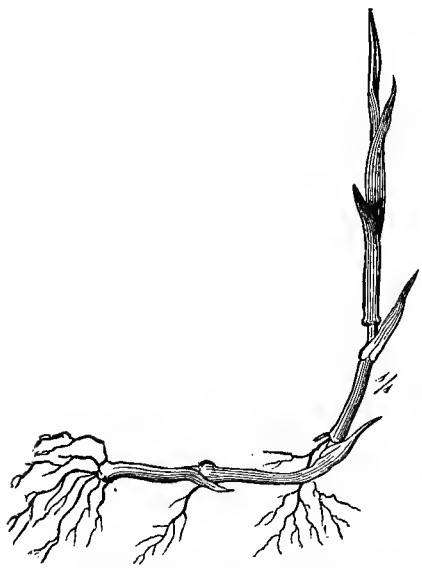

FIG. 2.—A young shoot or stolon detached from the parent, showing adventitious roots at the nodes, and scale-like leaves.

The rootstock of grasses is often stoloniferous, the stolons rooting freely at the nodes (fig. 2). It is not always possible to draw a sharp distinction between subterranean and surface stolons; the former have acute scales (leafless sheaths) at the nodes, while the latter have normally developed leaves. In some species the subterranean stolons are only a few inches in length, and when they have produced their leafy shoot are hardly distinguishable from the ordinary branches of the rootstock. These short stolons are mostly emitted in autumn and spring; they form a uniform

turf as opposed to one that is tufty. The subterranean stolons of some species, *e.g.* grasses of the seashore, and *Agropyrum repens*, the couch of hedgebanks and arable lands, attain a very great length and branch extensively underground, sending up leafy shoots at intervals of a few nodes, and ultimately a terminal shoot. Stoloniferous root-stocks are invariably perennial. The great abundance of grasses is largely due to their well-developed root-system, which enables them to supplant their rivals in the struggle for existence.

The leaves are solitary at each node and alternate; they have a long cylindric sheath, which is split down the side opposite the blade, and may be regarded as a very much compressed and involute petiole. This split sheath is one of the characters by which grasses are distinguished from the nearly allied family of sedges with entire leaf-sheaths. The sheaths closely invest the stem and give it a great amount of support; at the same time they functionate as leaves. At the mouth of the sheath, *i.e.* its junction with the blade, there is a translucent tongue-like projection close pressed to the stem; this is known as the ligule (fig. 3). Sometimes the leaf is auricled, the base of the blade being prolonged into a short tooth or spur on each side. In form, the leaves are usually more or less strap-shaped (linear), always simple (undivided) and entire at their margins; occasionally they are bristle-like (setaceous). They may be flat, or folded inwards from the midrib (conduplicate), or both margins may be rolled inwards (involute). Vernation is indicated by the form of the sheaths; when these are compressed the leaves are conduplicate in bud; when the young leaves are involute, the sheaths are round (terete). In some species the leaves are flat when young but become involute when fully grown. Some leaves taper gradually to the apex; others are suddenly pointed; others again are broadest near the middle (linear-lanceolate), tapering slightly to the base as well as more finely to the apex, these characters being constant in each species. The midrib and central part of the leaf are often sunk or depressed, so as to form a groove or channel on the upper side, and a keel below. Venation is always parallel, and the veins are often unequal, every alternate one, third, or fourth, etc., being stouter than the others, which is best seen by holding the leaf between the eye and the light. There are often longitudinal ridges or ribs on the upper surface of the leaf, usually one above each vein (fig. 4); these ribs vary considerably in different species, as regards their number and prominence, and may be flat, rounded or acute at the top; sometimes they are only perceptible as faint striations. Both surfaces of the leaf may be hairy or downy; commonly the upper surface only is so.

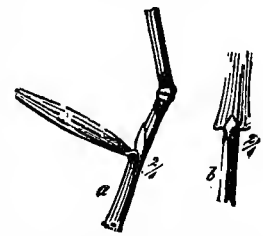

FIG. 3.—Showing tongue-like projection (ligule) at junction of stem and leaf-blade.

Hairiness or pubescence of the leaves is not a constant character in some species, but is less variable in respect to the lower sheaths. The leaves are often rough to the touch (scabrid) on the upper or both surfaces, and on the margins; this is most readily detected by the lips or tongue. If a scabrid leaf-margin be examined under the microscope it will be seen to be finely serrulate or sawlike, the asperities or minute teeth pointing towards the apex. The various shapes of the ligule sometimes help us to discriminate allied species; it may be acute, or its apex may appear as if cut off

FIG. 4.—Outline transverse section (enlarged) of leaf of *Lolium perenne*, showing ribs and venation. The dots represent fibrovascular bundles in cross-section.

abruptly (truncate); sometimes it is split down the middle (bifid), or torn into shreds (laciniate); at other times it is scarcely more than a margin at the mouth of the sheath, or it may be modified as a ring or tuft of hairs.

The flowering stem of grasses, usually spoken of as the culm, or popularly the straw, is quite distinctive of this order of plants, being hollow except at the knots or nodes which are a solid mass of fibres dividing the culm into a series of chambers. The culms are solid in the young state, but as they grow in length, the ground tissue of the centre ruptures, leaving only a thin ring to carry on the elongation of the internodes. From this period, therefore, the culm is fistular. In other respects, the structure of the culm is similar to that of the stems of other monocotyledons. If we make a very thin cross section through an internode of a culm and place it under the microscope, we see (fig. 5) a large central cavity bounded by cellular tissue (parenchyma) which is traversed longitudinally by isolated strings of woody tissue (fibro-vascular bundles), often disposed in two or more circles. Towards the outer part of the stem the cells are modified in having their walls thickened and hardened (sclerenchyma); these are often termed mechanical cells because of their function, namely to give strength and rigidity to the stem. A sheath of sclerenchyma surrounds each fibro-vascular bundle. The latter, once formed, is not able to grow further in thickness, having no longer any cambium or dividing-cells; the culm therefore does not increase in diameter. As the student is no doubt aware, these definite or closed bundles, as they are termed, are characteristic of all monocotyledons. Silica enters largely into the composition of the superficial tissue of the stems and leaves of grasses, as any one may demonstrate by using a blowpipe, which will fuse the silica into vitreous globules. In the mechanics of their structure, fistular culms exhibit much more specialization than the hollow iron pillars of man's contrivance for

obtaining, with economy of material, the maximum of strength and resistance to lateral strains, inasmuch as the cylinder formed by the tissues of the culm has its wall radially graduated in strength —vital tissue consisting of soft parenchyma and fibrovascular bundles innermost; outside of this a cylinder of sclerenchyma, and at the periphery the silicified cells of the epidermis. The culms of some bamboos have their mechanical cells and epidermis so hard as to resist the blow of a hatchet. The closely investing leaf-sheaths give a great amount of support to the stem which would otherwise, in many cases, be unable to support its own weight. The immense saving of tissue, represented by the large central cavity of the culms, enables them to grow with great rapidity; young bamboos have been observed to elongate 2–3 ft. in a day. A few grasses are exceptional in having the stems solid, *e.g.* the genera *Glyceria* and *Saccharum*. If we examine a transverse section of the stem of *Saccharum officinarum*, the Sugar-cane, we find that the fibrovascular bundles are most numerous near the circumference, the central part consisting mostly of parenchyma, among which the bundles are scattered sparsely.

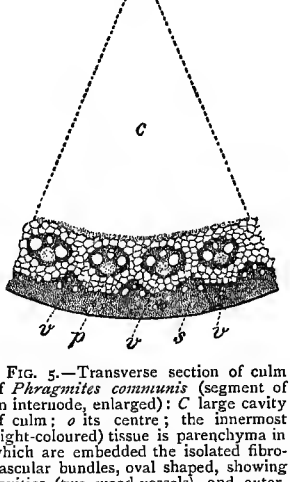

FIG. 5.—Transverse section of culm of *Phragmites communis* (segment of an internode, enlarged): *C* large cavity of culm; *o* its centre; the innermost (light-coloured) tissue is parenchyma in which are embedded the isolated fibro-vascular bundles, oval shaped, showing cavities (two wood-vessels), and externally bast; the peripheral part of the section (dark-coloured) is sclerenchyma, *s* (mechanical cells), in which are embedded smaller or imperfect bundles.

The flowers of grasses are enveloped in small scales or bracts (glumes) which are imbricated or overlapped so as to form little spikes or clusters (spikelets). Thus in fig. 14 there are thirteen spikelets represented; in fig. 26 there are ten spikelets. These glumes are the distinguishing feature of the *Glumaceæ*, a well-marked division of the *Monocotyledons*, and comprising, besides the grasses, a few other orders, notably the *Cyperaceæ*, sedges. The upper part of the stem forming the axis of the inflorescence is called the rachis; it is nearly always simple, *i.e.* undivided; but when two or more axes have a common insertion at the top of the stem, the rachis is termed compound (fig. 30). The simplest form of inflorescence in grasses is the spike, each spikelet being sessile (*i.e.* without a stalk or pedicel) on the rachis, and usually seated in notches or excavations (fig. 39) in two opposite rows (distichously) and alternately. More commonly the spikelets are borne on slender hairlike branches of the rachis, which have generally an alternate half-whorled insertion, and these branches are often

divided and sub-divided, forming the graceful airy panicle so characteristic of grasses (fig. 6). The ultimate branches of the panicle are of course the pedicels of the spikelets, and the number of spikelets contained in this paniculate form of inflorescence is often immense. In the raceme, an intermediate form of inflorescence, each spikelet has its pedicel inserted directly upon the rachis. The panicle may be pyramidal (figs. 7, 8, 37), or oblong (fig. 14), or cylindric (fig. 18), lax (figs. 19–26), or dense (figs. 18–21), spreading in all directions, or one-sided (unilateral). In some cases the branches of the rachis are so short that the inflorescence resembles a spike (figs. 13, 16); such a panicle is termed spikelike. Especially is this so with the genera *Phleum* and *Alopecurus* (figs. 18, 36,) which have such a dense contracted panicle that the extremely short branches are quite concealed. The inflorescence in its rudimentary state—a cluster of papillæ, each a rudimentary spikelet — will be found, some weeks before the flowering season, within the leafy shoots, close to their base, and immediately above the uppermost node.

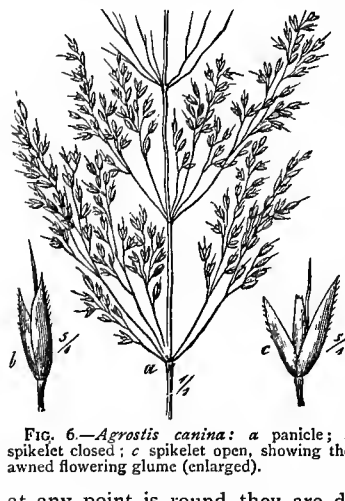

FIG. 6.—*Agrostis canina: a* panicle; *b* spikelet closed; *c* spikelet open, showing the awned flowering glume (enlarged).

The spikelets vary in shape from orbicular (nearly round) to narrowly-elliptical and tapering (lanceolate), or cylindrical; most commonly they are egg-shaped (ovate). They are often laterally compressed, *i.e.* flattened at the sides of the glumes, but in most *Panicaceæ*, they are somewhat dorsally compressed. When of varying diameter, but not compressed, so that a cross-section made at any point is round, they are described as terete. Let us now dissect a spikelet like that in fig. 7 (upper figure). The glumes, six represented in this figure, are sessile on a slender axis (rachilla) which is concealed, and are arranged distichously, *i.e.* in two opposite rows, and alternately in harmony with the phyllotaxis of the leaves of the stem. The pair of apparently opposite glumes at the base of the spikelet are empty; each of the others, called flowering glumes in contradistinction to the empty ones, bears in its axil, and envelops or embraces at its edges, another bract termed the palea (lower figure). Within the flowering glume and palea, and partly concealed by these, is the solitary sessile flower which we shall describe presently. None of these bracts form any part of what are technically known as floral envelopes. As the two empty glumes are inserted one slightly above the other, we speak

of the upper and lower; similarly the palea is not exactly on the same plane as the following glume. And here we must explain an unfortunate variance in terminology; some botanists call the flowering glume a palea, and then speak of the upper and lower paleæ, which the student will bear in mind when consulting the descriptive works of different authors.

A spikelet may contain one or any number of flowers; that taken by way of illustration is four-flowered. One-flowered spikelets are very common, *e.g.* in the tribes *Agrostideæ* and *Paniceæ*. The terms empty and flowering glumes are employed in their literal sense; some glumes are, strictly speaking, neither empty nor flowering, as they have a palea in their axil, but no flower; these abortive glumes occur commonly in the *Panicaceæ*. As the flower is solitary in the axil of its glume, it is obvious that the number of flowering glumes in any spikelet always corresponds to the number of flowers. Cases where there are no empty glumes at the base of the spikelet are very exceptional; but we have two British examples in *Nardus* and *Leersia*, while in *Lolium* we have an instance of only one empty basal glume. On the other hand, spikelets often contain more than two empty glumes, and these additional ones are situated either immediately above the two basal glumes or at the apex of the spikelet. For example, in *Anthoxanthum odoratum* (fig. 13), the third and fourth glumes are empty as well as the first and second; in the many-flowered spikelets of the *Poaceæ* it is nearly always the uppermost or terminal glume that is empty or abortive; in the *Panicaceæ* the third glume is usually abortive. The additional empty glume, whether in the upper or lower part of the spikelet, is often rudimentary, or merely represented by a stalk or pedicel. All such variations in the structure of the spikelet are important in classification, and the student will require to carefully observe them. Sometimes there is a tuft of hairs at the base of each flowering glume, on the rachilla; when these hairs are tangled, as in the genus *Poa*, the glumes are said to be webbed.

FIG. 7.—*Poa pratensis*: panicle to the left, enlarged spikelet above; below, flowering glume, palea and flower, more enlarged.

The glumes are more or less boat-shaped, thin but firm in texture, green, or tinged with brown or purple. They are very variously modified, and afford valuable characters for determining

the genera and species; more especially is this so with the flowering glume. The glumes are always nerved, *i.e.* with unbranched veins, the central or dorsal nerve usually stronger than the lateral ones. The glumes may either be rounded on the back, or compressed and keeled, the keel being formed by the prominence of the dorsal nerve on the outer surface. The nerves vary in number—one, three, five, etc., always an odd number—and either run parallel, or converge as they approach the apex of the glume; sometimes they slightly project beyond the apex (excurrent), (fig. 21), or they may vanish below it. The glumes may be hairy or downy on the outer surface, or scabrous along the nerves. The two empty glumes at the base of the spikelet often differ from each other, as well as from the flowering glume, both in size and in the number of nerves (fig. 27).

FIG. 8.—*Holcus lanatus:* lower figure, an enlarged spikelet; upper figure, the same with empty glumes removed to show dorsal awn of upper flowering glume.

The fine hair or bristle which is often present on the flowering glume is called the awn. It may be simply a prolongation of the dorsal nerve (figs. 16, 18), or it may be inserted at some point along that nerve (figs. 8, 36), or it may arise from the base of the glume, and is denominated terminal, dorsal, or basal, accordingly. It varies in length in different species, and may be smooth or, as is often the case, scabrid. When the tip of the glume is split (bifid) or notched, the awn arises from the bottom of the notch or sinus, and is styled subterminal. Sometimes the awn is sharply bent (geniculate or kneed) as in the Oat, and the part below the knee spirally twisted; the awn is then hygroscopic, the torsion increasing or diminishing with the varying humidity of the atmosphere. This hygroscopic movement can readily be observed by placing a few glumes so awned into water, or upon a wet surface. In one exotic genus, *Aristida*, the awn is compound, having three forks or branches; another exotic genus, *Pappophorum*, is remarkable in having the flowering glume armed with a dozen or more awns. Generally speaking, the lateral nerves of the flowering glume are not sufficiently excurrent to form awns. In many cases the dorsal nerve too is only slightly excurrent, forming a short point or mucro (fig. 31). The empty glumes are, as a rule, either mucronate or awnless; *Hordeum* and *Polypogon* are familiar exceptions, having long-awned empty glumes. The *Panicaceæ*, one of the primary series into which grasses are classified, are in-

variably characterized by imperfect awns which can hardly be considered more than mucros. The two-nerved palea is peculiar to grasses, as distinguished from the other glumaceous orders, and is never absent, unless we except the tribe *Oryzeæ* and *Phalarideæ*, which have a one- instead of a two-nerved scale in the axil of the flowering glume.

We have now to describe the flower (fig. 9). As already remarked, neither glumes nor palea constitute what are botanically known as the floral envelopes. The perianth of the grass-flower is very rudimentary indeed; it consists of two or three colourless scales (lodicules) which are so exceedingly minute that they can hardly be detected with the naked eye, and, unlike the perianth of most other flowering plants, they are of very little service to us in the classification of the Order, the *Bambuseæ* excepted. Hence the various modifications of the glumes have all the more importance. The lodicules are hypogynous (*i.e.* situated beneath the ovary), and may be entire or bifid, or fringed at the edges. The stamens, also hypogynous, are usually three in number; they have a long filament and a large, linear or oblong anther, which is notched at the ends, as the two lobes do not cohere throughout; it is pendulous and attached at the back (dorsifixed) to its filament by a joint, so that it is versatile, swinging as on a pivot. The pistil consists of a very minute more or less globular ovary, surmounted by two styles, each branching into a comparatively large feathery stigma. The ovary, although formed of two carpellary leaves (indicated by the two styles and stigmas), is one-celled, *i.e.* with a single cavity, and contains only one ovule, which is basal and erect, or nearly so, but inverted (anatropous) upon its stalk or raphe (fig. 10).

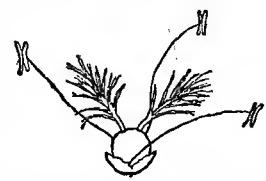

FIG. 9.—A grass-flower (*Poa*), showing globular ovary with 2 lodicules at its base, 3 stamens, and 2 feathery stigmas. Greatly magnified.

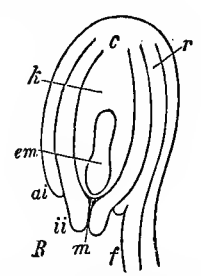

FIG. 10.—Inverted ovule: *f* funicle; *r* raphe; *ai* and *ii* outer and inner integuments; *m* micropile; *k* nucellus; *em* embryo-sac. Much magnified.

The symmetry of the grass-flower is rather obscure. Theoretically, the grass-flower is made up of ternate whorls, *i.e.* each whorl or circle of floral organs consists of three members or a multiple of that number, these members alternating one with another in the different whorls. Of the four series of organs which constitute a typical flower—calyx, corolla, stamens (androecium), and pistil (gynæcium)—the first is always absent in grasses, and the other whorls are often incomplete. The common type of grass-flower is shown diagrammatically in fig. 11 B. It has only three whorls;

the outermost consists of two lodicules placed at the anterior side of the flower, *i.e.* furthest from the axis or rachilla, the posterior lodicule being aborted or suppressed; three stamens constitute the middle whorl, while the innermost whorl consists of two carpellary leaves united into a single-celled ovary, which still retains two styles and stigmas. Suppression of the anterior stamen may occur, as in *Anthoxanthum odoratum* and some of the Bromes; sometimes the two posterior stamens are suppressed, as in *Festuca*

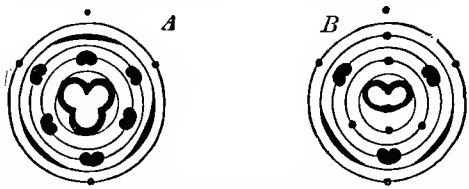

FIG. 11.—Diagrams of grass-flowers showing symmetry. *Explanation of symbols:* outside dot represents the axis (rachilla); the circles=whorls, and the dots on circles=missing members; crescentic marks=lodicules, the kidney-shaped=stamens; the innermost symbol with its half-circles represents stigmas, and its cavity the ovary. *A* Flower of Bambusa with outermost whorl missing, but full complement of members in the other whorls. *B* Common type of grass-flower with several members absent; one stamen is anterior (next the flowering glume), the other two are posterior (against the palea).

myurus.' The flowers of the genus *Bambusa* (bamboos), fig. 11 A, are perfectly regular, having three lodicules, six stamens, and three stigmas, the formula being Ko, C3, A3+3, G(3). If we regard the flower of the Lily family (K3, C3, A3+3, G3) as typical of Monocotyledons, and compare with it the flower of *Bambusa*, we find that the latter only differs in having the outermost perianth whorl of three segments suppressed, and in the innermost (fifth) whorl being modified by the carpellary leaves uniting to form a unilocular instead of a three-celled ovary.

As a rule the flowers of grasses are bisexual or perfect; although there are many instances of one or more imperfect (usually male) flowers in the same spikelet with bisexual ones, *e.g. Arrhenatherum* and *Panicum*. In tropical and subtropical regions, we sometimes find a complete separation of the sexes, as in *Zea mays* whose spikelets are always unisexual, those in the upper part of the inflorescence containing stamens only, the lower spikelets female.

In most grasses, the flowering glume diverges widely from the palea at the time of flowering, the anthers become pendulous, and the stigmas protrude one at each side of the flowering glume. In other cases the divergence or opening is just sufficient to let the anthers and stigmas emerge at the apex, either simultaneously or the stigmas first. The pollen cannot be scattered upon the stigmas of the same flower, when the anthers are pendulous, and its transference from one flower to another (cross-fertilization) is effected by the wind. A little reflection will show that the peculiarities of the structure of the grass-flower are all an extreme adaptation to

this anemophilous mode of pollination. The flowers are inconspicuous; the perianth (which in most other plants whose flowers are pollinated by insects, is large, brightly coloured, and so attractive) is in grasses which do not require the services of insects, reduced to microscopic size, and the flowers are protected by green uninviting bracts; the large anthers contain a copious quantity of pollen for dispersion broadcast, and the large feathery stigmas readily catch the pollen grains as they are wafted on the wind; moreover, as the grass-flower has only one ovule, a single pollen grain suffices for its fertilization. Pollination is thus amply provided for; and a second staminal whorl, being unnecessary, is usually suppressed.

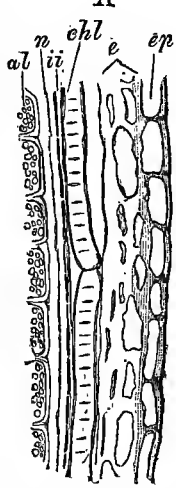

FIG. 12.—Cross-section through the pericarp and testa of a grain (×240); *ep* epicarp; *e* outer layers, and *chl* chlorophyll layer, together constituting the pericarp; *ii*, remains of the ovular integuments, and *n*, layer of nucellus, form the testa; *al* outermost layer of endosperm cells.

The process of fertilization of the ovule, which takes place quickly after pollination, is the same in grasses as in all other *Angiosperms*, *i.e.* plants whose ovules are enclosed in an ovary. The seed is ordinarily matured in the course of three or four weeks, the wall of the ovary becomes thin and dry, but adheres firmly to the solitary seed, and constitutes the pericarp (fig. 12). Such a fruit is termed a grain or caryopsis; for, convenient though it be to speak of the grains as seeds, this is not botanically correct. The caryopsis is very similar to the nut, but differs from it in having the pericarp adherent. The pericarp does not rupture until germination takes place; in other words, the fruit is indehiscent. *Sporobolus* is one of the rare instances of a free pericarp which, in this genus, splits into two portions or valves to allow the seed to escape. The seed has a very thin coat or testa (fig. 12, *ii* and *n*), and contains an unusually large quantity of endosperm. The position of the embryo, in relation to the endosperm, we have already noticed at the beginning of this chapter. It will be observed that in consequence of the inversion of the ovule, the radicle of the embryo is directed towards the base of the grain. We shall have something to say about the endosperm as a nutrient substance, when treating of the uses of grasses. In form, the grain may be ovoid, oblong, or spindle-shaped; it has often a longitudinal groove on one side, corresponding to the place where, in the development of the flower, the edges of the carpellary leaves cohered (the ventral suture) to form the ovary.

The fruit is liberated in various ways. When the inflorescence is a jointed spike, as in *Hordeum* and *Lepturus*, the rachis (axis of

inflorescence) breaks up at the joints or nodes, and each internode as it breaks off carries away with it a spikelet enclosing the fruit. In those grasses which have many-flowered spikelets, like *Poa* and *Bromus*, the rachilla (axis of the spikelet) is jointed, and its internodes break away separately, each with a fruiting glume attached (fig. 34). One-flowered spikelets often drop off the pedicel entire, *e.g. Alopecurus* and *Panicum*. Very frequently the grain adheres permanently to the palea, and sometimes also to the flowering glume; but whether adherent or free, it is nearly always enclosed in both, and as the fruiting glume retains the distinctive characters of the flowering glume, the fruits of the different species can be discriminated from each other by means of these spurious coverings. The fruit of the Bromes, for example, is distinguished by the apical notch and the straight subterminal awn of the fruiting glume (fig. 32); that of the Oat-grasses by the long geniculate and twisted dorsal awn (fig. 20); that of *Anthoxanthum* is enclosed in the second pair of empty glumes (fig. 13). When the entire spikelet falls off, as in *Panicum*, all the glumes persist around the fruit. In some grasses the fruiting glume has a tuft of hairs at the base, as in *Calamagrostis*, *Ammophila*, and *Deschampsia*. In *Poa* these hairs are cobwebby (arachnoid). Sometimes, *e.g. Phalaris*, *Panicum*, and *Milium*, the fruiting glume becomes hard and polished. Many other examples could be cited, and the student who acquires a thorough knowledge of the distinctive characters of the flowering glume, will have no difficulty in discriminating the so-called seeds of the different species.

Enveloped in one or more light chaffy glumes, the fruit is nicely equipped for wind-dispersal; for evidence of the colonizing powers of our meadow and pasture grasses, we have only to examine a piece of naked or mossy ground in autumn or spring, and we shall find hundreds of seedling grasses. Long, bent and twisted awns, like those of *Stipa* and *Avena*, are able to bury the fruit. The former are not native grasses, but the long feathery awns of *S. pennata* may often be seen in bouquets of dried grasses. Glumes awned in this manner are usually barbed at the base with stiff hairs, and the curvature and hygrometric movement of the awn, after the fruit has fallen to the ground, gives a screwing motion to the fruit, which thus bores its way by degrees into the soil or works into crevices. *Stipa spartea*, a North-American grass, misuses the power that Nature has endowed it with; its long awns fix themselves in the wool of sheep and penetrate the flesh. Wind is the universal disseminator of grass-fruits, but those with scabrid glumes or awns often adhere to the fur and feathers of animals and birds, and are thus transported to fresh localities. Migratory birds carry the grains, embedded in mud on their feet, over the sea to neighbouring islands and to other continents. Man himself undesignedly acts as a disseminator, by sowing weed-grasses along with cereal and other crops in a tilled soil, where they flourish and cannot be extirpated. Hence it is that certain agrarian species of grasses are found in every part of the civilized world.

Grasses propagate themselves very largely, of course, by means of subterranean stems, and those species which creep extensively underground are usually characterized by a paucity of flowering stems. Another mode of perpetuation, but much less frequent, is by means of leafy buds which are produced on the spikelets in place of sexual organs; they eventually fall to the ground, and under favourable conditions strike root. These viviparous forms are usually found on mountains where meteorological conditions are adverse to the pollination of flowers. One of our lowland species, *Cynosurus cristatus*, may sometimes be seen in a viviparous state in meadows and pastures; it is of special interest in this connection, because the young plants are borne on the flowerless spikelets.

CHAPTER II

British Species

THE grasses that we shall first describe are those which constitute the mass of the verdure of our meadows and pastures. With the exception of the last three or four, the species comprising this group are very abundant in all parts of Britain. *Festuca duriuscula*, *Lolium perenne*, *Dactylis glomerata*, *Poa pratensis* and *P. trivialis*, *Cynosurus cristatus*, *Holcus lanatus*, and *Agrostis vulgaris*, flourish in various other habitats, besides meadows and pastures — by roadsides, in waste places and on heathy uplands — and are apparently indifferent both to soil and situation, excepting *Agrostis vulgaris* and *Poa pratensis* which are partial to dry ground, and *Poa trivialis* which luxuriates in damp places. The first five species above-named, and *Anthoxanthum odoratum*, are also common in woods.

FIG. 13. — *Anthoxanthum odoratum:* panicle, flowering and closed; enlarged spikelet, above; below, to left, the same with two lowest empty glumes removed; below, to right, flowering glume and palea, much magnified.

Anthoxanthum odoratum, the Sweet-scented Vernal-grass (fig. 13), is the first of our perennials to flower. The rootstock is tufted; leaves flat, tapering above, usually hairy on both surfaces, dull light green; auricles minute, roundish, or reduced to hair-tufts; ligule truncate. Culms about a foot high. Panicle spike-like, with extremely short branches, rather uneven below, 2–2½ inches long, yellowish-green. Spikelets ⅓ inch long, terete, 1-flowered; second empty glume much larger than the lowest, and as long as the spikelet; third and fourth glumes empty, dorsally awned, brown and hairy; awns unequal, the longer bent, twisted, and sometimes slightly exceeding the tip of the spikelet; flowering glume minute, awnless; stamens, two. This grass is fragrant when bruised or withering, and imparts an

agreeable scent to hay : its flavour is bitter and aromatic. Flowering from early May to July.

Alopecurus pratensis, the Meadow Foxtail (fig. 36), comes next into flower. The rootstock has very short stolons ; leaves flat, rather broad, tapering above, with flattish ribs, pale green ; ligule truncate, scarcely as long as broad ; basal sheaths purplish-brown. Culms 2–3 ft. Panicle spike-like, cylindric, dense, 2–3 inches long, obtuse at both ends, pale green and silky. Spikelets about $\frac{1}{4}$ inch long, compressed, 1-flowered ; empty glumes united at the base, and the keel fringed with long, soft hairs ; flowering glume with a bent dorsal awn twice its length ; no palea. Perennial, flowering from middle of May to August.

Bromus mollis, the Soft Brome (fig. 14), is a tufted annual or biennial. The culms are 1–2 feet high ; leaves flat, rather broadly linear-lanceolate, greyish-green. All parts of the plant are clothed with soft hairs. Panicle erect, rather compact, with short branches, some of which bear only one spikelet. Spikelets $\frac{1}{2}$–$\frac{3}{4}$ inch long, conical above, greyish-green, 6- to 10-flowered ; glumes closely imbricate, pubescent ; flowering ones broad, rounded on the back, and with the margin distinctly obtusely angular above the middle, notched at the tip, and with a sub-terminal, straight awn about their own length ; nerves of palea ciliated ; upper part of ovary hairy, and styles lateral. Flowering from the latter part of May to August. Starved states of *B. mollis*, with culms a few inches high, and only 2–3 spikelets, or even a solitary one, may often be seen in dry places.

FIG. 14.—*Bromus mollis* : panicle.

Poa pratensis, the Smooth Meadow-grass (fig. 7), has an extensively creeping rootstock producing numerous stolons. Leaves flat, rather narrowly linear, keeled, but not evidently ribbed, bright green ; sheaths smooth ; ligule obliquely truncate. Culms, 1–2 ft., smooth. Panicle pyramidal and diffuse, with a slightly drooping apex, and often tinged with purple ; branches, 3–5 at each insertion. Spikelets $\frac{1}{5}$ inch long, generally 4-flowered ; glumes all compressed, keeled and awnless, the dorsal nerve running up to, but not exceeding, the tip ; flowering glumes webbed, with five distinct nerves, three of which are hairy. Perennial, flowering early June, July. Var. *P. augustifolia*, found in woods and shady places, has longer narrow leaves. Var. *P. strigosa* has narrow and ultimately involute leaves, and the panicle is closed after flowering : wall-tops and stony places.

Festuca duriuscula, the Hard Fescue, is readily distinguished from the other grasses of our meadows and pastures by its leaves, which are subsetaceous (almost bristle-like) and dark-green ; those springing from the rootstock are conduplicate, and when forcibly unfolded show three prominent ribs ; the culm-leaves are nearly flat ; ligule obsolete, except for two very minute auricles. The rootstock is more or less tufted, and shortly stoloniferous. Culms, 1½–2 feet. Panicle somewhat unilateral, with short, spreading branches. Spikelets about ½ inch long, purplish, and often glaucous, 5- or 6-flowered ; empty glumes unequal ; flowering ones narrow, rounded on the back, and tapering into a very short awn. Perennial, flowering mid-June, July.

FIG. 15.—*Dactylis glomerata* : lower left-hand figure an enlarged spikelet ; on right hand flowering glume, palea, and flower, more enlarged.

Lolium perenne, the Perennial Rye-grass, has a tufted rootstock, not creeping. Leaves narrow, tapering from the base, keeled, with prominent ribs, rather glaucous above, deep-green, smooth and shining beneath, auricled ; sheaths compressed and young leaves conduplicate ; basal sheaths bright red. Culms 1½–2 feet. Spikelets about ½ inch long, 6- or more flowered, and sessile edgewise, one in each notch of the rachis, forming a somewhat zigzag spike 4–8 inches long. There is only one empty glume at the base of each spikelet (the terminal spikelet excepted) ; flowering glumes obtuse, rounded on the back, as long as the empty one, sometimes awned (var. *aristatum*). In some examples the rachis is very short, and the spikelets crowded. Perennial, flowering from middle of June to autumn.

Dactylis glomerata, the Rough Cocksfoot (fig. 15), has a densely tufted rootstock, the basal part very stout, compressed, and colourless. Leaves long and rather broad, gradually tapering, conduplicate when young, afterwards flat, faintly ribbed or striated, and prominently keeled, bluish-green ; ligule long, acute. Culms 2–3 feet. Panicle stiff, unilateral, with a few alternate branches, the lower of which are remote, purplish. Spikelets about ¼ inch long, compressed, and 3- or 4-flowered, crowded into dense, one-sided clusters at the extremities of the branches ; flowering glumes with a ciliate keel, and a short, scabrid awn. In dwarf specimens the panicle is often reduced to a single cluster. Perennial, flowering from the latter half of June to autumn.

Poa trivialis, the Roughish Meadow-grass, so closely resembles *P. pratensis* that the novice is not likely at first sight to notice any difference. The absence of subterranean stolons in the former is an unequivocal distinction. Rootstock tufted, not creeping. Leaves flat, narrow, tapering gradually from the base, keeled, not ribbed, slightly rough on both surfaces and on the margins; sheaths also roughish, which is discovered by drawing them downwards through the fingers; ligule long and pointed. Culms 1½–2 feet. Panicle pyramidal, diffuse, erect, and pale green, the branches 5–6 at each insertion. Spikelets about ⅛ inch long, usually 3-flowered; glumes as in *P. pratensis*, the flowering glumes with five distinct nerves, the dorsal one hairy. Perennial, flowering middle of June, July. Var. *P. Kœleri*, found in woods, has smooth sheaths. Var. *P. parviflora* is a slender plant, with the spikelets 1- or 2-flowered.

Cynosurus cristatus, the Crested Dogstail (fig. 16), has a rather tufted rootstock, with numerous short stolons. Leaves flat, short, and narrow, tapering from the base, ribbed and keeled, bluish-green above, shining beneath, without auricles; basal sheaths yellow. Culms a foot or more high. Panicle spikelike, linear, unilateral, 2–3 inches long, stiff. Spikelets about ⅛ inch long, in pairs; the uppermost spikelet of each pair 2- to 5-flowered, the other spikelet sterile, consisting of about eight empty mucronate glumes. This dual character of the spikelets distinguishes Cynosurus from all other British grasses. Flowering glumes rounded on the back, 3-nerved, scabrid in the upper part, and tipped with a very short awn. The flowerless spikelets are sometimes viviparous. Perennial, flowering from close of June to August.

FIG. 16.—*Cynosurus cristatus*: figures to left enlarged, the lower one a pair of spikelets, the upper a flower with its glume and palea.

Holcus lanatus, the Meadow Soft-grass (fig. 8), has a densely tufted rootstock, never creeping. Leaves flat, rather broadly linear-lanceolate, velvety and whitish-green with the soft hairs clothing both surfaces; ribs uneven, some being prominent, others very low; basal sheaths white, with red veins—a peculiarity by which the plant is easily identified when not in flower. Culms, 1–2 feet. Panicle with short branches, mostly in pairs, spreading at the time of flowering; at once recognised by its colour—pale green or white, suffused with pink. Spikelets ⅛ inch long, downy, containing two flowers, the lower of which is perfect and its glume awnless, the upper flower pedicelled, staminate, its glume having a dorsal awn, which reaches to the tip of the spikelet, and ultimately curves into a hook; flowering glumes smooth and shining. Per-

ennial, flowering from end of June to autumn. Often called Yorkshire Fog.

Festuca pratensis, the Meadow Fescue (fig. 17), has a loosely tufted and shortly-stoloniferous rootstock. Leaves flat, gradually tapering, with equal, rounded, smooth ribs and roughish margins, auricled; shot with yellow in transmitted light; ligule very short; basal sheaths brown or reddish-purple. Culms 2 feet. Panicle turned to one side, and the branches in pairs, one branch bearing several spikelets, the other bearing but one spikelet. Spikelets half an inch or more in length, tinged with brown, 8- or 9-flowered; flowering glumes rounded on the back, mucronate, or the mucro often absent, owing to the dorsal nerve barely extending to the tip. Perennial, flowering close of June, July. Var. *F. loliacea*, the Spiked Fescue, has the spikelets almost sessile on the rachis, and may easily be passed over as an example of *Lolium*.

FIG. 17.—*Festuca pratensis:* two lower figures enlarged, the right a spikelet, the left a flowering glume, etc.

Trisetum flavescens, the Yellow Oat, is abundant on heathy uplands, as well as in meadows and pastures, particularly where the soil is calcareous. Rootstock with slender stolons. Leaves narrow, flaccid, tapering finely, hairy on both surfaces, and with ciliate margins, light green; lower sheaths clothed with spreading-deflexed hairs; ligule very short. Culms 1–1½ feet. Panicle spreading, with numerous short branches, 5–6 at each insertion; at first it is greenish-yellow, then bright yellow, when it is easily recognised, glossy. Spikelets ¼ to ⅓ inch long (much smaller than those of our other Oats), oblong or wedge-shaped, and compressed, 3- or 4-flowered; flowering glumes keeled and bifid, *i.e.* the tip split into two segments, each of which is terminated by a short seta or bristle; the flowering glumes have also a slender kneed and twisted dorsal awn nearly twice their length. Perennial, flowering early part of July, August.

Agrostis vulgaris, the Fine Bent, has a rootstock more or less tufted, and sometimes stoloniferous. Leaves flat, short and narrow, tapering from the base, not keeled, dull green; sheaths smooth: ligule truncate. Culms 1–1½ feet. Panicle with numerous hair-like triply-forked branches which are diffuse both in flower and fruit. Spikelets $\frac{1}{10}$ to $\frac{1}{12}$ inch long, purplish-brown and shining, 1-flowered; empty glumes narrow and acute, the lower one with the upper part of the keel scabrid; flowering glume hyaline, truncate, and usually

awnless. Perennial, flowering early July to Autumn. Var. *A, nigra* has erect, taller stems, and is more robust: sheaths and panicle rough, and the truncate ligule rather long.

Phleum pratense, the Common Catstail or Timothy-grass (fig. 18). is common in England, but less so in Scotland and Ireland. Rootstock tufted; var. *stoloniferum* with numerous stolons. Leaves flat, tapering above, with low, flat, uneven ribs and rough margins, greyish-green; ligule truncate, toothed. Culms 1½ feet. Panicle spikelike, cylindric and dense, 3–6 inches long. Spikelets ⅛ inch long, compressed, 1-flowered; empty glumes truncate, with a rigid scabrous terminal awn not quite half their length, the keel ciliated with long, stiff hairs; flowering glume hyaline, 3-nerved, toothed at the apex, awnless. In dry pastures the panicle is frequently not more than an inch long, and the base of the stem swollen (var. *P. nodosum*). Perennial, flowering mid-July, August.

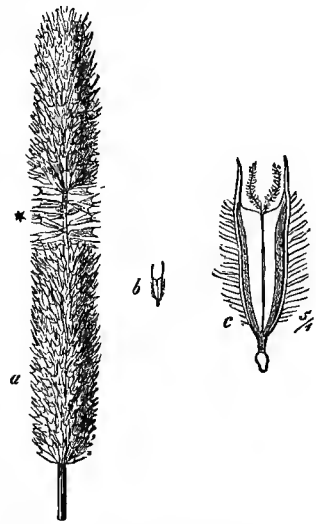

FIG. 18. — *Phleum pratense: a* the spikelike panicle; *b* a spikelet, nat. size; *c* spikelet enlarged.

Hordeum pratense, the Meadow Barley, is frequent in damp meadows in England, especially near the coast; very rare in Scotland, and local in Ireland. Rootstock rather loosely tufted. Leaves narrowly linear-lanceolate and finely tapering, with scabrid ribs, hairy, dull green; ligule truncate and very short. Culms 1½–2 feet. Spike 2–2½ inches long, compressed, yellowish-green, at once recognised by its similarity to the spike of the cultivated barley. Spikelets inserted three in each notch of the rachis, ½ inch long (exclusive of the awns), 1-flowered; the lateral spikelets of each triad staminate, the central one bisexual; empty glumes all bristle-like and scabrid, not ciliated, prolonged into an awn twice their length; flowering glumes narrow, rounded on the back, and obscurely 3-nerved, tapering into an awn not quite their length. All the awns are scabrid. Perennial, flowering middle of July, August.

Bromus racemosus, the Smooth Brome, is not unfrequent throughout Britain, but is liable to be confounded with its near ally, *B. mollis*. Culms 2–3 feet. Leaves firm and thinly hairy, deep-green. Panicle long and narrow, erect, the branches reduced to short pedicels, and rarely bearing more than one spikelet. Spikelets about ½ inch long, smooth or slightly scabrid, glossy, with an

acute tip, 5- to 10-flowered; glumes closely imbricate, both in flower and fruit; the flowering glumes differ from *B. mollis* in having their margins curved near the middle, not angular. Biennial, flowering June, July.

Bromus commutatus, the Tumid or Confused Brome, is hardly distinguishable from the foregoing, and should perhaps only rank as a variety: it is found in pastures and waste ground. The panicle is slightly drooping and more branched, the lower branches often bearing two or more spikelets. The flowering glumes have a blunt angle on each side and are dull green with a brownish tinge; fruiting glumes loosely imbricated, their margins involute.

Anthoxanthum Puelii, Puel's Vernal-grass, occurs in sandy pastures in the south of England. It is very similar to *A. odoratum*, but annual and more slender. Culms numerous, about 9 inches high; ligule oblong and laciniate. Panicle spikelike, lax; tips of the two awned glumes jagged, and the longer awn extending far beyond the apex of the spikelet. Flowering in July.

Our next group comprises a dozen species which grow on downs, commons, uplands, heaths and moors. Several of them occur also in breezy situations by the coast.

Festuca ovina, the Sheep's Fescue, is abundant all over Britain, in hillside pastures and copses, and on mountain slopes. It is very closely allied to *F. duriuscula*, but the rootstock is densely tufted, without stolons, and the leaves are apparently solid and filiform (threadlike); ligule two very minute lateral lobes. Culms slender, 6–9 inches. Panicle short, contracted and glaucous. Spikelets few, smaller than the allied species just named, on very short branches or pedicels, $\frac{1}{6}$ to $\frac{1}{4}$ inch long, oval, 4- or 5-flowered; flowering glumes narrow, rounded on the back, tapering into a mucro or short awn; fruit golden-brown. Perennial, flowering latter part of June. Var. *F. major* is a taller plant with a larger panicle; stem-leaves broader than the radical; flowering glumes usually awned.

Nardus stricta, the Mat-grass, is found in great abundance on wet heaths and moors, as well as in elevated pastures and by heathy waysides, in places where water collects; widely distributed throughout Britain. It is readily known by its tussocks of stiff, bristlelike leaves, these tussocks consisting of numerous tufts closely matted together and swollen at the base. The leaves are so closely involute as to appear solid, with a groove on the upper side, scabrid. Culms wiry, 6–9 inches. Spike slender, unilateral, purple. Spikelets about $\frac{1}{4}$ inch long, 1-flowered, sessile and solitary in two rows of notches on one side of the rachis; no empty glumes; flowering glume subulate, keeled and prolonged into a short scabrid awn. The ovary differs from that of all other British grasses in having only one style and stigma. Perennial, flowering middle of June.

Briza media, the Common Quaking-grass (fig. 19), is plentiful on downs, heaths, and upland pastures, and often on poor meadow-

land ; it is distributed all over Britain. Rootstock tufted ; leaves flat, firm, rather short, tapering above, with scarcely perceptible ribs, rough margins, dull glaucous green ; ligule short and truncate. Culms about a foot high. Panicle deltoid or pyramidal, lax, with capillary spreading branches. Spikelets pendent, $\frac{1}{6}$ to $\frac{1}{4}$ inch long, subtriangular, or broadly ovate and compressed, tinged with brown or purple, 6- or 7-flowered ; glumes very closely imbricate, broad, deeply concave or saccate, rounded on the back, obtuse at the tip, and awnless ; empty glumes smaller than the lowest flowering ones. Perennial, flowering middle of June, July.

Deschampsia flexuosa, the Wavy Hair-grass, is generally distributed throughout Britain on dry heaths and in upland pastures and copses, always growing in abundance. Rootstock rather densely tufted, producing numerous leaves, which are setaceous and solid, usually curved, smooth, dark-green. Culms 1½ ft., reddish-purple. Panicle with slender, spreading, wavy branches, which are mostly in pairs and triply-forked. Spikelets ¼ inch long, purplish-brown and glossy, 2-flowered ; flowering glumes with a tuft of hairs at the base, a truncate and toothed or jagged tip, and a bent and twisted awn inserted near the base, and exceeding their length by one half. Perennial, flowering in July.

FIG. 19.—*Briza media:* left-hand figures enlarged, the upper a spikelet, the lower a flowering glume with its palea and flower.

Triodia decumbens, the Decumbent Heath-grass, is found in the same habitats as *D. flexuosa* and is widely distributed, though not very common. Rootstock tufted, rather stout, decumbent and compressed. Leaves narrow, stiff, and often involute, glaucous above ; sheaths hairy ; ligule, a ring of hairs. Culms about a foot high. The panicle rarely bears more than 5 or 6 spikelets, which are shortly pedicelled, about ⅛ inch long, green, tinged with violet, 3- or 4-flowered ; glumes awnless, the empty ones nearly equal, large, and enclosing all the flowering ones ; the latter have a tuft of hairs at the base, are rounded on the back, and 3-toothed at the apex. Perennial, flowering latter part of July.

Molinia cærulea, the Purple Melic, is frequent on wet moors all over Britain. Its leafy tufts are closely matted, and the basal part is somewhat swollen, not compressed. Leaves flat and finely tapering, with long scattered hairs near the base ; sheaths smooth, with a few hairs in place of ligule. Culms wiry, 1–2 ft., with a single node near the base. Panicle long and narrow, the branches

very short, erect, and more or less adpressed to the rachis; it is instantly recognised by its dull violet colour. Spikelets about ¼ inch long, 2- or 3-flowered, with a terminal rudimentary glume; glumes awnless, the empty ones shorter than the flowering and 1-nerved; flowering glumes terete, acute, 3-nerved. Perennial, flowering in August.

Avena pubescens, the Downy Oat, is frequent on downs and in the dry upland pastures of districts where the underlying rock is chalk or limestone; rather sparingly but widely distributed. Rootstock shortly creeping, stoloniferous. Leaves rather broad, flaccid, and clothed with soft hairs; lower sheaths also hairy. Culms about 2 ft. Panicle very narrow, with a few short, rarely divided branches. Spikelets about ½ inch long, pale straw-colour tinged with violet, 2- or 3-flowered; flowering glumes hairy at the base, rounded on the back, and with a long bent and twisted dorsal awn. Perennial, flowering latter part of June.

FIG. 20.—*Avena pratensis*: part of panicle showing sparse branching and 3 spikelets, one open and 6-flowered.

Avena pratensis, the Smooth Narrow-leaved Oat (fig. 20), also shows partiality for calcareous soil, and occurs in the same habitats. It is rather common in Great Britain, but unknown in Ireland. Rootstock densely tufted, without stolons. Leaves narrow, often involute, rigid and ribbed, margins scabrid; neither leaves nor sheaths are hairy. Culms about 2 ft. The inflorescence closely resembles that of the preceding species, but the spikelets are ½ to ¾ inch long and 3- to 6-flowered. In both these Oats the long geniculate awns are conspicuous. Perennial, flowering latter part of June.

Agrostis canina, the Brown Bent (fig. 6), grows abundantly on moors and peaty heaths, and is distributed throughout Britain, although rather locally. Rootstock loosely tufted, producing trailing and rooting leafy shoots. Leaves extremely narrow, flat; sheaths smooth. Culms 1–2 ft., decumbent. Panicle with numerous capillary branches, spreading at time of flowering, afterwards close. Spikelets $\frac{1}{10}$ inch long, 1-flowered; flowering glume hyaline, truncate and toothed at the apex, with a bent and twisted dorsal awn inserted a little below the middle, and usually

exceeding the apex; palea absent. Perennial, flowering July, August.

Koeleria cristata, the Crested Hair-grass, is not unfrequent throughout Britain on chalk downs, commons and dry, rocky pastures, both at a considerable elevation and near the coast. Rootstock tufted. Leaves narrow, with a few well-marked ribs, ultimately involute, dull-green. Culms 6–12 inches. Panicle spike-like with very short branches, slightly interrupted in the lower part. Spikelets $\frac{1}{8}$ inch or rather more in length, compressed, silvery-green, with a faint purple tinge, 2- or 3-flowered; empty glumes rather shorter than the flowering ones, the latter mucronate, colourless, with a green, scabrid keel. Perennial, flowering middle of July.

Sesleria cærulea, the Blue Moor-grass (fig. 21), grows in the mountainous pastures of limestone districts, very often on the outcropping rock. Northern counties of England, west of Ireland, Scotch Highlands. In Durham county it descends to the coast. Rootstock tufted; leaves flat, narrowly linear, tipped with a mucro, scabrid on the margins, rather stiff, purplish-green. Culms 6–12 inches high, with the uppermost leaf only half an inch long. Panicle dense, ovoid or shortly oblong, scarcely an inch in length, dark-blue and silvery-grey, with a few bracts or empty glumes at its base, sheathing the pedicels. Spikelets $\frac{1}{8}$ inch long, almost sessile, 2- or 3-flowered; glumes mucronate, the flowering ones with 5 nerves, 3 or all excurrent, forming short setæ or bristles. Perennial, flowering in May.

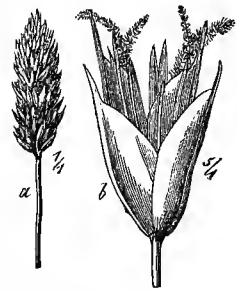

FIG. 21.—*Sesleria cærulea*: *a* capitate inflorescence; *b* a spikelet enlarged, showing two flowering glumes.

Agrostis setacea, the Bristle-leaved Bent, is abundant on dry heaths, commons and downs, especially towards the coast; but it is confined to the southern half of England. Its dense tufts of stiff, setaceous, almost capillary leaves, and the close cylindric panicle—the branches being very short—distinguish it from the other Bent-grasses. Sheaths scabrid. Culms 9–12 inches. Spikelets $\frac{1}{8}$ inch long, 1-flowered; empty glumes acute, awnless; flowering glume with a kneed and twisted *sub-basal* awn twice its length, two tufts of short hairs at the base, and two minute setæ (formed by the slightly excurrent lateral nerves) at the tip; palea very minute. A microscope is necessary for the examination of the flowering glume; the two setæ, for example, are shorter than $\frac{1}{100}$ inch. Perennial, flowering July.

Agrostis vulgaris, var. *pumila*, is a dwarf form 1–4 inches high, growing in very dry places in hilly districts; the branches of the panicle are stouter, and empty glumes broader, than in the typical species; flowering glumes usually awned.

Poa pratensis, var. *subcœrulea*, is a dwarf glaucous purplish form, found on wall-tops, dry heaths and mountains.

Deschampsia cæspitosa, var. *brevifolia*; leaves short, panicle much smaller than in the typical plant; dry uplands, mountains.

The grasses forming our third group are semi-aquatic, growing in ditches, ponds and marshy places, and by the margins of rivers and streams.

Alopecurus geniculatus, the Floating Foxtail, is a very common grass all over Britain, in ditches, ponds and marshy places. Rootstock with decumbent and geniculate branches, rooting below, often floating. Leaves short with rough ribs, dull green. Culms about a foot high, sharply bent at the lower nodes. Panicle spikelike, cylindric and dense, much narrower than that of *A. pratensis*, and purplish-green. Spikelets $\frac{1}{10}$ inch long, 1-flowered; empty glumes awnless, united at the base and ciliated on the keel; flowering glume with a sub-basal awn nearly twice its length; no palea. Perennial, flowering early June to autumn. *A. pronus* is a prostrate form.

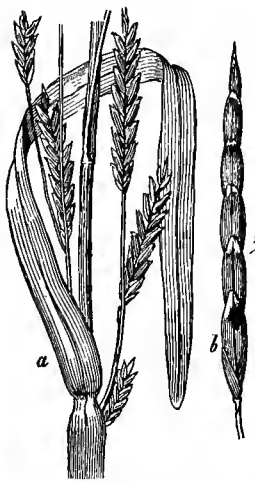

FIG. 22. — *Glyceria fluitans*: *a* leaf and lower portion of panicle; *b* an enlarged spikelet viewed edgewise, showing scarious tips of glumes.

Glyceria fluitans, the Floating Sweet-grass (fig. 22), almost invariably accompanies the species last described, but is not confined to stagnant water, as it fringes the rivulets, and often floats in the current. Rootstock without subterranean stolons, but producing stout procumbent or floating branches which root below. Leaves long, broadly linear, conduplicate at first, then flat, with faint ribs, flaccid, speckled in transmitted light; ligule prominent. Culms about 2 ft. Panicle long and slightly branched, the branches adpressed to the rachis, and some of them bearing only one spikelet. Spikelets about an inch long, cylindric at first, then linear and compressed, pale green, 12- to 15-flowered; glumes rounded on the back and awnless, the flowering ones with 7 nerves which vanish below the colourless tip. Perennial, flowering early June to autumn. Sub-species *G. plicata* has leaf-sheaths distinctly furrowed, the panicle more branched and spreading in fruit, lowest branches about five; flowering glumes twice as long as broad, 3-toothed. Var. *G. pedicellata* has also furrowed sheaths, lowest panicle branches in threes. Var. *G. declinata* is a dwarf state with smooth sheaths, spikelets few-flowered and palea longer than the

flowering glume. Both these varieties have the flowering glume 3-toothed.

Deschampsia cæspitosa, the Tufted Hair-grass (fig. 37), luxuriates in wet, spongy soil, and is very common in such places, in meadows and pastures, woods and wayside ditches throughout Britain Easily recognised by its dense tussocks of leaves, 1–3 ft. long, very narrow and tapering finely, dark-green, stiff and excessively scabrid on the upper surface and margins; the ribs, usually seven in number, are remarkably prominent, opaque, with translucent interspaces. Culms 2–4 ft. Panicle large, repeatedly branched, the branches numerous at each insertion and widely spreading. Spikelets numerous, $\frac{1}{8}$ inch long, silvery-purple, containing two flowers and a rudiment; flowering glumes hairy at the base, with a truncate jagged tip and a very slender slightly curved awn inserted near the base, and scarcely extending beyond the tip. Perennial, flowering middle of July.

Phalaris arundinacea, the Reed Canary-grass, is a reedlike species, frequent throughout Britain on the margins of rivers, streams and ponds, and in marshy parts of woods. Rootstock creeping; leaves large, broadly linear-lanceolate, finely striated; sheaths terete; ligule rather prominent. Culms 4–5 ft. Panicle lax, the branches mostly in pairs, spreading at time of flowering. Spikelets rather crowded on the branches to within half an inch of the rachis, $\frac{1}{4}$ inch long, compressed, pale green, often tinged with rose-purple, 1-flowered, with two rudiments (hairy pedicels) beneath the flowering glume; glumes awnless, the empty ones keeled, the flowering glume polished and ultimately indurated. Perennial, flowering middle of July. The Ribbon-grass commonly grown in gardens is a variety having the leaves striped with white or pale yellow.

FIG. 23.—*Agrostis alba*: 2 panicles, one open in flower, the other closed in fruit; on the right, above, a spikelet enlarged, below the same minus its empty glumes.

Agrostis alba, the Marsh Bent (fig. 23), grows in damp and marshy places almost everywhere; sometimes found in dry situations, where it varies from the typical form. This species closely resembles *A. vulgaris*, but the ligule is long and acute, sheaths roughish, and the branches of the panicle, though spreading at time of flowering, close together in fruit. The rootstock has long creeping or floating stolons. Culms 1–2 ft. Spikelets $\frac{1}{8}$ inch long, green or purplish; glumes as in *A. vulgaris*, but the keel of the lower empty glume scabrid along nearly its whole length; flowering glume rarely awned. Perennial, flowering latter part of July to autumn.

Festuca elatior, the Tall Fescue, is frequent in wet meadows and on the banks of streams throughout Britain. Very closely allied to *F. pratensis* and sometimes hardly distinguishable from it. Rootstock tufted, with stout stolons. Leaves large, broadly linear and tapering above, flat, firm, with prominent rough ribs and scabrid margins, dark green. Culms 2–3 ft. Panicle widely spreading, with paired branches, each bearing two or several spikelets which are $\frac{1}{2}$–$\frac{3}{4}$ inch long and 5- or 6-flowered; flowering glumes rounded on the back and tapered into a mucro, or very short awn. Perennial, flowering July and August.

Glyceria aquatica, the Reedy Sweet-grass, grows in dense patches in, or at the margin of ponds and sluggish rivers, and in marshes; rather common in England, rare in Scotland and Ireland. Rootstock very stout and extensively creeping. Leaves 2–3 ft. long and nearly an inch broad, linear and suddenly pointed, stiff and erect, speckled in transmitted light; ligule short and truncate. Culms 4–6 ft. Panicle large, much branched and spreading, the branches unequal, and many at each insertion. Spikelets numerous, $\frac{1}{3}$ inch long, compressed, brownish, 5- to 10-flowered; glumes rounded on the back, obtuse, awnless, the flowering ones 7-nerved. Perennial, flowering in August.

FIG. 24.—*Catabrosa aquatica*: upper figure an enlarged spikelet; lower figure, a flower with its glume and palea.

Phragmites communis, the Common Reed (fig. 38), forms thickets by the margins of lakes and in marshes; widely distributed throughout Britain, and abundant in many parts, notably the Fen district. Rootstock thick, jointed, and extensively creeping. Leaves large, broadly linear-lanceolate, striated; ligule a circle of hairs. Culms 6–8 ft. The dense plumy panicle is at first purple, then brown, ultimately greyish-brown by reason of the copious growth of white hairs on the rachilla of the spikelets. Spikelets $\frac{1}{2}$ inch long, 3 to 5-flowered, the lowest flower staminate; glumes awnless, the empty ones very unequal, the flowering ones subulate and enveloped in the long silky hairs. Perennial, flowering middle of September in the north of England, earlier south. A depauperate form, *A. nigricians*, is sometimes met with; it is about half the size of the typical plant, and the spikelets are only 1- or 2-flowered.

Catabrosa aquatica, the Water Whorl-grass (fig. 24), is rather thinly but widely distributed throughout Britain, in ponds and marshy places, and by the sides of streams. Rootstock with long creeping or floating branches which root at the lower nodes. Leaves flat, broadly linear, obtuse, flaccid. Culms ascending to

one foot or more. Panicle pyramidal and diffuse, with very evident half-whorls of unequal branches, 3–5 at each insertion. Spikelets about ⅛ inch long, obconic, yellowish purple, usually 2-, sometimes 3-flowered. All the glumes have erose tips (*i.e.* truncate and with shallow notches—a perfectly distinctive character), and are awnless; empty glumes unequal, and not more than half the length of the flowering ones, the latter 3-nerved. Perennial, flowering June, July.

Calamagrostis lanceolata, the Purple-flowered Small-reed, prefers the shade of woods and hedges, though sometimes occurring in open situations, but always on moist or swampy ground; it is confined to England, and local. Rootstock creeping with long stolons. Leaves linear, with numerous unequal slender ribs, flaccid. Culms 2–4 ft., slender. Panicle rather lax, spreading at time of flowering, tinged with rose-purple, shining. Spikelets nearly ¼ inch long, numerous, 1-flowered; empty glumes very narrow and much longer than the flowering one, awnless; flowering glume enveloped by silky hairs which slightly exceed its tip, and with an extremely minute awn springing from the apical notch. Perennial, flowering in July.

Alopecurus fulvus, the Orange-anthered Foxtail, is closely allied to *A. geniculatus* and occurs in the same habitats, but is restricted to the southern half of England. Comparing the two species, the distinctive characters of *A. fulvus* are: leaves pale green with slightly rough ribs; empty glumes a little shorter than the flowering one; awn arising from the middle of the flowering glume and extending very little beyond the tip. The anthers are shortly oblong (not narrow), and bright orange scarlet, which enables one to recognise the species at a glance when it is in flower. Perennial, flowering June to autumn.

Leersia oryzoides, the European Cut-grass, as a British plant is only recorded from a few localities in S.E. England; it grows by the sides of streams and in marshes; abundant by the Boldre River, Hants; Surrey, Sussex. Rootstock extensively creeping. Leaves flat, broadly linear-lanceolate with excessively scabrid margins, pale green. Culms 2–3 ft. Panicle lax with capillary branches, partly concealed in the inflated sheath of the uppermost leaf. Spikelets nearly ¼ inch long, half oval, pale green and translucent, 1-flowered; no empty glumes; flowering glume 3-nerved, keeled, awnless, the nerves ciliated with stiff hairs; palea with only one nerve or keel, also ciliate. Flowers of the exserted portion of the panicle mostly abortive. Perennial, flowering in autumn.

Deyeuxia neglecta, the Narrow Small-reed, is extremely rare; found in bogs at Oakmere, Cheshire; on the shores of Lough Neagh, Ireland, and in Caithness. Very closely allied to *Calamagrostis lanceolata*. Rootstock shortly creeping; leaves extremely narrow with few ribs, flaccid; uppermost ligule blunt. Culms 2–3 ft. Panicle very narrow and lax. Spikelets ⅛ inch long, containing one flower and a rudiment in the form of a pedicel tipped with a

hair-tuft ; flowering glume nearly as long as the empty ones ; hairs at its base only about half as long ; awn inserted below the middle of the flowering glume and scarcely exceeding its apex. The Irish variety, *D. Hookeri*, has the uppermost ligule acute, and the hairs are about three-fourths the length of the empty glumes. Perennial, flowering June, July.

Deschampsia flexuosa, var. *setacea*, *uliginosa* or *discolor*, has leaves conduplicate (not solid), glaucous ; uppermost ligule long and acute, pedicel of upper flowering glume longer ; turfy bogs.

Our fourth group consists of a dozen species, which, with one exception, are found only in woods, copses, and shrubby places, or by shady hedgerows.

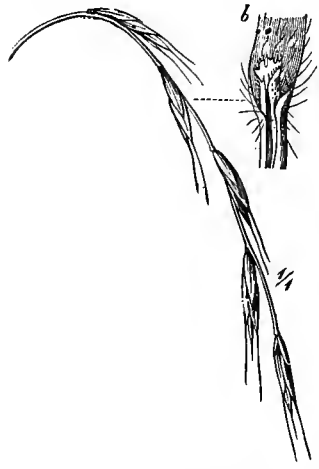

FIG. 25. — *Brachypodium sylvaticum*: drooping spike ; *b* mouth of sheath enlarged to show ligule.

Holcus mollis, the Creeping Soft-grass, is perhaps the commonest of our sylvan species, and is generally distributed throughout Britain ; sometimes met with in open situations. Rootstock extensively creeping. Leaves flat, rather broadly linear-lanceolate, more or less hairy, with very uneven ribs and slightly rough margins ; basal sheaths white with red veins. Culms 1–1½ ft. Panicle with short, mostly paired branches, spreading when in flower. Spikelets nearly ¼ inch long, greenish-white or marked with purple, 2-flowered ; the lower flower perfect and its glume awnless, the upper staminate with a dorsal awn on its glume ; empty glumes nearly smooth but ciliated on the keel ; awn scabrid, considerably exceeding the spikelet, ultimately kneed but not hooked. Perennial, flowering middle of July to autumn.

Festuca gigantea, the Great Bearded Fescue, is fairly abundant and generally distributed. Rootstock tufted. Leaves large, flat, tapering, scabrid above and on the edges, smooth and shining beneath, bright green. Both leaves and sheaths are glabrous (without hairs) ; auricles prominent, purplish-brown. Culms 2–5 ft. Panicle rather large, diffuse and drooping, the branches inserted in pairs. Spikelets ½ inch long, narrow, tapering, pale green and glossy, about 5-flowered ; flowering glumes rounded on the back, with a bifid tip and a subterminal awn about twice their length. This grass has a Bromelike habit, but the glabrous ovary

and terminal styles do not accord with the characters of *Bromus*. Perennial, flowering latter part of July, August.

Bromus asper, the Hairy Wood Brome, is almost as frequent as the preceding species. Rootstock tufted. Leaves large, flat, broadly linear-lanceolate, hairy above, bright green ; lower sheaths thickly clothed with spreading deflexed hairs. Culms 3–6 ft., often overtopping the shrubs. Panicle with long arching branches, 3–5 at the lower insertions. Spikelets about an inch long, drooping, cylindric at first, then much compressed, about 8-flowered ; flowering glumes rounded on the back, notched at tip, and with a subterminal awn half their length ; apex of ovary hairy, styles lateral. Perennial, flowering close of July, August.

Brachypodium sylvaticum, the Slender False-brome (fig. 25), will usually be seen on the dry slopes of woods, and on shady hedge-banks ; it is rather common and generally distributed. Rootstock tufted, not creeping. Leaves broadly linear-lanceolate, soft and very hairy on both sides, with ciliate margins, light yellowish-green ; sheaths clothed with spreading-deflexed hairs. Culms 1–2 ft., slender. Spike drooping ; spikelets ¾–1 inch long, subcylindric, on pedicels so short that they appear sessile on the rachis, 8- to 10-flowered ; flowering glumes entire, *i.e.* not notched at the tip, and with a terminal awn their own length ; upper part of ovary hairy. Perennial, flowering latter part of July, August.

FIG. 26.—*Melica uniflora* : upper figure an enlarged spikelet ; lower same with empty glumes removed to show the clavate (club-shaped) body on left.

Milium effusum, the Spreading Millet, is fairly common in moist woods throughout England, rather scarce in Scotland and Ireland. Rootstock shortly stoloniferous. Leaves broadly linear-lanceolate, with faint smooth ribs but very scabrid margins, flaccid, pale bright green ; ligule long. Culms 3–4 ft. Panicle with remote half-whorls of long slender widely-spreading branches, several at each insertion. Spikelets disposed mostly at the distal portions of the branches, ⅛ inch long, egg-shaped, not compressed, pale green, 1-flowered ; glumes all equal, rounded on the back and awnless, the flowering one smooth, becoming hard and polished in fruit. Perennial, flowering early June.

Melica uniflora, the Wood Melic (fig. 26), is found on dry slopes and rocky places in woods ; rather frequent and generally distri-

buted. Rootstock with slender stolons. Leaves slender, flat, linear-lanceolate, light green ; ligule almost obsolete, but on the opposite side of the mouth of the entire sheath is a subulate lobe peculiar to this grass alone. Culms about 1½ ft. Panicle with a few long slender branches in pairs. Spikelets about ⅙ inch long, oval, erect, purplish-brown or maroon-red, containing one flower and a terminal club-shaped body formed of several colourless rudimentary glumes ; glumes rounded on the back and awnless, the empty ones as long as the flowering one, the latter 5-nerved and pale greenish-yellow. Perennial, flowering latter part of May, June.

Poa nemoralis, the Wood Meadow-grass, is not unfrequent in woods and copses, and curiously enough, this delicate-looking species is also found on the summits of our highest mountains, where it varies a good deal from the lowland form. Rather common, and generally distributed in England, more rare in Scotland and Ireland. Rootstock very shortly creeping. Leaves very narrow, tapering from the base finely, dark green ; sheaths smooth, ligule hardly apparent. Culms about 2 ft., and so frail that they break if not carefully handled. Panicle pyramidal, slightly drooping, the branches 3–4 at the lower insertions. Spikelets ⅙ inch long, narrowly ovate, pale green, 2- to 4-flowered ; glumes compressed, keeled, without awn or mucro, the flowering ones webbed and obscurely 5-nerved. Perennial, flowering middle of July.

Agropyrum caninum, the Fibrous or Wood Couch, is rather thinly but widely distributed throughout Great Britain ; scarce in Ireland. Rootstock not at all creeping, and without stolons. Leaves flat, linear-lanceolate, hairy above with faint ribs, auricled, flaccid, and bright green. Culms very slender, 2–3 ft. Spike slender ; spikelets ½ inch long, broadside to the rachis, one in each notch and usually 4-flowered ; flowering glumes with a slender wavy awn their own length. Perennial, flowering latter part of July.

Calamagrostis epigeios, the Wood Small-reed, is not unfrequent in the south of England, becoming scarce northwards ; very rare in Ireland. It is partial to shade and damp soil, or places that are occasionally inundated ; but we have found it on the dry ballast hills of the Tyne. Rootstock creeping with long stolons. Leaves very long, stiff, and ultimately involute with very scabrid margins, rather glaucous ; ligule very long. Culms 2–4 ft. Panicle dense and plumy, lobed, dull purplish-brown. Spikelets numerous, ¼ inch long, 1-flowered ; the flowering glume is enveloped in silky hairs, and has a dorsal awn inserted about midway along the keel and extending a little beyond its apex ; empty glumes and silky hairs twice the length of the flowering glume. Perennial, flowering early August.

Melica nutans, the Nodding Melic, is found on shady banks and rocky places in the mountainous woods of Western England and of Scotland. Rootstock and leaves as in *M. uniflora*, but the mouth of the sheath is without a lobe. Culms a foot high. The spikelets, about half a score in number, are disposed in a drooping

raceme, the very short branches from which they depend being seldom divided. The spikelets are ¼ inch long or rather more, oval, purplish-brown, 2-flowered with the characteristic terminal clavate rudiments; glumes awnless, the empty ones shorter than the flowering. Perennial, flowering latter part of May, June.

Festuca sylvatica, the Wood Fescue, is both local and scarce, although widely distributed, occurring chiefly in hilly and mountainous districts. Rootstock densely tufted. Leaves large, flat, broadly linear and tapering above, with flat ribs and scabrid margins, dark green and shining beneath; sheaths rough, ligule rather short, toothed. Culms about 3 ft., with short, scale-like, acute, leafless sheaths at the base. Panicle much branched, symmetrically spreading, and erect. Spikelets numerous, about ¼ inch long, 3- to 5-flowered; flowering glumes narrow, rounded on the back and tapering into a mucro. Ovary hairy at the top. Perennial, flowering middle of July.

Hordeum sylvaticum, the Wood Barley, is a rare woodland grass confined to England and occurring principally on chalk and limestone soils. Rootstock loosely tufted, creeping. Leaves flat, rather broad, and tapering from near the base, with scattered hairs above, dark-green, auricled; sheaths clothed with deflexed hairs; ligule short and truncate. Culms about 3 ft. Spike nearly cylindric. Spikelets ½ inch long, three in each excavation of the rachis, 1-flowered; the flowers of the two lateral spikelets bisexual, the middle spikelet with a staminate flower; empty glumes all bristle-like, not ciliate, scabrid, prolonged into an awn about their own length; flowering glumes narrow, faintly 3-nerved, with an awn about 1½ times their length. Perennial, flowering late July.

The grasses of the seashore are a numerous group, which may be divided into three smaller groups; 1st, the grasses which grow in loose sand; 2nd, those growing in sandy pastures and dry waste places by the sea; 3rd, those partial to salt marshes, the banks of tidal rivers, and muddy places by the sea.

In the loose sand of the seashore, or on the dunes or sand-hillocks:—

Ammophila arundinacea, the Common Sea-reed or Marram, is the commonest of our sand-grasses, generally distributed, and always growing in abundance. Rootstock extensively creeping by means of long subterranean stolons. Leaves long, narrow, rigid, and ultimately convulute, with a few thick ribs; ligule very long and split. Culms 2–3 ft. Panicle spikelike, 4–5 inches long, dense, stout, and spindle-shaped, pale green or straw-color. Spikelets about ½ inch long, stiff, containing one flower and a stalk-like rudiment; flowering glume a little shorter than the empty ones, shortly bearded at the base, and with a minute awn from just below the bifid tip; hairs one third the length of the flowering glume. Perennial, flowering middle of July.

Agropyrum junceum, the Sea Couch, is scarcely less abundant than the preceding, and like it has an extensively creeping root-

stock. Leaves narrow, firm, and more or less involute, the upper surface clothed with fine short hairs, ribs very prominent and unequal; ligule short. All parts of the plant are glaucous. Culms 1½ ft. Spike long and arching, the rachis stout but fragile, and readily breaking at the joints. Spikelets solitary in the notches of the rachis and broadside to it, ¾–1 inch long, pale green, 4- to 8-flowered; glumes rigid, awnless, with a blunt truncate or notched tip, and faintly nerved. Perennial, flowering early July.

There are two maritime forms of Agropyrum, intermediate between this species and *A. repens*, and distinguishable chiefly by the structure of the leaves. *A. pungens* has erect culms in dense tufts; leaves involute and rigid, with thick, prominent ribs, scabrid on the upper surface with a row of asperities on each rib. Spike compact, erect. This form is scarce, growing on the banks of tidal rivers. *A. acutum* has decumbent stems in loose tufts; leaves similar, but with less prominent ribs, and rough with scattered asperities, not in rows. Spike lax and slightly arching. It grows in sandy ground, and is rather scarce. In neither of these forms is the rachis brittle, nor have the leaves a close pile of hairs. Spikelets 5- to 12-flowered.

Festuca rubra, the Creeping Fescue, is of frequent occurrence all round our coasts. Rootstock not tufted, but extensively creeping with long stolons—a habit which distinguishes it from the nearly related *F. duriuscula*. It is further known by the firmer and broader, but more or less involute, glaucous leaves with several thick ribs; basal sheaths downy and purplish-red. Panicle drooping, spikelets ⅝ inch long. Perennial, flowering latter part of June, July.

Elymus arenarius, the Sea Lyme-grass, is distributed rather sparingly around our coasts. Rootstock stout, creeping and stoloniferous. The whole plant is intensely glaucous and is readily known from all our other maritime grasses by its large, broad, flat leaves, with numerous prominent equal ribs; auricled; ligule very short. Culms 3–4 ft. Spike stout, 6–12 inches long, erect. Spikelets 1 inch long, in pairs or threes, seated broadside in excavations of the rachis, 2- or 3-flowered: glumes rigid, subequal, terminating in a mucro, the flowering ones hairy. Perennial, flowering July.

Poa bulbosa, the Bulbous Meadow-grass, is found locally in S.E. England, growing on the sand and fine shingle of the shore; abundant on Yarmouth Denes, Norfolk. Rootstock densely tufted, the base of each shoot swollen and bulb-like. Leaves short, narrow and curved, margins scabrid. Culms about 6 inches high, swollen at base. Panicle 1–1½ inches long, close, the branches mostly in pairs. Spikelets about ⅛ inch long, usually 4-flowered; glumes keeled, compressed and awnless, the flowering ones silky-hairy, and webbed. Perennial, flowering April to June. This grass is propagated by its bulbs; towards autumn they become detached and are blown about the sands; eventually they strike root.

Ammophila baltica, the Baltic Sea-reed, has only one British station, Ross Links, on the Northumbrian coast (opposite Holy

Island), growing there in company with *A. arundinacea*, which it greatly resembles. Culms 4–5 ft. Panicle 8–10 inches long, and lobed (not fusiform), with a purple tinge; glumes narrower than in the other species, and very acute; hairs at the base of the flowering glume half its length. Perennial, flowering in August.

Hordeum murinum, var. *arenarium*, growing in loose sand, has the stems branching and rooting below.

Catabrosa aquatica, var. *littoralis* or *minor*, occurring on wet sand by the sea, is a dwarf form, 1–2 inches high, with 1-flowered spikelets.

Growing in sandy pastures and dry waste places by the sea:—

Phleum arenarium, the Seaside Cats-tail, is not unfrequent on the English coast, scarcer in Ireland and Scotland. Culms 2–6 inches high, tufted. Leaves not more than an inch long, rather broad. Panicle dense, shortly cylindric or somewhat club-shaped, being narrowed towards the base, ½–1 inch long. Spikelets ⅛ inch long, containing one flower and a pedicel-like rudiment; empty glumes tapering into a mucro, the flowering one very small and awnless. Annual, flowering May, June.

Glyceria distans, the Reflexed Sweet-grass (fig. 27), seems to prefer dry, sandy ground, but may also be found on the margins of brackish rivers and marshes; it is frequent all round our coasts, rarely occurring inland. Root-stock without stolons. Leaves flat. Culms 1–1½ ft. Panicle spreading on all sides, the branches 4–5 at each insertion, horizontal in flower and deflexed in fruit. Spikelets about ¼ inch long, 5- or 6-flowered; flowering glumes blunt and scarious at the tip, not mucronate, faintly nerved. Perennial, flowering July, August.

FIG. 27. *Glyceria distans:* lower branches of open panicle deflexed; enlarged figures, below to left, a spikelet; to right, a flower with its palea and hyaline-tipped glume; above, the empty glumes.

Glyceria loliacea, the Dwarf Sweet-grass, is rather sparsely distributed around the English and Irish coasts, and is rare in Scotland. Culms rigid, stout, 3–4 inches long, growing in small tufts. Leaves short and slender. Inflorescence like a miniature spike of *Lolium*, the spikelets being almost sessile on the rachis, and, except the lower ones, solitary, all facing one way. Spikelets ⅓ inch long, green, rarely tinged with purple, about 9-flowered; glumes closely imbricate, blunt and scarious at the tip, and minutely mucronate, the flowering one strongly 3-nerved. Annual, flowering latter part of June.

Hordeum maritimum, the Sea Barley or Squirrel-tail-grass, is confined to the shores of England and is more frequent in the south than in the north. Culms 6–12 inches, decumbent. Leaves rather narrow, tapering from base. Spike 1–2 inches long, pale green, ultimately brownish-yellow. As in the other wild barleys, the spikelets are disposed three in each notch of the rachis; they are $\frac{1}{4}$–$\frac{1}{3}$ inch long, 1-flowered; the lateral spikelets contain a staminate flower, the central spikelet a bisexual one; empty glumes scabrid, the inner one of the lateral spikelets half-ovate, the rest bristle-like, all terminating in an awn twice their length; lateral flowering glumes with a short awn about their own length, central flowering glume with an awn nearly twice its length; all the awns scabrid. Annual or biennial, flowering June to autumn.

Gastridium lendigerum, the Awned Nit-grass, occurs locally in the southern half of England, and should be looked for in places that are occasionally flooded by rains or tides. Culms numerous, 6–10 inches high. Leaves short and flat. Panicle spike-like, compact, lobed, pale green and glistening, ultimately straw-colour. Spikelets rather more than $\frac{1}{8}$ inch long, 1-flowered; empty glumes both with a glossy swelling at the base—an unequivocal character; the flowering glume is very much shorter than the empty ones, and has usually a slender subterminal awn. Annual, flowering June to September.

Festuca uniglumis, the Single-glumed Fescue, is found sparingly on the coasts of the southern half of England and eastern Ireland; unknown in Scotland. Culms 6–12 inches, tufted. Leaves very narrow, more or less involute. Spikelets about $\frac{1}{2}$ inch long, 3- to 6-flowered, on very short pedicels, forming a short, bristly panicle, resembling the spike of the barley-grasses, but unilateral. The minuteness or absence of the lower empty glume is a peculiarity of this species; upper empty glume narrowed into a short awn; flowering glumes with a terminal awn exceeding their own length. Annual, flowering in June.

Cynodon dactylon, the Creeping Dogstooth-grass, grows sparingly along the coast from Dorset to Cornwall, and is perhaps most abundant in the neighbourhood of Penzance. Channel Islands. Stems prostrate and creeping extensively, rooting and sending up leafy shoots; leaves short, stiff, and more or less involute. Culms about 6 inches high. Spikes, four or five at the top of each culm, radiating like fingers, and about an inch long. Spikelets sessile, in two rows on each spike, $\frac{1}{12}$ inch long, laterally compressed, purplish, each containing one flower and a rudiment above it; glumes awnless, the empty ones nearly equal. Perennial, flowering July, August.

Corynephorus canescens, the Grey Hair-grass, is one of our rarities; the only authentic localities for it being Lowestoft Denes, Suffolk; Yarmouth Denes, Norfolk; and shores of Jersey. Leaves in dense tufts, short, bristle-like. Culms about 6 inches high. Panicle with short branches, silvery white, and faintly tinged with green or purple. Spikelets $\frac{1}{8}$ inch long, 2-flowered; the flower-

ing glumes have a curious dorsal awn; a ring of hairs divides it into two equal portions, the lower stout, striated, and slightly twisted, the upper part slender but gradually thickened towards the tip, so as to be somewhat club-shaped. Perennial, flowering in June, July.

Mibora verna, the Early Sand-grass (fig. 28), or Knappia, is a diminutive annual found only on the S.W. coast of Anglesea and the shores of the Channel Islands. The culms are capillary, 1–3 inches high, tufted. Leaves extremely short and narrow, with white sheaths. The spikelets, numbering from five to ten, are almost sessile in a spikelike raceme, which is about half an inch long; the spikelets are $\frac{1}{12}$ inch long, and 1-flowered; glumes truncate and awnless, the flowering one a little shorter and downy. Flowering March, April.

The three grasses next described are indigenous only to the Channel Islands:—

Bromus maximus, the Great Brome, is found in sandy places on the shores of those islands; it does not occur anywhere in Britain proper, except on the Tyne ballast-hills, where we found it four years ago. Culms stout, 10–18 inches high; leaves rather broad, hairy on both surfaces. Panicle with a few scarcely divided branches, usually shorter than the spikelets, nodding in fruit. Spikelets $1\frac{1}{4}$ inch long (exclusive of the awns), oblong, 5- or 6-flowered; flowering glumes imbricated, with a subterminal straight stout awn $1\frac{1}{2}$–2 inches (longer than that of any other Brome). Stamens usually two. Annual, flowering latter part of June, July.

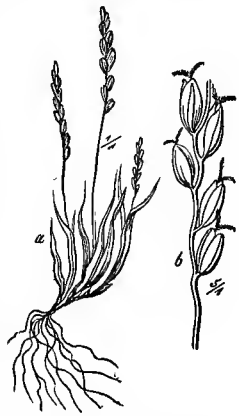

FIG. 28.—*Mibora verna*: *a* plant, nat. size; *b* raceme enlarged, showing subsessile spikelets.

Lagurus ovatus, the Ovate Hare's-tail, is found only in Guernsey. Culms tufted, 6–12 inches. Leaves broad, downy; sheaths inflated. Spikelets $\frac{1}{3}$ inch long, 1-flowered, with a stalk-like rudiment, densely crowded into a soft ovate-ovoid head which looks like a tuft of fur, and is only $\frac{3}{4}$ inch long, almost white; empty glumes very narrow and plumose, the margins being fringed with long silky hairs; flowering glume ending in two bristles, and with a long kneed and twisted awn inserted a little below the tip. Annual, flowering in June. The capitate inflorescence may often be seen in the grass-bouquets of the shops—mostly, however, larger cultivated specimens.

Cynosurus echinatus, the Rough Dogstail, occurs very locally in sandy pastures on the shores of the Channel Islands; it is sometimes met with in England as a casual of cultivated fields. Culms 1–2 feet. Leaves broad with scabrid margins. Panicle compact ovoid or lobed, about an inch long, bristly. Spikelets $\frac{1}{4}$ inch long,

of two kinds, paired, one of each pair 2- or 3-flowered, the other sterile ; glumes of the sterile spikelets terminating in an awn their own length ; flowering glumes similarly awned. Annual, flowering June, July.

Festuca ovina, var. *glauca*, common on sea banks, is an intensely glaucous form with short, rigid, recurved leaves ; flowering glumes awned.

Bromus mollis, var. *hordaceus*, is a dwarf prostrate form with glabrous spikelets (*i.e.* not hairy or downy), growing in dry and sandy places by the sea. Var. *Lloydianus*, found on the shores of the Channel Islands, has the awns bent outward in fruit.

Festuca elatior, var. *arundinacea*, with scabrid leaf-sheaths and the branches of the panicle spreading in fruit, is found on moist, sandy banks by the sea.

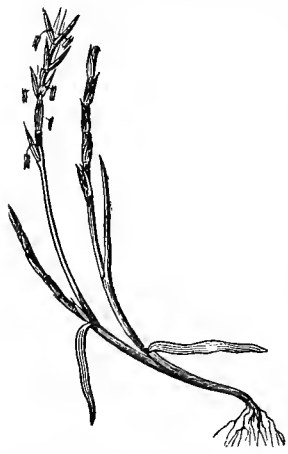

FIG. 29.—*Lepturus filiformis :* on one spike the spikelets are flowering and divergent, the other spikes closed.

Agrostis alba, var. *stolonifera*, Fiorin-grass, occurs chiefly on sea-banks ; it has prostrate stems, which root freely at the nodes, and the panicle is dense, lobed, and dull green.

Growing in salt marshes, on the banks of tidal rivers, and in muddy waste places by the sea :—

Glyceria maritima, the Creeping Sea Sweet-grass, is frequent on all the British coasts, and grows in abundance. Rootstock densely tufted, producing numerous trailing leafy stolons, the leaves of which are fleshy, closely involute, and ending in a hard point. Culms about a foot high. Panicle rather one-sided and contracted, with short ascending branches, 2–3 at the lower insertions, pale green or purplish on one side, glaucous. Spikelets adpressed to the branches, about $\frac{1}{3}$ inch long, containing usually five, but sometimes as many as eight flowers ; flowering glumes with a scarious blunt tip, the dorsal nerve reaching it, but not excurrent. Perennial, flowering in July. Var. *G. hispida* has rough panicle-branches ; var. *G. riparia* is a slender form with fewer spikelets.

Lepturus filiformis, the Sea Hard-grass (fig. 29), is frequent in the southern half of England, becoming scarce northward ; very rare in Scotland, and distributed sparingly around the Irish coast. Culms tufted, about 6 inches high ; leaves short, ultimately involute. Spike cylindric, very slender, often slightly curved, green and shining. Rachis excavated and jointed, and the spikelets so deeply sunk, one in each excavation that, except when flowering

and therefore divergent, they are hardly discernible ; they are $\frac{1}{6}$ inch long and contain one perfect flower and a rudiment ; glumes awnless, the empty ones rigid, both on the outer side ; the flowering one as long, hyaline with a green nerve. Annual, flowering latter part of July, early August.

Alopecurus bulbosus, the Tuberous Foxtail, is distributed locally around the coast of the southern half of England. It is very similar to *A. geniculatus*, from which, however, it is distinguished by the basal internodes of the stems being swollen and bulb-like. Leaves very narrow, with prominent ribs, pale green. Panicle cylindric, tapering above, 1–2 inches long, dense but slender. Spikelets $\frac{1}{7}$ inch long, 1-flowered ; empty glumes very acute and free, *i.e.* not cohering at the edges ; keel ciliate ; flowering glume with a sub-basal awn twice its length ; no palea. Perennial, flowering in June.

Glyceria procumbens, the Procumbent Sweet-grass, is frequent in S.E. England, but rare in the north ; not recorded from Scotland, and doubtfully native in Ireland. Rootstock tufted, the culms numerous, 6–8 inches, prostrate or ascending. Leaves flat, sheaths inflated. Panicle compact, one-sided, with very short rigid distichous branches, 2–3 at each insertion, never deflexed, glaucous-green. Spikelets $\frac{1}{4}$ inch long, almost sessile, crowded, 4- or 5-flowered ; flowering glume with a blunt scarious tip, the dorsal nerve sometimes slightly excurrent, forming a minute mucro. Annual or biennial, flowering June, July.

Glyceria Borreri, Borrer's Sweet-grass, is a very local species found on the south and east coasts of England, and in Ireland ; it is intermediate between *G. distans* and *G. procumbens* ; but may be known by its much smaller spikelets, $\frac{1}{8}$–$\frac{1}{5}$ inch long, which are wholly green, and by the dorsal nerve of the flowering glume extending beyond the tip to form a minute mucro. The branches of the somewhat one-sided panicle are very short, 2-3 at each insertion, never deflexed. Perennial, flowering July, August.

Spartina stricta, the Twin-spiked Cord-grass, occurs locally on the south and east coasts of England, growing plentifully where it is established. Rootstock extensively creeping. Leaves jointed to the sheaths and easily broken off, shorter than the spikes. Culms about a foot high, each bearing usually two, sometimes three, unilateral spikes which are erect and so closely contiguous as to appear like a single spike ; rachis prolonged to the tip of the uppermost spikelet. Spikelets 6–10 on each spike, half an inch or rather more in length, rigid, 1-flowered ; empty glumes very unequal, downy, the upper one mucronate ; flowering glume a little shorter than the longer empty one, 1-nerved, awnless. Styles united for about half their length. Perennial, flowering in August.

Spartina alterniflora, the Many-spiked Cord-grass, is abundant on the mudflats at Southampton. It is perhaps only entitled to rank as a sub-species. The leaves are not jointed to the sheaths, and are as long or longer than the spikes. Culms 2–3 feet each, bearing five or more spikes, not so close together as in the fore-

going species ; rachis prolonged beyond the uppermost spikelet for about half an inch. Spikelets numerous ; empty glumes smooth. An intermediate form, *S. Townsendii*, occurs on the mudflats at Hythe, Hants. It has several spikes on each stem ; leaves jointed to the sheaths and shorter than the spikes; rachis produced beyond the uppermost spikelet ; empty glumes slightly downy. These are rigid grasses, more or less submerged, with a rancid odour.

Polypogon monspeliensis, the Annual Beard-grass, is met with but rarely on the south and east coasts of England. Culms tufted, 1–3 feet. Leaves flat, with very scabrid ribs. Panicle spikelike, 1–6 inches long, dense, slightly lobed, pale greenish-yellow, and silky. Spikelets $\frac{1}{10}$ inch long, 1-flowered; empty glumes with an awn, nearly three times their length, springing from the apical notch ; flowering glume much smaller than the empty ones, sometimes mucronate. Annual, flowering June, July.

Polypogon littoralis, the Perennial Beard-grass, usually accompanies the last species. It has a creeping rootstock. The panicle is markedly lobed and purplish ; acute empty glumes, with an awn about equalling their length ; flowering glume with an awn exceeding the tip of the spikelet. Perennial, flowering July.

Our sixth is the agrarian group, comprising those grasses which are to be found in cultivated fields, generally among corn or clover, and on waste ground adjacent.

Avena fatua, the Wild Oat, is frequent throughout England, but much less so in Scotland and Ireland. Culms 3 ft. Leaves broadly linear, flat, thin with scattered hairs above. Panicle lax, spreading on all sides. Spikelets $\frac{3}{4}$–1 inch long, pendulous, usually 3-flowered ; flowering glumes rounded on the back, bifid, the lower half clothed with long fulvous hairs ; awn dorsal, kneed and twisted, twice the length of the flowering glumes. This species closely resembles the cultivated oat, from which it may be distinguished by the flowering glumes being all awned, very hairy, and in fruit dark-brown. Annual, flowering July, August.

Alopecurus agrestis, the Slender Foxtail, is common in the south of England, where it is known as Black-grass, but becomes scarce northward ; not naturalized in Scotland and Ireland. Culms erect, 1–2 ft. ; leaves short, thin, with a few broad ribs ; ligule prominent. Panicle spikelike, dense, about 3 inches long, narrow, tapering to a point at both ends, purplish. Spikelets $\frac{1}{4}$ inch long, 1-flowered ; empty glumes united nearly to the middle, smooth, with a row of short hairs on the keel ; flowering glume with a dorsal awn twice its length ; palea absent. Annual, flowering June to autumn.

Bromus secalinus, the Rye Brome, is rather thinly distributed over England, and scarcer still in Scotland and Ireland. Culms 2 ft. or more ; leaves slightly hairy, sheaths nearly glabrous. Panicle slightly branched. Spikelets $\frac{1}{2}$–$\frac{3}{4}$ inch long, glabrous and about 10-flowered. This species is readily distinguished from our other annual Bromes by the flowering glumes being loosely imbri-

cate at time of flowering and quite separate from each other when in fruit, with the margins involute; flowering glumes rounded on the back, notched at the tip, and with a variable awn sometimes as long as the flowering glume, at other times reduced to a mucro. Var. *B. velutinus* has the sheaths and spikelets downy. Annual or biennial, flowering in July.

Lolium temulentum, the Annual Darnel, is found throughout Britain, but is not frequent. Culms 2–3 ft. Leaves tapering from the base, rough on the upper side. The spike is similar to that of *L. perenne*, but the spikelets possess a well-marked character in the long empty glume which reaches as far as, or even exceeds, their apex; flowering glumes terminating in an awn their own length. *L. arvense* is a variety with the awn very short or absent. Annual, flowering during the summer months.

L. italicum, Italian Rye-grass, is often met with on the borders of fields as an escape from cultivation. Culms tufted 2–3 ft. Leaves rather broad, yellowish-green; sheaths terete. Spikelets diverging from the rachis, pale green, 8- to 10-flowered; empty glume much shorter than the spikelet; flowering glumes with a long slender awn. Perennial or biennial.

Bromus arvensis, the Taper Field Brome, is more plentiful in S.E. England than elsewhere. Culms 1–2 ft.; leaves and sheaths hairy. Branches of the panicle very long, slender and widely spreading. Spikelets ½ inch long and about 8-flowered, lanceolate, tinged with purple; flowering glumes with a subterminal awn about half an inch long; palea as long as the flowering glume. Annual or biennial, flowering July, August.

Avena strigosa, the Bristle-pointed Oat, is rare in England, but frequent in the north of Scotland; sparingly distributed in Ireland. It has rather smaller spikelets than *A. fatua*, all turned to one side and 2-flowered; flowering glumes with a dorsal awn, and terminating in two long bristles; almost smooth, and ultimately dark-brown. Annual, flowering in July.

Setaria viridis, the Green Bristle-grass, occurs chiefly in the S.E. counties of England, but casually as far north as Aberdeen. The inflorescence of the Bristle-grass is spikelike, and more or less cylindric. The spikelets are minute, dorsally compressed, awnless, and have long scabrid bristles on their pedicels; they contain one perfect flower and one staminate. In the species under notice the culms are 4–6 inches high; leaves flat with scabrid margins; sheaths with a ring of hairs at the mouth. Panicle about 1½ inch long, usually pale green; the bristles, 3–6 to each spikelet, are covered with asperities pointing forward. Annual, July, August.

Setaria verticillata, the Rough Bristle-grass, is very rare; Norfolk, Surrey and Middlesex are the only counties recorded for it. Culms 1–2 ft. Panicle about 2 inches long, interrupted in the lower part, purplish. Bristles usually two to each spikelet, with the asperities pointing backward, so that the panicle feels rough when drawn through the hand downwards. Annual, flowering July, August.

Apera Spica-venti, the Spreading Silky Bent, should be sought for in sandy cultivated fields, particularly those which are occasionally flooded; but it is very rare, and almost confined to S.E. England. Culms tufted, about 2 ft. Panicle with numerous capillary branches, diffuse at time of flowering. Spikelets $\frac{1}{12}$ inch long, shining, and tinged with purplish-brown, containing one flower and a pedicel-like rudiment; lower empty glume smaller than the upper; flowering glume membranous, entire, with a slender, wavy, subterminal awn 3–4 times its length; anthers linear. Annual, flowering June, July.

Apera interrupta, the Dense-flowered Silky Bent, is a subspecies or variety with a contracted and interrupted panicle, the branches short and adpressed, not spreading. Spikelets green; anthers oval. Extremely rare; Cambridge, Suffolk, Norfolk.

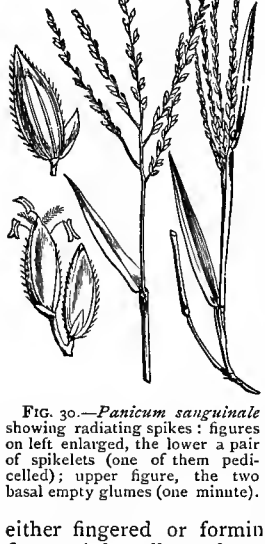

FIG. 30.—*Panicum sanguinale* showing radiating spikes: figures on left enlarged, the lower a pair of spikelets (one of them pedicelled); upper figure, the two basal empty glumes (one minute).

Panicum sanguinale, the Cocksfoot Finger-grass (fig. 30), is a scarce cornfield casual, found in S.E. England. Culms about a foot, ascending; leaves and sheaths somewhat hairy. Spikes about five on each culm, radiating so as to appear digitate or fingered, 2–3 inches long. Spikelets in pairs along one side of the rachis, $\frac{1}{8}$ inch long, acute, purple; glumes awnless, the flowering one smooth. Annual, flowering July, August.

Panicum Crus-galli, the Loose Panic-grass, is equally rare. The leaves are harsh, glabrous, and without a ligule. Spikelets $\frac{1}{6}$ inch long, crowded on the alternate partial spikes which thus resemble lobes, green or tinged with purple; third glume tipped with a mucro or short awn. Annual, flowering July, August. In both these grasses, the inflorescence consists of several spikes either fingered or forming a lobed panicle; the spikelets are flattened dorsally, and contain one perfect flower together with a staminate one beneath, or a third empty glume; the lowest empty glume is very minute; fruiting glume indurated and polished.

Briza minor, the Small Quaking-grass, occurs in dry sandy fields, generally among corn, in the extreme south of England, from Hants to Cornwall, but is very rare; in Jersey and Guernsey frequent. Culms 6–10 inches, tufted; leaves short, yellowish-green; ligule long and pointed. Spikelets similar to those of *B. media*, but smaller, barely $\frac{1}{6}$ inch long and pale green; empty glumes longer than the flowering ones. Annual, flowering July.

In our seventh group are the grasses which are not partial to any of the habitats already mentioned, and which grow by roadsides and in waste places, or on wall-tops, or in sandy and chalky fields. Two or three of them occur in other habitats as well, but most abundantly on waste ground.

Poa annua, the Annual Meadow-grass (frontispiece) is the commonest grass in Britain, growing abundantly in every conceivable habitat, but especially in waste places, garden ground, by roads and footpaths, and in pastures; it even grows in the crevices of street pavement. Culms tufted, weak, ascending or prostrate, and sometimes rooting below, 2 inches to a foot high; leaves flat, linear, often transversely wrinkled, ribless but keeled, the apex suddenly pointed, and concave or "hooded." Panicle deltoid and rather one-sided, the branches mostly paired, the longer one spreading laterally, the other in front. Spikelets $\frac{1}{6}$ inch long and about 5-flowered; glumes compressed, keeled, acute, awnless, not webbed. The whole plant is flaccid and bright green; annual or biennial, flowering March to December. All our other species of *Poa* are perennial.

FIG. 31.—*Agropyrum repens*: central figure, the spike; on right hand a spikelet enlarged; on left, a flower, enclosed in its glume and palea, more enlarged.

Agropyrum repens, the Common Couch (fig. 31), is very abundant in waste places, on field borders and arable land, and we have never seen a hedgebank from which it was absent; it is universally distributed. Rootstock extensively creeping, with long subterranean stolons. Leaves flat, rather broadly linear-lanceolate, usually hairy on the upper surface, with numerous faint, unequal, slightly scabrid ribs, auricled; ligule scarcely more than a margin. Culms 2–4 ft. Spike 3–4 inches long, or more. Spikelets sessile, broadside to the rachis, one in each excavation, $\frac{1}{2}$–$\frac{3}{4}$ inch long, 4- or 5-flowered; empty glumes nearly equal, the flowering ones acute or mucronate or, var. *A. barbatum*, with a short, stiff awn. Perennial, flowering July, August.

Arrhenatherum avenaceum, the False Oat, is a common grass by roadsides and hedgerows, and is frequent, too, in meadows, pastures and woods; distributed all over Britain. Rootstock extensively creeping. Leaves flat, broadly linear-lanceolate, with low unequal ribs, slightly hairy above; ligule short, toothed. Culms 2–4 ft., the basal internodes often swollen into little knobs (var. *A. nodosum*) whence the popular name of Onion Couch.

Panicle long, lax, and spreading, the branches several at each insertion, and very unequal in length. Spikelets $\frac{1}{3}$ inch long, pale green or purplish, 2-flowered; the lower flower is staminate and its glume has a long kneed and twisted dorsal awn; the upper flower bisexual, its glume with a short, straight, subterminal awn. Perennial, flowering close of June to autumn.

Hordeum murinum, the Wall Barley, is a familiar grass in dry waste places and on banks by roadsides; common in England, rare in Scotland and Ireland. It has a curious predilection for growing along the bottom of walls and in the vicinity of houses. Culms 6–18 inches. Leaves very flaccid, tapering above, hairy on both surfaces, auricled; sheaths inflated, and except the lowest, glabrous. Spike about 2 inches long, bristly, with long awns. Spikelets three in each notch of the rachis, about $\frac{1}{2}$ inch long, 1-flowered, the lateral spikelets staminate, central one bisexual; empty glumes of the middle spikelet linear-lanceolate, of the lateral spikelets bristle-like and scabrid, all with a terminal awn about twice their length; one of the empty glumes of each lateral spikelet is usually ciliated; flowering glumes with an awn considerably exceeding those of the empty glumes. All the awns are scabrid. Annual or biennial, flowering early July to autumn.

FIG. 32.—*Bromus sterilis:* drooping panicle; below, enlarged, a flowering glume (showing long subterminal awn) with its palea and flower.

Bromus sterilis, the Barren Brome (Fig. 32), is very often seen in dry waste places and on roadside banks, usually under the shelter of hedges; widely distributed. Culms about 2 feet. Leaves tapering above, more or less hairy; ligule lanceolate. Panicle with long, slender, arching branches, 3–5 at the lower insertions, most of them bearing only one spikelet. Spikelets about an inch long (exclusive of the awns), 7- to 10-flowered, pale green, or tinted with purple; empty glumes very unequal, the upper 3-nerved, lower 1-nerved; flowering glumes strongly 7-nerved, bifid, with a straight, subterminal, scabrid awn about an inch long. A handsome grass, recognizable at once by its large drooping long-awned spikelets. Annual or biennial, flowering latter part of June.

Phalaris canariensis, the Common Canary-grass, is often met with as a casual in waste places about towns and villages, and on the borders of cultivated fields where refuse has been deposited.

Culms about 2 feet. Leaves flat, broad, tapering from the base, striated and auricled; ligule prominent; topmost sheath much inflated. Spikelets crowded and regularly imbricated into a small compact egg-shaped head, 1–1½ inches long; the spikelets are ¼ inch long and contain one perfect flower, and beneath it two rudimentary glumes (small lanceolate scales); glumes awnless, the empty ones with a winged keel, pale yellow with a green stripe on each side; flowering glume polished. Annual, flowering in July.

Growing on dry banks and wall-tops, in gravelly waste places, and pastures:—

Aira præcox, the Early Hair-grass, is frequent all over Britain. Culms tufted, capillary, 1–4 inches high. Leaves very short and setaceous. Panicle ¼–1 inch long, with very short scarcely divided branches, pale green. Spikelets few, about ⅛ inch long, 2-flowered without any rudiment; flowering glumes with two longish teeth at the apex, also with a kneed and twisted dorsal awn nearly twice their length. Annual, flowering May or early June.

Aira caryophyllea, the Silvery Hair-grass, is closely allied to the last species, and not less frequent. Culms taller, 6–8 inches; leaves setaceous, sheaths roughish when stroked downwards. Branches of the panicle triply-forked and spreading. Spikelets silvery-grey. Annual, coming into flower rather later than *A. præcox*.

Festuca myurus, the Mousetail Fescue, is a rather scarce grass found in the southern half of England and in Ireland. Culms 1–1½ feet; leaves extremely narrow, convolute and bristle-like. Panicle very narrow, unilateral, and nodding, 6 inches or more in length, branched only at the base, the branches adpressed to the rachis. Spikelets about ½ inch long, 5–8-flowered; upper empty glume three times as long as the lower; flowering glumes entire, tapering into an awn exceeding their own length. There is usually but one stamen in each flower. Annual, flowering close of June.

Festuca ambigua, the Ambiguous Fescue, is a smaller variety with an erect, dense, fusiform panicle, the upper empty glume 3–6 times as long as the lower one; it occurs on the south coast in loose sand, but is very rare. *F. sciuroides*, the Barren Fescue, a sub-species of *F. myurus*, is rather frequent all over Britain. Culms 6–10 inches high. Panicle narrowly oblong, about 3 inches long; upper empty glume about twice as long as the lower.

Glyceria rigida, the Hard Sweet-grass, is a wiry little annual, frequent in England, scarcer in Scotland and Ireland; calcareous soil suits it best. Culms slender, 3–4 inches high. Panicle about 2 inches long, purplish, with very short distichous branches, each bearing 3–5 spikelets which are ¼ inch long and about 7-flowered; flowering glumes quite separate from each other (not imbricate), faintly 3-nerved, and with a scarious slightly mucronate tip. Flowering June, July.

Poa compressa, the Flat-stemmed Meadow-grass, is not unfrequent in England, but very scarce in Scotland and Ireland. Rootstock extensively creeping, stoloniferous. Leaves narrowly

linear, dull green ; sheaths greatly compressed ; ligule truncate. Culms 1½–2 feet, decumbent. Panicle somewhat unilateral with short branches, 2–3 at the lower insertions. Spikelets ⅙ inch or rather more in length, 4- to 8-flowered ; glumes compressed, keeled, and awnless, the flowering ones slightly webbed, and with three faint hairy nerves. Perennial, flowering in July. Var. *P. polynoda* has the flowering glumes free, faintly 5-nerved ; dry stony places.

Growing in sandy or chalky fields :—

Bromus erectus, the Upright Perennial Brome, is found on dry pastures and wayside banks, and is not unfrequent in the S. and E. parts of England, although of rare occurrence elsewhere in Britain. Rootstock shortly creeping, densely tufted. Leaves long and extremely narrow, clothed with scattered hairs on both surfaces, margins conspicuously fringed, culms 2 feet or more. Panicle branches 2–3 at each insertion, nearly erect, and most of them bearing a solitary spikelet. Spikelets an inch long, purplish and about 8-flowered ; empty glumes respectively 1- and 3-nerved, flowering ones faintly 7-nerved, with a subterminal awn about half their length ; anthers large, orange-coloured. Perennial, flowering close of June, July. Var. *B. villosus* has the flowering glumes hairy all over.

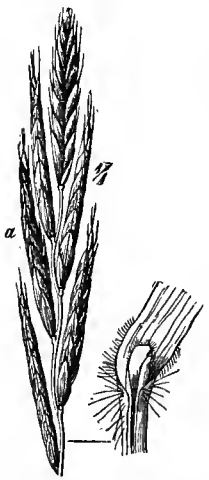

FIG. 33. — *Brachypodium pinnatum* : *a* erect spike ; on right, mouth of sheath enlarged to show ligule.

Brachypodium pinnatum, the Heath False Brome (Fig. 33), is not unfrequent on downs, heaths and dry pastures in the south and east of England, showing a decided partiality for chalky and limestone soils ; it is not known to occur in any other part of Britain. Rootstock creeping, stoloniferous. Leaves firm, ultimately involute, clothed with very short hairs or glabrous, margins not ciliate. Culms 1–2 ft. The inflorescence is similar to that of *B. sylvaticum*, but the spike is erect, and the awn is shorter than the flowering glume, sometimes indeed only a mucro. The spikelets are about an inch long and nearly erect. Perennial, flowering in July.

Phleum phalaroides, the Purple-stemmed Catstail, is a rare species found in sandy and chalky fields in the eastern counties of England. Rootstock tufted, stoloniferous. Culms about a foot high. Panicle narrowly cylindric and dense, 2–4 inches long. Spikelets ⅛ inch long, 1-flowered, with a stalk-like rudiment ; empty glumes abruptly narrowed into a short, stiff awn, and the keel ciliated, with short distant hairs ; flowering glume minute, awnless. Perennial, flowering in July.

Bromus madritensis, the Upright Annual Brome, is occasionally met with in dry sandy places in the southern half of England,

chiefly near the coast; Channel Islands. Culms 6–12 inches. Leaves narrow, more or less hairy. Panicle erect, the few branches rather close, scarcely divided, and shorter than the spikelets. Spikelets $\frac{3}{4}$–$1\frac{1}{4}$ inch long, wedge-shaped, 8- to 10-flowered; flowering glumes not imbricated, with a slender subterminal awn about their own length, and ultimately curved; stamens usually two. Annual or biennial, flowering close of June. Var. *B. rigidus* has a dense panicle, the rachis, pedicels and glumes downy.

Panicum glabrum, the Smooth Finger-grass, occurs in sandy places in S.E. England, but is extremely rare. It is closely allied to *P. sanguinale*. Culms 6 inches, prostrate or decumbent; leaves and sheaths glabrous. Culms usually bearing three digitate spikes about $1\frac{1}{2}$ inch in length. Spikelets $\frac{1}{12}$ inch long, on one side of the rachis, in pairs; one spikelet sessile, the other pedicelled; dorsally compressed, downy, purplish, each containing one flower and a third empty glume; lowest empty glume minute or absent. Annual, flowering in July, August.

Our last is the alpine group of grasses, all, with the exception of *Hierochloe borealis*, restricted to high mountains.

Growing in crevices and on ledges of rock, and among rocky debris:—

Poa alpina, the Alpine Meadow-grass, is the commonest of our mountain grasses, abundant in the Highlands; also found on the Cumbrian mountains and Snowdon; West of Ireland. The rootstock is stout, shortly creeping. Culms about a foot high, rather wiry, the base of each thickly clothed with decayed leaf-sheaths and thus having a bulbous appearance by which the species can be unmistakably distinguished from all its allies. Leaves broadly linear, thick, firm, keeled, abruptly pointed and hooded, slightly glaucous; ligule very prominent. Panicle erect, the branches usually in pairs, spreading. Spikelets $\frac{1}{6}$ inch, usually purplish, 4- or 5-flowered; glumes compressed, keeled and awnless, as in all species of *Poa*; the flowering ones free, *i.e.* not webbed, with three of the five faint nerves silky-hairy. Perennial, flowering in June, July; commonly viviparous.

Deschampsia alpina, the Alpine Hair-grass, is plentiful on the Braemar mountains, Lochnagar, etc.; it is regarded by some as a sub-species or variety of *D. cæspitosa*, from which it differs in the following characters: leaves short, culms 6–12 inches; panicle branches quite smooth. Spikelets nearly $\frac{1}{4}$ inch long; awn inserted above the middle of the flowering glume. Usually viviparous. Perennial, flowering late summer and autumn.

Poa laxa, the Wavy Meadow-grass, is a rare native of the loftier mountains of Inverness and Aberdeen, as Ben Nevis and Lochnagar. The rootstock is rather slender, densely tufted, not creeping; leaves thin, flaccid, narrowly linear, channelled, hooded at the tip; ligule very prominent, lacerate. Culms 6–9 inches, weak and bending. Panicle lax, slightly drooping, the lower branches generally paired, closed in fruit. Spikelets 3-flowered; flowering

glumes slightly webbed and with three of the nerves silky-hairy. Perennial, flowering July, August. *Poa stricta*, the Straight-stemmed Meadow-grass, is very closely related, but the stems are firm and straight; the leaves taper gradually to the point and are flat throughout, not hooded. Branches of the panicle spreading in fruit. Nearly always viviparous.

Growing by springs and rills:—

Alopecurus alpinus, the Alpine Foxtail, is not unfrequent in the Clova glens, and is abundant on Lochnagar. Rootstock stoloniferous; leaves thick with very prominent ribs. Culms about a foot high. Panicle dense, ovoid-oblong, not more than an inch in length, purple. Spikelets $\frac{1}{6}$ inch long, 1-flowered; empty glumes united for about one-fourth of their length, awnless, the keel ciliated with very long hairs; flowering glume with a dorsal awn scarcely extending beyond its tip or sometimes absent, or (var. *Watsoni*) exceeding the glumes by about one-third of their length; no palea. Perennial, flowering in July.

Phleum alpinum, the Alpine Catstail, is found in the same localities as the last-named, and its panicle is very similar, but recognizable at a glance by its bristly aspect. Rootstock somewhat creeping, with short stolons; leaves short, flat, uppermost sheath inflated. Culms about 12 inches. Spikelets $\frac{1}{6}$ inch long, 1-flowered; empty glumes truncate with a rigid scabrid awn their own length, the keel ciliated with long stiff hairs; flowering glume awnless. Perennial, flowering in July.

Hierochloe borealis, the Northern Holy-grass, is only known to exist in one British locality, viz. on the banks of Thurso River, Caithness. Rootstock creeping, stoloniferous; leaves flat, tapering. Culms about a foot. Panicle widely spreading, its branches capillary and flexuous. Spikelets $\frac{1}{8}$ inch long, brown and shining, 3-flowered; the two lower flowers male with three stamens each; the uppermost flower perfect with two stamens; glumes keeled, awnless, the empty ones nearly as long as the spikelet, the flowering ones mucronate, scarcely awned; palea of the perfect flower 1-nerved. Perennial, flowering in May and June; sweet-scented.

There are also mountain forms of—

Avena pratensis; leaves broader than in the lowland species; lower sheaths much compressed; some of the branches of the panicle bearing 2–3 spikelets. Var. *A. alpina.*

Molinia cærulea, var. *depauperata*; spikelets few, 1-fl., green.

Deschampsia flexuosa, var. *montana*; leaves shorter, spikelets larger and more purplish than in the normal form.

There are several rare alpine forms of *Poa nemoralis* (*P. glauca*, *P. cæsia*, *P. Balfourii*), variously regarded as species or varieties, but there is no accordance among botanists as to their differential characters.

Festuca ovina, described in the heath and upland group, is very plentiful on mountains, reaching the highest summits, where it is often viviparous. Var. *tenuifolia* has longer radical leaves, and the flowering glumes not awned, but mucronate.

CHAPTER III

Classification

THE *Gramineæ* as a family are readily distinguished from all other plants; the most nearly related order is the *Cyperaceæ* (Sedges), but differing from the grasses in many characters, *e.g.* the three-sided stems, entire leafsheaths, absence of ligule; flowers without a palea, anthers basifixed and entire at the apex, styles solitary with simple, not feathery, stigmas; ovary surrounded by bristles or enclosed in an urceolate (bottle-shaped) bracteole or perigynium; embryo at the base of the endosperm, not lateral. But while the grasses are such a very natural family, their classification into primary division, tribes, and genera is more difficult perhaps than that of any other order of plants. The flowers and fruit are of very little value for this purpose, and the characters are mainly drawn from the structure of the spikelets and the various modifications of the glumes. None of the groups can be defined one from another absolutely, as there are ambiguous or intermediate forms connecting them, the result being a network of genera related in different ways and various degrees. We shall give, as plainly as possible, a short account of Bentham's classification and a synopsis of the British genera, noting the exceptions as they occur in the different tribes.

The grasses are divided into two great series, *Panicaceæ* and *Poaceæ*, and this primary division is founded upon a combination of two kinds of characters: first, the articulation of the spikelet upon the pedicel, or the articulation of the rachilla (axis of the spikelet); secondly, the position of the imperfect flower or third empty glume or rudiment (when present) in relation to the bisexual flower, that is, whether situated above or below it.

We have seen, when considering the structure of the spikelet, that the significance of the articulation lies in the fact that it determines the manner in which the fruit is liberated. If, for example, the spikelet is jointed upon its pedicel, when the fruit matures the entire spikelet will drop off. This is what takes place in the *Panicaceæ*; normally, not a glume remains on the rachis or branches of the panicle after the fruit is dispersed.

In the *Poaceæ* the spikelets are not (with some exceptions) jointed on the pedicel; the articulation is in the rachilla, so that when the fruit is mature each internode of the rachilla breaks away,

carrying with it a fruiting glume (fig. 34). The pair of empty glumes at the base of the spikelet remain attached to the pedicel; this is shown in fig. 35, which compare with fig. 14, showing the spikelets of the same plant when in flower. The articulation is not always evident at time of flowering, but in the fruiting season it can be detected by the facility with which the fruiting glume can be broken off. We thus see that in the *Panicaceæ* the empty glumes are deciduous; in the *Poaceæ* persistent in fruit. In the case of 1-flowered spikelets of *Poaceæ*, the rachilla is that minute fragment, by some termed the callus, embraced by the base of the flowering glume, and the joint or articulation is between this fragment and the pedicel, *i.e.* above the empty glumes.

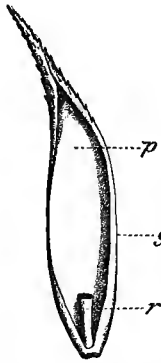

FIG. 34. — A fruiting glume of *Dactylis glomerata*: *r* a piece (internode) of the rachilla; the glume next above (in the spikelet) was seated on the top of it; *g* margin of glume inflected over *p*, the palea; grain concealed between glume and palea.

With regard to the second character on which the primary division is based, in the *Panicaceæ* the imperfect (staminate) flower, or additional empty or rudimentary glume, is always situated below the bisexual flower; in other words, the imperfection is near the base of the spikelet. There are never more than four glumes, the two lowest of which are empty; the next, *i.e.* the third one, may also be empty, or it may enclose a palea or a male flower; the fourth, *i.e.* the uppermost glume, encloses the bisexual flower.

In the *Poaceæ*, on the other hand, the imperfection is in the upper part of the spikelet; the male flower or additional empty glume or rudiment (when present) being at the apex of the spikelet, *i.e.* terminal; hence it is sometimes spoken of as the produced rachilla. The spikelets may contain one or any number of bisexual flowers, and have accordingly three or more glumes; some species of *Eragrostis* have as many as 50 flowering glumes in a spikelet.

FIG. 35.—Portion of panicle of *Bromus mollis*, after shedding of fruit, showing the persistent empty glumes.

Series A. PANICACEÆ. Spikelets articulated to the pedicel (below the empty glumes), containing one bisexual flower, with a male flower or third empty glume or rudiment beneath. Only two tribes are represented in Britain, viz. :—

Tribe PANICEÆ. The principal character is the hardening of the flowering glume around the fruit; flowering glume awnless. There are three British genera:

Genus 1. *Panicum*. Rachis compound, spikes often spreading like fingers from a common insertion (digitate), or panicle lobed;

spikelets flattened dorsally; no bristles; lowest empty glume much smaller than the second one, sometimes rudimentary (fig. 30).

2. *Setaria.* Panicle dense, spike-like, with numerous bristles on the pedicels, which remain after the spikelets fall off; spikelets dorsally compressed.

3. *Spartina.* Rachis compound; spikes appressed; spikelets much flattened laterally; styles united for half their length.

Tribe ORYZEÆ. Inflorescence paniculate; spikelets laterally compressed; glumes 3 or 1; empty glumes minute or absent; palea with one nerve or keel; stamens variable, 6, 2 or 1. We have only one representative of this tribe in Britain, viz. :—

Genus 4. *Leersia.* Empty glumes absent, flowering glume translucent, stamens 3.

Series B. POACEÆ. Spikelets rarely articulated to the pedicel, the articulation being above the empty glumes, *i.e.* in the rachilla; the male flower or additional empty glume or rudiment (when present) is usually terminal; spikelets containing one or many bisexual flowers. Six tribes are represented in Britain.

Tribe PHALARIDEÆ. Spikelets with one bisexual flower, and two staminate ones or two additional empty glumes or rudiments beneath; no terminal rudiment; glumes 6, or 5 and a palea. The position of the imperfect flowers or rudimentary glumes, beneath the bisexual flower, is an exception to one of the characters of the *Poaceæ*. Another peculiarity of this tribe is that the palea of the terminal flower is 1-nerved or keeled, so that it is doubtful whether it be a glume or a palea; strictly speaking, the term pale aapplies to a 2-nerved scale attached to the secondary axis of the spikelet. This is also the case in the tribe *Oryzeæ*, which has close affinities with the *Phalarideæ*; these tribes, therefore, may be regarded as transitional between the two primary series. There are three British genera:

Genus 5. *Phalaris.* Third and fourth glumes small and empty, or aborted and simply represented by pedicels.

6. *Anthoxanthum.* Third and fourth glumes empty, awned; flower bisexual with two stamens, its glume awnless (fig. 13).

7. *Hierochloe.* Two lower flowers staminate (3 stamens each); terminal flower bisexual, with two stamens.

Tribe AGROSTIDEÆ. Spikelets with one bisexual flower, terminal, or sometimes with a stalklike rudiment (continuation of the rachilla) above it; glumes not more than three. The British genera whose spikelets have no rudiment are:

Genus 8. *Milium.* Panicle widely spreading; spikelets minute, terete; glumes neither keeled nor awned; fruiting glume indurated.

9. *Alopecurus.* Panicle cylindric, dense; spikelets articulated to the pedicel; flowering glume with a dorsal awn; palea when present 1-nerved, but in the British species absent. The articulation of the spikelet to the pedicel is one of the characters of *Poaceæ*, and if the 1-nerved palea be regarded as a glume, then we have here both characters of that series, but the habit of *Alopecurus* (fig. 36) is identical with that of *Phleum.*

10. *Phleum.* Panicle cylindric, dense ; flowering glume rarely awned ; when present, the awn is terminal. In some species the spikelet has a rudiment (fig. 18).

11. *Mibora.* Spikelets terete, minute, few in a simple spike (fig. 28).

12. *Agrostis.* Panicle usually spreading ; flowering glume thin and colourless ; palea absent in some species (fig. 23).

13. *Polypogon.* Panicle dense ; empty glumes with long awns. The spikelets are articulated to the pedicel.

14. *Calamagrostis.* Flowering glume with a tuft of hairs at its base on the rachilla.

FIG. 36.—*Alopecurus pratensis*: central figure the spike (diminished) ; lower figures enlarged—the left a spikelet, the right same, minus empty glumes to show dorsally awned flowering glume.

In the following genera the spikelets have a rudimentary glume or naked pedicel, above the bisexual flower :

15. *Gastridium.* Base of each empty glume swollen into a round prominence, and ultimately indurated ; flowering glume minute, hyaline.

16. *Apera.* Flowering glume with a long subterminal awn.

17. *Deyeuxia.* Flowering glume with a tuft of hair at its base, and dorsally awned.

18. *Ammophila.* Panicle dense ; spikelets large, rigid ; flowering glume with a tuft of hairs at its base, and a very minute subterminal awn.

19. *Lagurus.* Empty glumes fringed with long silky hairs on the margins, and therefore plumose or feathery. Spikelets massed into an ovoid head ; flowering glume with a long dorsal and two terminal awns.

The genera *Calamagrostis*, *Deyeuxia* and *Ammophila* are closely allied, and these again are nearly related to *Agrostis*. In the last named there is not a decided ring of hairs at the base of the flowering glume, nor is there any rudiment.

Tribe AVENEÆ. Spikelets containing two or more flowers, and often a terminal rudiment ; flowering glume with a bent and twisted awn on the back. The distinctive tribal character is the dorsal awn which, in the lower part below the bend or knee, is spirally twisted. The following genera, with the exception of *Aira*, have a terminal rudiment or empty glume, and there is often a tuft of hairs at the base of the flowering glume.

Genus 20. *Aira.* Flowers two, bisexual ; no rudiment.

21. *Corynephorus.* Awn jointed in the middle, and thickened towards the tip (club-shaped).

22. *Deschampsia.* Awn short, nearly straight (fig. 37).

In some species of *Aira* and *Deschampsia*, the twist of the awn is scarcely perceptible.

23. *Trisetum.* Spikelets small, much flattened laterally, 2- to 6-flowered; flowering glume keeled, with a long dorsal awn, and tipped with two short awns or setæ.

24. *Avena.* Spikelets large, 2- to 6-flowered; flowering glumes terete, rounded on the back (keelless), and with a long dorsal awn (fig. 20).

In the next two genera, the spikelets contain two flowers, one of which is staminate (with stamens only).

25. *Holcus.* Lower flower bisexual, its glume awnless; upper flower staminate, its glume awned (fig. 8).

26. *Arrhenatherum.* Lower flower staminate and its glume awned; upper flower bisexual (the reverse of Holcus).

Tribe CHLORIDEÆ. Spikelets sessile in two rows on one side of the rachis, 1- or more-flowered, with a terminal rudiment; glumes keeled, and spikelets compressed laterally: rachis neither notched nor jointed. The inflorescence is very like that of some *Panicaceæ*, but the rudiment is terminal, and the empty glumes are persistent.

Genus 27. *Cynodon.* Rachis compound, spikes fingered; spikelets 1-flowered.

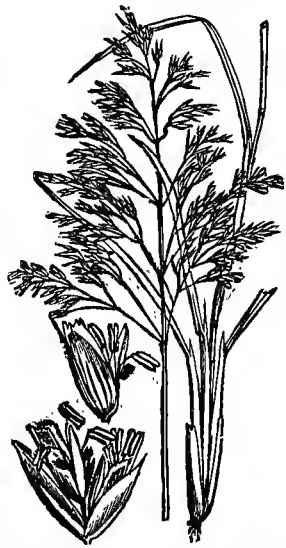

FIG. 37.—*Deschampsia cæspitosa*; left-hand figures enlarged—the lower a spikelet, the upper a flowering glume, etc., showing short straight dorsal awn.

Tribe FESTUCEÆ. Spikelets containing two or many flowers, and often a terminal rudimentary glume; awn absent, or terminal or subterminal, not twisted, straight. There are eight sub-tribes, of which six are represented in Britain.

Sub-tribe TRIODIEÆ. Spikelets 2- or more-flowered; flowering glumes tipped with three teeth, lobes or short awns.

Genus 28. *Triodia.* Flowering glumes with three broad teeth.

Sub-tribe ARUNDINEÆ. Spikelets 2- or more-flowered; flowering glumes enveloped in long silky hairs growing on the rachilla.

29. *Phragmites.* Lowest flower staminate (fig. 38).

Sub-tribe SESLERIEÆ. Inflorescence spikelike, or capitate (in the form of a head), with bracts (empty glumes) either at the base or forming sterile spikelets.

30. *Sesleria.* Pedicels of lower spikelets sheathed by a simple bract or empty glume (fig. 21).

31. *Cynosurus.* Fertile spikelets accompanied each by a spikelet of empty glumes (fig. 16).

Sub-tribe ERAGROSTEÆ. Spikelets 2- or more-flowered; flowering glumes 3-nerved.

32. *Koeleria.* Panicle spikelike; spikelets compressed; flowering glumes keeled, translucent.

33. *Molinia.* Panicle contracted; spikelets oblong; flowering glumes rounded on the back, firm and coloured.

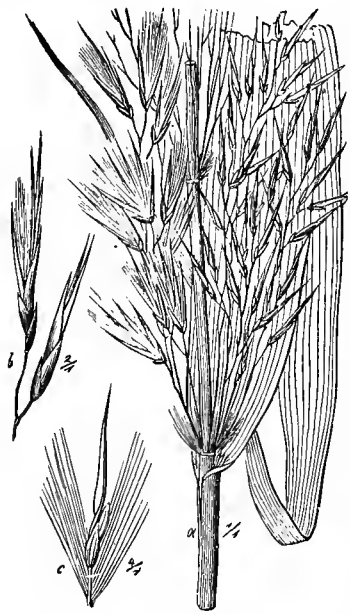

FIG. 38.—*Phragmites communis*: *a* lower portion of panicle; *b* two spikelets, twice natural size; *c* a spikelet, four times enlarged with empty glumes and lowest flower removed to expose the bearded rachilla.

34. *Catabrosa.* Panicle spreading widely; spikelets wedge-shaped; glumes with very blunt erose tips (fig. 24).

Sub-tribe MELICEÆ. Spikelets 2- or more-flowered, with two or more terminal empty glumes.

35. *Melica.* Terminal rudimentary glumes convolute, forming a club-shaped body (fig. 26).

Sub-tribe EUFESTUCEÆ. Spikelets 3- or many-flowered; flowering glume with five or more nerves; awn, when present, terminal or, sometimes, subterminal, never dorsal or twisted.

36. *Dactylis.* Spikelets in dense clusters. Panicle and clusters one-sided (fig. 15).

37. *Briza.* Spikelets nodding or pendulous; glumes very deeply boat-shaped (almost vesicular), broad, rounded on the back, awnless, obtuse, closely imbricate (fig. 19).

38. *Poa.* Flowering glumes compressed and keeled throughout their entire length, acute, never awned; nerves reaching the tip (fig. 7).

39. *Glyceria.* Flowering glumes rounded on the back, awnless; nerves usually falling short of the blunt scarious tip. Sometimes the glumes are keeled near the apex, but not below (figs. 22 and 27).

40. *Festuca.* Flowering glumes rounded on the back, acute, mucronate or awned; sometimes keeled in the upper part, not below; ovary smooth (fig. 17).

41. *Bromus.* Flowering glumes rounded on the back, with the tip notched or bifid, and awned from the notch; top of ovary hairy; styles lateral, *i.e.* inserted below the apex (figs. 14 and 32).

42. *Brachypodium.* Spikelets on extremely short pedicels, so as to appear sessile on the rachis, the inflorescence spikelike (figs. 25 and 33). Flowering glumes awned.

It is important to note carefully the generic characters of *Poa*, *Glyceria*, and *Festuca*. These three genera are all well represented in our flora, and many of the species are very abundant; inattention to the characters which distinguish these genera one from another would therefore lead to confusion.

Tribe HORDEEÆ. Spikelets sessile, in notches or excavations of the simple rachis (inflorescence truly spiked). A very simple character, and there is no possibility of mistaking this tribe. The notched rachis is well shown in fig. 39. There are three sub-tribes.

Sub-tribe TRITICEÆ. Spikelets one in each notch of the rachis, many-flowered.

Genus 43. *Lolium.* Back of the glumes towards the rachis (spikelets edgewise).

44. *Agropyrum.* Margins of the flowering glumes against the rachis (spikelets broadside) (fig. 31).

Sub-tribe LEPTUREÆ. Spikelets one in each notch, 1-, rarely 2-flowered.

45. *Lepturus.* Empty glumes two in the British species (fig. 29).

46. *Nardus.* Empty glumes absent.

Sub-tribe ELYMEÆ. Two or three spikelets at each excavation.

47. *Hordeum.* Spikelets containing one flower and a rudiment, many-awned.

48. *Elymus.* Spikelets 2- or more-flowered, not awned in the British species.

FIG. 39.—Spike of wheat, *Triticum vulgare*: spikelets removed from lower part to show *(g)* notches or excavations of the rachis.

So far, we have only considered the British tribes and genera; to have incorporated with them the exotic tribes would only have served to confuse the beginner. The following complete list (which the student may ignore altogether if he chooses, or at least until he has mastered the British genera) of tribes, and the more important genera, is given because many of the latter are mentioned in the chapters on Distribution and Uses.

Series A. PANICACEÆ, described in the preceding pages, is divided into six tribes, viz.:

PANICEÆ, characters already given. This tribe comprises thirty genera, the leading ones being *Panicum*, *Paspalum*, *Pennisetum*, *Olyra*.

MAYDEÆ. Spikelets always unisexual, male ones in the upper part of the inflorescence, female spikelets in the lower part; or (in *Pariana*) male spikelets surrounding the females at each node. This is a tribe of eight small genera, tropical or American, including *Zea Mais* (maize) and *Coix lachryma*.

ORYZEÆ, characters already given, comprises nine genera, mostly tropical or American, including *Oryza sativa* (cultivated rice) and *Zizania aquatica*.

TRISTEGINEÆ. Spikelets solitary (rarely paired or clustered) on the inarticulate branches of the panicle; flowering glume thin, often hyaline, and frequently with a terminal bent awn. This is a tribe of twelve genera, mostly tropical, the chief being *Arundinella*.

ZOYSIEÆ. Spikelets scattered singly, or clustered along the inarticulate rachis or pedicels of the inflorescence; fruiting spikelets often falling off in little clusters; flowering glumes often smaller than the empty, and hyaline. A tribe of thirteen small genera, the typical one *Zoysia*.

ANDROPOGONEÆ. Spikelets in pairs at each node of the jointed rachis or branches of the inflorescence, or terminal in triplets; flowering glume much smaller than the lower or empty ones, hyaline, and often with a bent or twisted awn. Sometimes one of the spikelets of each pair is imperfect or rudimentary. This tribe comprises twenty-six genera, mostly tropical or subtropical, the largest *Andropogon*; other large genera are *Pollinia*, *Ischæmum*, *Chrysopogon*, *Rottbœllia*. This tribe includes also *Saccharum* (*S. officinarum*, the sugar cane) and *Sorghum* (*S. vulgare*, dourra).

Series B. POACEÆ, described in the preceding pages, is divided into seven tribes, viz.:

PHALARIDEÆ, characters already given. Nine genera, *Phalaris* being the typical one, *Ehrharta* the largest.

AGROSTIDEÆ, characters already given. Thirty-eight genera, the largest *Aristida*, *Stipa*, *Muehlenbergia*, *Sporobolus*, *Agrostis*, *Deyeuxia*.

AVENEÆ, characters already given, comprises twenty-two genera, *Danthonia* being by far the largest. Other leading genera are *Trisetum*, *Avena*, *Eriachne*, *Deschampsia*.

CHLORIDEÆ, characters already given, contains twenty-eight genera, mostly tropical or subtropical, the typical and largest one being *Chloris*. Includes *Bouteloua* and *Eleusine*.

FESTUCEÆ, characters already given, is the largest tribe of all, comprising sixty-nine genera, the more important of which are *Eragrostis*, *Poa*, *Festuca*, *Bromus*, *Glyceria*, *Melica*, *Triodia*, *Pappophorum*.

HORDEEÆ, characters already given, contains twelve genera, the more important of which are *Hordeum* (including the cultivated barleys), *Triticum* (wheat and spelt), *Secale* (rye), and *Agropyrum*, differing technically from *Triticum* in the lateral nerves of the flowering glume not running parallel, but converging towards the tip.

BAMBUSEÆ. Culms ligneous (woody) and commonly arborescent; leaves usually jointed to the sheaths; spikelets 1- or many-flowered, awnless; lodicules three. This tribe comprises twenty-two genera, the leading ones *Bambusa*, *Arundinaria* and *Chusquea*.

CHAPTER IV

Geographical Distribution

GRASSES are at once the most abundant and the most universally distributed of all flowering plants; there is no hiatus in their world-wide diffusion; they flourish in every part of the earth where vegetation can exist. The *Gramineæ* number 3,100–3,200 species, and are therefore among the largest families of flowering plants, ranking only after the *Compositæ*, 10,000 species, and the *Orchideæ* and *Leguminosæ*, about half as numerous. The number of species of grasses, in proportion to the total number of species of flowering plants, is about $\frac{1}{4}$ in arctic and antarctic regions, about $\frac{1}{12}$ in temperate climates, and from $\frac{1}{12}$ to $\frac{1}{25}$ within the tropics; but in countless myriads of individuals the grasses far surpass every other order, and growing *en masse* as they commonly do, they constitute in many, if not most, regions the grand characteristic feature of the flora. Treeless, grassy plains are estimated to occupy rather more than one-fourth of the land-surface of the globe.

The cooler parts of the north temperate zone are characterized by dwarf tender grasses, with short, slender leaves, forming a close continuous turf. In low fertile plains the culms grow for the most part 2–3 feet high; on hillsides and elevated tablelands with a poorer soil, they are much shorter; in shady and swampy situations they rise to 4–6 feet, and have proportionately larger foliage. Where an insular climate prevails, with frequent rains, a humid atmosphere and temperate summer heat, and in mountainous regions whose slopes and valleys are irrigated throughout the warm months by melting snow, the earth is covered with a thick matted, velvety, evergreen sward. In no part of the world do we find such a beautiful "carpet of living green" as in the western parts of Great Britain, the "Emerald Isle" and the alpine pastures of Middle Europe. Under a continental climate of scorching summer heat and low winter temperature, the grasses do not form such a compact sod, and the green turf which clothes the ground in spring soon becomes brown and withered; the grassy expanse of the Kirghiz steppes is then transformed into a dusty desert, and the dry western plains of North America, which have a more luxuriant but equally sun-dried turf, are subject to prairie-fires. The eastern prairies of the Mississippi plain, with a more abundant rainfall and

moister soil, produce a rich grass vegetation like that of Middle Europe, particularly on the benches or terraces which rise from the banks of the rivers.

The frozen tundra of the arctic region, when thawed during the brief spell of summer, exposes a growth of stunted grass mixed with mosses and lichens. Alpine summits of lower latitudes have a similar vegetation ; the higher we climb, the more dwarfed and sparse do the grasses become, until their ascent to the snow-line is arrested by the denudation of the rocky surface.

In the warmer parts of both temperate zones, particularly on the borders of the tropics, there is much diversity in the aspect of gramineous vegetation. Regions of great heat, scanty rainfall, and dry sandy soil—the immense deserts of S.W. and Central Asia, the Sahara, the Great Basin of North America ; and in the southern hemisphere the Kalahari and Great Victoria deserts—are, in general, characterized by thorny shrubs and a sparse growth of harsh grasses, 2–3 inches to 1-2 feet high, the leaves short, rigid, sapless and involute. Transpiration in these desert-grasses is thus diminished to the lowest degree, to enable them to conserve their vitality during the prevalence of hot winds and prolonged drought. In moist localities, by springs, wadies, and in saline marshes, the grasses rise to several feet ; rarely, however, is there such a tall dense growth as the belts of *Phragmites communis* around the lakes of the Aralo-Caspian basin. Wide stretches of burning sand, impregnated with salt and utterly desiccated throughout the year, are destitute of vegetation ; but wherever there is ground-moisture or a little precipitation at any season, this ensures a growth of grasses, although perhaps of brief duration, dotted over the plains in tufts or patches, or forming extensive oases.

In sub-tropical regions of moderate rainfall, followed by a season of drought, the grasses of dry plains, like those of the southern portion of the prairie region and of the western plateau of North America, and the pampa of Argentina, west of long. 63°, grow mostly in isolated clumps, 4–5 feet high, the foliage rigid and very scabrid. But elevated plateaux and mountainous districts, as in South Africa, Mexico, and S.E. Australia, produce a short, close and soft turf, which during the rainy months resembles the sward of a more equable climate. The grasses of moist rich plains attain a stature of 6–9 feet, and grow in close contiguity, forming thickets. A typical example of luxuriant sub-tropical grasses is *Gynerium argenteum*, the Silvery Pampas-grass, which grows in the rich humid soil of the eastern part of the Parana and La Plata plain. It would be impossible, says the *Naturalist in La Plata*, to give anything like an adequate idea of the exquisite loveliness, at certain times and seasons, of this queen of grasses, the chief glory of the solitary pampa. One may ride through many leagues of this grass, which spreads away for miles on every side, the myriads of white plumes (as high as one's head), touched with varied colour, blending in the distance, and appearing almost like the surface of a cloud.

The mountainous regions of Northern India, although within the temperate zone, produce a grass vegetation thoroughly inter-tropical in character, by reason of the torrential rains of the summer monsoon. Here flourish the noble bamboos with ligneous culms, the taller kinds 50, 70, and even 90 feet high. The average diameter of a 60 feet culm is 5 inches near the base. "These arborescent grasses, which cover the sides and tops of the mountains throughout the continent of India, form one of the peculiar as well as most striking features of Oriental scenery. Few objects present a more attractive sight in the wild forests of this country, than a clump of these beautiful plants, with their tall bending stems and delicate light green foliage." The bamboos are abundant throughout the whole of S.E. Asia and the Malay Archipelago, varying much in habit; species with tall columnar culms, and profusely branched above, are common; others are slender, flexible, and semi-scandent, while many have a low, shrubby habit of growth. They frequently form jungles of vast extent, dense and impenetrable, with a uniform aspect (as there are seldom more than two or three species in the same jungle) and a poor undergrowth, in consequence of deep shade. Most species flower simultaneously over large tracts of country, at intervals of a great many years; they then die off, and their place is taken by seedlings, which grow with great rapidity. *Bambusa arundinacea*, the Great Bamboo, grows for the first 2–3 years as a clump of foliage, making only rootway; then it begins to throw up its gigantic culms, 30–100 in a clump, which may grow 20–30 feet during a month.

In the torrid zone, more particularly within the rainy belt, grasses give place, for the most part, to dense forests; but wherever there is a tract of more open country, the great heat and moisture combine to produce a dense vegetation of tall herbaceous grasses (as distinguished from the bamboos with ligneous culms), which rise to 12 or 15, and in some cases to 20 feet, during the rainy season; in the dry season they lie down. Grasses of this description are most abundant on the continent of Africa, in the Senaar, Senegambia, Guinea, and the equatorial lake region. The extremes of the two tropical seasons are most marked on the llanos of the Orinoco of South America; during the rainy season, June–August, the plain is flooded, and a luxuriant growth of grass ensues; in the dry season the soil is baked hard as stone, and the grasses are utterly parched up. Elevated regions of the torrid zone have a grass vegetation quite different to that of the low-lying plains. The high plateaux and mountain-slopes are clothed with a short green turf resembling that of the cool temperate zones. But on the Andes, and in other mountainous parts of inter-tropical America, jungles, forests, or belts of bamboo occur, as in the tropical countries of the East.

The *Panicaceæ* are, generally speaking, tropical or warm temperate in their distribution, while the *Poaceæ* predominate almost to monopoly in the temperate and colder regions of both hemispheres, and are fairly well represented within the tropics. In reading the

following notes on the distribution of the more important genera, the tribes to which the latter belong will be found on reference to the chapter on Classification.

We will consider the tropical genera first. *Panicum* is the largest; nearly 800 supposed species have been published, but the number of fairly distinct species is probably not more than 250–300; they abound in all tropical and warm-temperate regions of the world. *Andropogon*, *Aristida*, *Eragrostis* and *Stipa*, each comprise about 100 species, abundant within the tropics; also found in temperate regions, more particularly of North America. The genera particularly numerous in America are: *Paspalum*, comprising 160 species, tropical or sub-tropical, the greater number American, not more than five belonging exclusively to the old world, and only two (introduced) in Southern Europe; *Sporobolus*, about 80 species, spread over the warmer and temperate regions both of the old and new worlds, mostly, however, American, few European or Asiatic; *Muehlenbergia*, nearly 60 species, chiefly American, extending from the Andes of South America over the northern continent generally, very few in Central or Eastern Asia; *Olyra*, about 20 species, all tropical American with one exception, which is tropical African; *Bouteloua*, about 25 American species, northern or southern, but chiefly western. The genera most numerous in Africa are: *Danthonia*, nearly 100 species, widely dispersed over the warmer regions of the world, the greater number, however, South African; *Pennisetum*, about 40 species, chiefly African, of which two or three are dispersed over the Mediterranean region, tropical or sub-tropical Asia, or tropical America, a few endemic in Asia, Australia or tropical America; *Ehrharta*, 24 species, of which 20 are South African, 2 in the Mascarene Islands, and 2 in New Zealand. *Chloris*, *Ischœmum*, *Pappophorum*, *Chrysopogon* and *Arundinella* each comprise 20–40 species, dispersed over the warmer regions of both eastern and western hemispheres; *Pollinia* comprises 25 tropical old-world species, with a few in extra-tropical Eastern Asia; *Eriachne*, 22 species, of which 20 are Australian (one of them occurring also in tropical Asia), the remaining two endemic in tropical Asia.

The large genera of temperate regions are: *Deyeuxia*, nearly 120 species, dispersed over the temperate or mountain regions of the globe, particularly numerous in the Andes of South America, extending northward to the Arctic circle and southward to the Patagonian peninsula; *Festuca*, about 80 well-defined species (some botanists have made over 230), almost universally distributed, but most abundant in the northern temperate regions of the old world, with not many American or tropical species; *Poa* is another cosmopolitan genus of about 80 species (they have been estimated by some authors at over 200), particularly abundant in the northern hemisphere and sparingly represented within the tropics; *Agrostis*, 100 species, very widely dispersed, especially common in the temperate regions of the northern hemisphere, some almost cosmopolitan. Spread over the temperate or colder

regions, northern or southern, both of the old and new worlds, are: *Trisetum*, 50 species; *Glyceria*, 30 species; *Agropyrum*, 20 species; *Triodia*, 20 species (very few extending into the tropics in America or Africa); *Deschampsia*, 20 species (also sparingly represented in mountain regions within the tropics); *Avena*, 40 species, mostly in the temperate regions of the old world, with a few in extra-tropical North and South America, one or two of the annuals widely dispersed as cornfield weeds. Distributed over the temperate regions of the northern hemisphere are: *Bromus*, 40 species, with a very few tropical or southern; and *Melica*, 30 species, some extending down the Andes into extra-tropical South America and some occurring in South Africa.

The 32 genera above mentioned comprise about 2,000 species, nearly two-thirds of the total number; the remaining 1,200 are grouped into about 266 genera, many of which are monotypic, *i.e.* having but one species. 100 genera are common to both the old and new worlds, and upwards of 50 are common to the extra-tropical regions of both the northern and southern hemispheres. More than 50 genera are endemic in America; of these, 20 belong to the Mexicano-Texan region, a few of them extending into California and several down the Andes of South America as far as Bolivia; other 20 are tropical or sub-tropical, including a few Brazilian monotypic ones, while about ten genera are restricted to North America. Gray's *Manual of the Northern United States* describes 66 genera, of which no less than 35 are also British. For Europe, *Nyman's Conspectus* enumerates 116 genera, which include the 48 British. Less than 20 genera are endemic in Europe, and about a dozen (nearly all monotypic) are confined to the Mediterranean region. Many of the European genera range over the whole world, but are of course most abundant in the northern hemisphere. Harvey's South African genera are 89, of which 26 are represented also in Britain. Of the 90 Australian genera, 54 are found in both the old and new worlds, half of them being chiefly tropical; 18 other genera belong to the Indo-Australian region (ranging from Australia over the Malay Archipelago into South-Eastern Asia); 3 genera are common to Australia and New Zealand, and 1 occurs also in South Africa; only 14 genera are endemic in Australia, noted for its peculiar fauna and flora—a remarkable illustration of the wide diffusion of this family. Out of 30 genera indigenous to New Zealand, no less than 17 are found also in Britain.

The distribution of the *Bambuseæ* is peculiar; this tribe comprises 22 genera, of which 16 occur in India, China, Japan, the Malay Archipelago, Polynesia, Africa, Madagascar, and include the 8 genera of berry-bearing bamboos (with a thick fleshy pericarp) confined to the East. 6 genera, comprising 70 species, are confined to tropical America. Only 2 genera are common to both eastern and western hemispheres. The large genera are *Bambusa*, 24 species, confined to Africa and the East with the sole exception of *B. vulgaris*; *Arundinaria*, about 24 species,

found in both hemispheres, and *Chusquea*, upwards of 30 species, all restricted to America, and ascending on the Andes as high as *Arundinaria* does on the Himalayas. In the whole extent of North America north of Mexico there is only one species of uncultivated bamboo, *Arundinaria macrosperma*; in Europe there is not one native species, while on the continent of Africa there are only one or two native flowering species known.

Confining our attention now to the distribution of British grasses, many species occur in the southern and south-eastern parts of England that have not been observed further north. Most of these, as *Polypogon monspeliensis* and *P. littoralis*, *Agrostis setacea*, *Phleum phalaroides*, *Gastridium lendigerum*, *Corynephorus canescens*, *Cynodon dactylon*, **Bromus madritensis*, **Festuca uniglumis* and **F. myurus*, **Briza minor*, *Poa bulbosa* and *Brachypodium pinnatum*, are common all round the Mediterranean, extend up the west coast of Europe to the English Channel, some reaching Scandinavia. Those marked * occur locally or sparingly in Ireland. *Lagurus ovatus*, *Cynosurus echinatus*, and *Bromus maximus* do not get further than the Channel Islands, except as introduced casuals, and are not indigenous to Britain proper. The last-named is naturalized on the Tyne ballast-hills, its northernmost station. *Cynodon dactylon* is common in all warm regions, and in India is one of the most valuable pasture grasses. A few species occur in the Scotch Highlands that are not found elsewhere in Britain, viz. *Alopecurus alpinus*, *Phleum alpinum*, *Poa laxa*, *P. stricta*, and *Deschampsia alpina*; not by reason of the somewhat higher latitude, but because of the elevation of the mountains there, as these species occur in more southerly latitudes on the continent of Europe, on the Alps and Pyrenees. The grasses found at the highest elevations in North Britain are: above 4,000 ft., *Deschampsia alpina* and *Festuca ovina*, the latter occupying the highest summits in abundance; from 3,000 to 4,000 ft., *Deschampsia flexuosa*, *Anthoxanthum odoratum*, *Nardus stricta*, *Poa alpina*; also *Poa annua* about the springs and rills; from 2,000 to 3,000 ft., *Alopecurus alpinus*, *Avena pratensis*, *Festuca duriuscula*, *Phleum alpinum*, *Sesleria cærulea*. *Hierochloe borealis*, whose only British locality is the extreme north of Scotland, is abundant in Iceland, Northern and Arctic Europe, Siberia and Arctic America.

One species is confined to the eastern side of Britain, namely *Ammophila baltica*, on the coast of Northumberland, while another species, *Mibora verna*, occurs only on the Isle of Anglesea. The former extends all round the shores of the Baltic from Gothland to Holland, the latter is found throughout Western Europe, including the Channel Islands, and in North Africa. *Melica nutans*, distributed over Arctic Europe and Northern Asia, is restricted in Britain to the western counties, but is not recorded from Ireland. Several species are dependent upon the cultivation of the soil for their occurrence and perpetuation in our country; they are usually introduced with grass and clover seeds. Such are *Panicum Crus-galli*, *P. glabrum* (*Digitaria humifusa*), *P. sanguinale*, *Setaria*

viridis S. verticillata, Avena fatua, A. strigosa, Apera Spica-venti, Anthoxanthum Puelli, Briza minor. These agrarian species are rarely persistent in any locality, and most of them occur as British only in the south of England ; some have a world-wide distribution, tracking the tiller of the soil into every new region where he locates himself. *Phalaris canariensis* is spread all over Britain as a casual, through the universal use of its grains for feeding cage-birds. An extensive coastline gives us a large proportion of littoral species, about one-sixth of the total number.

We have no well-marked species that is not found also on the continent of Europe, although varieties peculiar to Britain have been raised to specific rank by some botanists. *Deyeuxia neglecta*, var. *Hookeri*, on the shores of Lough Neagh, Ireland, is not known to occur anywhere else. There are also some mountain varieties of *Poa nemoralis*, in the Scotch Highlands, which do not precisely correspond to continental forms—doubtless the result of insulation. According to *Nyman's Conspectus*, the European species of grasses number 570 ; those of the British Islands number about 120, inclusive of sub-species, but exclusive of many varieties some of which are regarded as species by continental botanists.

Several of our grasses range northward beyond the Arctic Circle. Recorded from Greenland are—**Phalaris arundinacea, Anthoxanthum odoratum, Hierochloe borealis, *Alopecurus alpinus, *A. geniculatus, Phleum alpinum, *Agrostis vulgaris, A. canina, Calamagrostis lanceolata, *Deschampsia cæspitosa, D. flexuosa, *Catabrosa aquatica, *Poa alpina, *P. pratensis, *P. nemoralis, P. annua, P. cæsia, *Glyceria fluitans, *Festuca ovina, F. rubra, *Agropyrum repens, Nardus stricta, *Elymus arenarius.* Those marked * occur also in East Arctic America. *Agrostis vulgaris, Anthoxanthum odoratum, Catabrosa aquatica* and *Nardus stricta* are found only south of the Arctic Circle.

More than half our grasses have a wide range eastwards, being abundant all over Europe, dispersed through Siberia, except the extreme north and east, and more than twenty are found on the high plateaux of Central Asia and on the Himalaya and other mountains. The latter are *Alopecurus pratensis, A. geniculatus, Phleum alpinum, Agrostis canina, A. vulgaris, Polypogon monspeliensis, Calamagrostis epigeios, Trisetum flavescens, Avena fatua, A. strigosa, Phragmites communis, Poa nemoralis, P. alpina, Glyceria aquatica, G. fluitans, G. distans, G. procumbens, Festuca elatior, F. ovina, Brachypodium sylvaticum, Lolium temulentum, Agropyrum repens, A. caninum, Hordeum pratense.*

Comparing our grass flora with that of the Northern United States (north of North Carolina and Tennessee, and east of the Mississippi), we find that no less than 32 species are indigenous to both countries, beside which 28 other British species have been introduced from Europe, most of them now naturalized. Altogether, out of 114 species described in Gray's Manual, 60 are also British. Chapman's *Flora of the Southern States* gives a very different result, for the number of indigenous species occurring

also in Britain falls to 12, but he introduced species number 21. The grass flora of the Azores is almost identical with that of S.W. Europe, the African element being very slight. Godman's *Natural History* enumerates 51 species of grasses, 30 of these are British and the remainder are nearly all from Southern Europe; only four species are peculiar to the Azores.

On the Andes of South America, our grass flora is represented generically by *Deyeuxia*, *Deschampsia*, *Trisetum*, *Triodia*, *Melica*, *Poa*, *Festuca*, *Panicum*, *Bromus*. Some of our species, even, have reached the southern extremity of the continent, *e.g. Phleum alpinum*, *Deschampsia flexuosa*, *Agropyrum repens*. The affinity of the South African grass-flora with that of Europe is also generic, not specific. A few British species are recorded, viz. *Calamagrostis epigeios*, *Aira caryophyllea*, *Phragmites communis*, *Kœleria cristata*, *Poa annua*, *Lolium temulentum*, *Avena fatua;* also *Hordeum murinum* about seaport towns; most of these, however, have been introduced.

Some of our grasses are indigenous to the mountainous regions of Australasia. In New Zealand, for example, *Alopecurus geniculatus*, *Hierochloe borealis*, *Agrostis canina*, *Deschampsia cæspitosa*, *Kœleria cristata*, and *Festuca duriuscula* are native, the last-named one abundant in the mountain pastures. Many British species have been introduced and become naturalized. The indigenous grasses of New Zealand number only 75 species.

The geographical distribution of the cereal grasses, *i.e.* those which are cultivated for the sake of the grain, is intimately associated with the history and civilization of mankind. Most of the cereals have been cultivated in the old world in times pre-historic, and their original habitat, or home, is largely conjectural. The cereals cultivated in greatest antiquity were wheat, spelt, barley and rice.

Small grains and ears of wheat have been found in very ancient Egyptian monuments, dating back to B.C. 2500–3000. Another variety of wheat with small grains was cultivated in Switzerland in the earliest stone age, abundant evidence of which is found in the remains of the lake dwellings. The cultivation of wheat is also very ancient in China, where an annual ceremony was instituted, B.C. 2700, of sowing five kinds of seed, wheat being one. It is probable that this grain was cultivated in Western Asia 2000–3000 years before that epoch, and that the Euphrates valley was then its principal habitat. The 200–300 varieties of wheat are referable to four races: *Triticum vulgare*, *T. turgidum*, *T. durum*, and *T. polonicum*, all of which are probably derived from a single species.

Spelt, as distinguished from the true wheats, has the ripe grain enclosed in the husk. Its numerous forms may be grouped under three names: *Triticum spelta*, *T. dicoccum* (with two grains in each little ear) and *T. monococcum* with a 1-grained ear. *T. monococcum* cannot be crossed with any other form of wheat or spelt,

being quite exceptional in this respect, although probably it was derived from a small-grained wheat in very remote times, and gave rise to the other forms of spelt. Spelt was most anciently cultivated in Eastern temperate Europe and the neighbouring countries of Asia.

Of barley, there are three principal forms or species: *Hordeum distichon* (two-rowed), *H. vulgare* (one-rowed) and *H. hexastichon* with six rows of grains in the ear. The last-named was the kind most commonly cultivated by the ancient Egyptians, and by the lake-dwellers of the stone age in Switzerland and of the age of bronze in Italy and Savoy. The only form now found wild is *H. distichon*, the least productive; it was cultivated by the Swiss lake-dwellers. *H. vulgare* seems to have been less cultivated in antiquity than either of the other species. *H. distichon* was probably the ancestral form, anterior to the time when the monuments were built by the ancient Egyptians.

Rice, *Oryza sativa*, was one of the cereals anciently cultivated in Southern Asia. In the Chinese ceremony already mentioned, great importance was attached to the sowing of this grain. Its cultivation in India dates at least from the Aryan invasion; spreading westward, it was cultivated in the Euphrates valley 400 years B.C., and reached Egypt in the early centuries of the Christian era. It was introduced into Spain by the Arabs, first cultivated in Italy in 1468, and twenty-five years later carried by Columbus to America. Rice probably existed before all cultivation in Southern Asia; there are now more than 100 varieties.

Maize, *Zea Maïs*, was unknown to the people of the old world until the discovery of America. It was then in cultivation over a very large part of that continent, and was the only cereal. The discovery of ears and grains of maize in the burial-mounds of North America (of the race preceding the present native race), and in the tombs of the Incas of Peru, is evidence that this grain was extensively cultivated in America in the early part of the Christian era; and from the numerous varieties of maize found in these monuments, it is inferred that it was in cultivation for a long period previous. Maize does not appear to occur anywhere in a wild state. Columbus brought it to Europe; it then spread rapidly eastward, and within half a century was diffused throughout South-east Asia and the East Indian Archipelago.

The cultivation of oats and rye is not so ancient as that of the other cereals, perhaps not earlier than the Christian era. The numerous varieties of the oat may be grouped under two species: *A. sativa* and *A. orientalis*. It is doubtful whether oats and rye (*Secale cereale*) occur really wild, though half-wild and naturalized forms are frequent in Eastern temperate Europe and Asia Minor—probably the original habitat.

Some of the millets (grasses with small grains) were cultivated in very ancient times. *Setaria italica* is one of the five plants whose seeds are sown in the observance of the Chinese ceremony, and its cultivation was very common in the temperate parts of the

old world in pre-historic time. It has been found among the remains of the lake-dwellings of the stone period, probably arriving there through Russia and Austria from China and Japan. The specific name is inappropriate. *Sorghum vulgare*, dourra or Kaffir-corn, and *Sorghum saccharatum*, Sweet-sorghum, are (with maize) exceptional among the cultivated grains in having been dispersed eastward; they are largely cultivated in tropical Africa and are probably native there, having spread from Egypt into Arabia, India, and China. *Panicum miliaceum* was cultivated in pre-historic time in Southern Europe, Egypt, and Asia; it grows wild south of the Caucasus. *Eleusine coracana* is largely cultivated in Southern Asia and the Malay Archipelago, where it is probably native.

For further information on this subject, refer to A. de Candolle's *Origin of Cultivated Plants*.

The geographical distribution of the cereals at the present day falls broadly into three zones or mighty girdles around the earth—a tropical, a north temperate and a south temperate. They are by no means sharply defined from each other, especially in the northern hemisphere, where a commixture of the tropical and north temperate zones extends over several degrees of latitude.

The broadest zone is that of the tropical grains—maize, rice and millets. Maize is distributed over 90° of latitude—45° on each side of the equator, including all the United States, Central America, and South America except the extreme southern part of the peninsula, the whole of the continent of Africa, the southern portion of Eurasia, all Malaysia, and Oceania. The rice belt is not so broad, as although in Europe its northern climatal limit coincides almost with that of maize, it is 10° nearer the equator on the continents of North America and Asia, and its southern boundary is similarly curtailed. Millets, most generally cultivated in Africa and Asia, have as wide a range of temperature as maize.

The northern zone of temperate grains—wheat, barley, oats and rye—has a breadth of 40° of latitude in the old world, but scarcely 30° on the American continent, because the extreme continental character of the climate prevents cultivation far northward. The polar limit is erratic. On the humid Pacific slope of North America it is probably near the 55th parallel, somewhat higher on the eastern side of the Rockies (which deprive the S.W. winds of their excessive moisture), falling gradually to 50° as we cross the continent to the Atlantic. In Western Europe it recedes to the 70th parallel (the effect of the warm Gulf-Stream), but excludes Iceland; in Western Siberia it approaches 60°, and in Eastern Asia falls to about 50°. The equatorial limit of the northern zone varies with the elevation of the earth's surface; in India it passes to the south of the Tropic of Cancer on the Deccan plateau; on the plains of the Western Continent it is a few degrees north of that line.

All the temperate grains can be grown within the tropics, at an altitude of 6–12,000 feet. In Abyssinia, for example, oats and barley grow up to 12,000 feet; maize to 9,000 feet. In Mexico, wheat and barley are grown on the temperate tablelands (*tierras templadas*) and in the cold mountain regions, in the latter at a height of 8,000 feet above the sea; maize is grown everywhere at the lower elevations. On the Andes of Chile and Bolivia, both temperate and tropical grains are grown in vertical zones, barley at the highest altitude, maize and rice at the lowest, wheat between. At 10,000 feet the climate is as well adapted for the growth of the temperate grains as it is "perfect for the European constitution."

The southern zone of temperate grains has for its boundaries the tropic of Capricorn and the 40th parallel.

We will now consider the distribution and cultivation of the cereals on each continent, taking Europe first. Barley, oats and rye are associated with pines and firs, and these grains reach their most northerly limit of culture in Scandinavia (by reason of the modifying influence which the Gulf Stream exerts upon the climate there), barley growing as far north as the 70th parallel, where uninterrupted sunshine ripens it in 90 days; oats to 68°, wheat to 63°. In Eastern Russia, where the climate is strictly continental (away from sea influences), the northern limit of these cereals is several degrees lower. Oats and rye are the grains most generally cultivated around the lower Baltic and in the northern part of the great central plain (in Germany and Russia), often in association with barley, sometimes with wheat. Wheat is associated with deciduous trees, and predominates all over Middle Europe—the northern half of France, S.W. Germany, the plains of Lombardy and Hungary, and in the 'black earth' region of Russia between the Carpathians and the Ourals. Barley, oats and rye here accompany wheat in varying proportions. The growth of grain on the Alps ceases at an altitude of about 4,000 feet, but on some of the southern slopes rye ascends 1,500 feet higher. Maize, associated with the vine and olive, comes into cultivation south of the 48th parallel, at first sparingly, then generally; wheat is grown everywhere in company with maize; on the other hand, rye, oats, and barley become minor crops the more as we go southward. Lastly, rice appears in the evergreen zone of Southern Europe, where there is sufficient irrigation, viz. the south of Portugal, the low-lying parts of Spain on the Mediterranean, and the valleys of the Po and Lower Danube. Rice is associated with such fruits as figs, oranges, grapes, olives, and almonds, whose thriving depends upon the mildness of winter and the high summer temperature enjoyed by this part of Europe, owing to its situation on the shores of a great inland sea and to the protection from cold N. and E. winds afforded by the Pyrenees, Alps, Carpathians, and Balkans. The chief cereals of Europe are wheat and rye; oats and barley come next; maize, rice, spelt and millets last. The countries having the largest acreage under a given cereal assume the following order: wheat, Russia, France, Italy, Hungary; oats, Russia, Germany, France; barley and rye,

Russia and Germany. France stands first among the wheat-producing countries of Europe, as, although this country has not nearly so large an acreage under wheat as Russia, the average yield is 17 bushels per acre. The wheat crop of France is 300,000,000 bushels; of Russia, 250,000,000; of Hungary, Italy and Germany, each from 120,000,000 to 150,000,000 bushels; Spain, 80,000,000. The wheat crop of Europe is close upon 1,400,000,000 bushels.

In the British Isles, wheat does not ripen at a greater elevation than 1,000 feet, while barley and oats are precarious crops at an altitude of 1,500 feet. A large part of the British Isles (all Scotland except the Lowlands, Ireland, Wales, and the West of England) is not so well adapted for the cultivation of wheat as of oats and barley, owing to excessive moisture brought by the prevailing Atlantic winds, and to the elevation of the surface. Oats and barley therefore predominate. In England, wheat, barley and oats are cultivated in nearly equal proportions, the acreage under each of these cereals being from $1\frac{3}{4}$ to 2 million acres; only 80,000 acres are devoted to rye. The acreage under oats in Scotland (1,000,000) is five times more than that under barley. Ireland has $1\frac{1}{4}$ million acres devoted to oats, while the proportion under barley is only one-eighth. In both Scotland and Ireland, the acreage under oats is 25 times more than that under wheat; rye everywhere a small crop. In Wales the cultivation of oats ($\frac{1}{4}$ million acres) is rather more than twice as large as that of barley, and five times greater than that of wheat. The wheat crop of the United Kingdom is about 60,000,000 bushels, the average yield per acre being about 30 bushels (highest in Scotland, 37 bushels). Oat-crop 180,000,000 bushels, average yield 40; barley 80,000,000 bushels, yield 34 bushels. A bushel of wheat = 60 lbs., of barley 50 lbs., of oats 39 lbs.

In Asia, the distribution of the cereals falls into zones of elevation rather than zones of latitude, except in the north, because the greater part of this continent, lying within the temperate zone, presents as its main physical features deserts of sand impregnated with salt, or extensive and lofty mountain ranges, and is therefore unfit for cultivation. The northern limit of grains in Siberia is the 60th parallel; rye and oats chiefly in the northern part, together with barley; wheat in the fertile plains of the south-west, mostly in the upper basins of the Obi and Yenisei, to the foot of the Altai range. Crops ripen with great rapidity in the higher latitudes, where in summer the sun is above the horizon for twenty hours each day; east of the Yenisei there is hardly any cultivation. The great desert belt (a continuation of the Sahara) stretches almost uninterruptedly from the Red Sea to the Pacific, through Arabia, Persia, Afghanistan, Russian Central Asia, and the great Gobi to Manchuria; the eastern half of it is almost totally destitute of cultivation: on the Iranian plateau wheat and barley are grown in the elevated parts; rice in the marshy lowlands, fertile valleys, and riverine tracts where irrigation can be practised, often in association with wheat, and sometimes with maize. The Persian wheat crop is about 20,000,000 bushels. In Asia Minor and Arabia

wheat, barley, and millets are grown mostly in the coastal regions. The wheat crop of Asiatic Turkey is about 45,000,000 bushels. In Caucasia wheat ascends to 6,500 feet, barley 1,500 feet higher; the lowlands on both sides of this range produce rice, maize, and wheat. In striking contrast to the great sterile belt is the extreme fertility of S.E. Asia, the monsoon region with periodic and abundant rains. In India, barley is largely grown in the Punjab and the north-west, while the cultivation of wheat "extends through every district of the North-West Provinces, Oudh, the Punjab, Sind, the Central Provinces, and Berar; also through every part of the Bombay Presidency, with the exception of some of the coast districts; it is also grown in many parts of the interior of the Madras Presidency." There are about 25,000,000 acres under wheat in India, and the yearly crop is 250,000,000 bushels. On the Himalayan slopes, the distribution in vertical zones is somewhat as follows: rice, up to 5,000–6,000 feet; wheat (often associated with maize and barley), up to 9,000–10,000 feet; barley ascending to 12,000 feet. The acreage under maize is only about one-twelfth that of wheat. Oats are little cultivated, and chiefly for the horses of Europeans. Rice is extensively cultivated throughout the continent, and is the staple crop in the Ganges delta, where two harvests are general, with an occasional third, but smaller one; the average yield per acre is 10–12 maunds (1 maund=82 lbs.). Most varieties of rice are semi-aquatic, but there are some which grow on the hillsides, ascending to 8,000 feet. Taking India as a whole, however, neither rice nor wheat is the predominant grain, but millets, of which there are a great many kinds, *e.g. Sorghum vulgare*, *Pennisetum typhoideum*, *Eleusine coracana*, *Setaria italica*, *Panicum miliaceum*, *P. miliare*, *P. frumentaceum* and *P. colonum*, *Paspalum scrobiculatum*, and *Coix lachryma*. The great plain of China, embracing the basins of the Hoang-Ho and Yang-tse-Kiang, is one of the vastest and richest lowland plains in the world, with a deep loess of inexhaustible fertility. In the northern part of this plain, wheat and millets predominate, associated in smaller proportion with barley and maize; in the central and southern parts, rice, often associated with wheat. Wheat- and paddy-fields often adjoin each other. The rice-growing tracts support the densest population in the world. Japan, with a climate greatly modified, like that of the British Isles, by a warm ocean current from the south, and with an abundant rainfall during the monsoon, produces rice and wheat as staples, the wheat-crop being 15,000,000 bushels. Millets, barley, and maize are minor crops. Throughout the Indo-Chinese peninsula, rice everywhere predominates, in the low, marshy, steaming plains, and in the valleys and deltas of the great rivers, the quantity produced defying computation. Rice is also the staple cereal throughout Malaysia, sometimes associated with maize.

The continent of Africa, like that of Asia, has an immense desert belt, the Sahara, where cultivation is impracticable; but in remarkable contrast is the extremely fertile delta of the Nile, with a deep alluvial soil annually inundated, and producing luxuriant

crops of rice, wheat, barley, maize, and dourra; the Nile wheat crop is 10,000,000 bushels. In the Barbary States, maize and wheat predominate, associated with millets, barley, and rice, in the low-lying Tell country, and on the northern slopes of the Atlas highlands; but there is very little cultivation in Tripoli. The Algerian wheat crop is 25,000,000 bushels. Taking Africa as a whole, the chief cereals are maize and millets, the latter mostly *Sorghum vulgare* (dourra or Kaffir-corn); rice is sparingly dispersed throughout nearly the whole continent, but is cultivated most largely in the Nile delta and low-lying coastal region of Senegambia and Guinea. The Soudan is a fertile belt producing maize, dourra, and rice. For Abyssinia, we have already mentioned the vertical zones of cereal cultivation; maize and millets are the staples of this fertile country. In South Africa, wheat, barley, and oats, are grown most generally south of the 30th parallel; maize (mealies) is everywhere the prevailing grain, yielding abundant crops. The temperate grains are now being grown on the Mashonaland plateau, lat. 18° S., which has an elevation of 4,500–6,000 feet above the sea, the mean annual temperature being 53° F., and the yearly rainfall thirty-four inches.

On the American continent, oats predominate in the eastern part of British North America, associated with barley and wheat; the yield averaging for oats and barley about 30 bushels, for wheat 17. Rye is very little cultivated. In the western part of the Dominion, which has a hotter climate, wheat predominates. Manitoba, with its famous wheat district of the Red River Valley, has 1,000,000 acres under wheat, 400,000 under oats, and about 100,000 under barley, the average yield being as above stated; rye a very small crop. The Canadian wheat crop is about 45,000,000 bushels.

In the United States, rye and barley, except in the Pacific States, are not much cultivated, but about 30,000,000 acres are devoted to oats. The United States wheat crop is 4–500,000,000 bushels, the average yield being 12. Maize is everywhere associated with wheat, from the Ottawa basin and the Upper St. Lawrence valley to the Mexican Gulf, maize always taking a long lead. The maize crop of Iowa, for example, is 350,000,000 bushels; oats, 120,000,000; wheat, 35,000,000. In Texas, the maize crop is 75,000,000 bushels; oats, 15,000,000; wheat, 8,000,000. Maize is by far the largest cereal crop in the United States—about 2,000,000,000 bushels of 60 lbs. West of the 100th meridian to the Pacific States (but excluding these and Utah) there is hardly any cultivation, owing to barrenness of the soil and lack of irrigation. In the Pacific States, which receive an abundant rainfall from the moisture-laden S.W. winds, wheat, oats, and barley are very extensively cultivated, wheat predominating especially in California (in the Great Valley between the Sierra Nevada and the coast range). The Californian wheat crop is 33,000,000 bushels; barley 16,000,000; maize, oats, and rye are much smaller crops. The rice-growing states are the Carolinas, Georgia, and Louisiana, the last-named producing by

far the most rice. In Mexico, Central America, the West Indies, and tropical South America, maize is the staple and in many districts the only cereal cultivated. In mountainous parts, however, the more temperate climate enables wheat and barley to be grown. In low-lying, well-watered localities, rice is cultivated, though not extensively. Paraguay has over 8,000,000 acres under maize, and 400,000 under rice. Uruguay produces about 5,000,000 bushels of wheat. Chile enjoys a cooler climate than the other South American States, by reason of its elevation and the influence of the cold Antarctic Drift current; the cultivated region is a long upland valley between two snow-clad cordilleras of the Andes, wheat predominating especially in the southern part, associated largely with barley. The wheat crop of Chile is 16,000,000 bushels.

"The region of cereals of the Argentine Republic may roughly be described as extending from latitude 30° to 41° south, and is bounded westwards by longitude 65°, and eastwards by the River Uruguay and Atlantic coast; or, in other words, this region includes roughly the three provinces of Santa Fé, Entre Rios, and Buenos Ayres, and the eastern portion of that of Cordova. In the greater part of this immense plain wheat will grow satisfactorily without artificial irrigation. But south of latitude 41° and west of longitude 65° rain does not come regularly enough." With irrigation, wheat and other crops could be grown even much further south, as is shown by the satisfactory crops of the Welsh Chubut colony, in latitude 43° south. The possible area of cereal cultivation in Argentina, without irrigation, is estimated to be upwards of 200,000,000 acres, of which not more than 5 per cent. is as yet touched, but a large proportion is only suitable for maize. The chief cereal in the province of Buenos Ayres is maize, its crop being more than half the total quantity produced in the Republic; wheat is the predominant grain in Santa Fé, this province producing more than half the wheat crop of Argentina. Barley and rye are minor crops. Rice is grown in the northern parts of the Republic bordering on the tropics. The wheat export of Argentina in 1892 was 17,000,000 bushels; in 1893, 37,000,000; in 1894, 60,000,000; local consumption, 20,000,000.

On the continent of Australia cereal cultivation is almost confined to the coastal regions and the fertile plain of the river Murray. The mountain range in the east cuts off the rainfall brought by the prevailing S.E. winds, so that the interior consists mostly of sandy saline deserts. Maize is extensively cultivated on the north coast (chiefly around the Gulf of Carpentaria) and on the east coast, associated in some parts with rice; in tropical Queensland, maize, various millets, and a little rice; wheat only in the southern half of the colony, with maize and a small proportion of barley and oats; but wheat is a very precarious crop, the yield per acre in some years of drought being as low as 3 bushels, in others, 20. Maize thrives best, giving a heavy yield; in the northern part, two crops a year. In New South Wales wheat predominates, the acreage under this cereal being twice as large as

that under maize; but the yield per acre of maize is as large again as that of wheat. In Victoria and South Australia also, wheat is the leading crop, oats and barley coming next at a great distance; maize, sorghum and rye very small crops. The yield per acre of wheat in Victoria is 14 bushels, in South Australia only 7–8 bushels. In Western Australia (south of the 29th parallel) wheat predominates, barley, oats, and maize coming a long way behind; average yield of wheat, 11 bushels. In Tasmania wheat is the leading crop, then oats; barley insignificant; the average yield per acre is variable, but normally nearly as high as in New Zealand. In the latter colony the proportions (but not the acreage) of land under these three cereals were until recently about the same as in Tasmania, oats following close upon wheat; but now there is more land under oats than under wheat; the yield per acre is, wheat, 20 bushels, oats, 30, barley, 25; rye is cultivated in some parts. The cultivation of maize in New Zealand is confined to the North Island, the mean annual temperature of which is 57° F.; wheat, oats, and barley are grown principally in the South Island, which has a mean annual temperature of 52°—only 1° above that of London and New York. The long periods of drought, to which the Australian colonies are subject, are unknown in Tasmania and New Zealand. It will be noticed that the oat is as important a cereal in these two colonies as in the cold temperate regions of the northern hemisphere. The Australasian wheat crop is about 40,000,000 bushels.

The world's wheat crop is estimated to be 2,400,000,000 bushels.

CHAPTER V

Uses.

FOR manifold uses, and for the universality and supreme importance of some of these uses, more especially in relation to the food of man and beast, the *Gramineæ* are pre-eminent among all the families of plants. Claiming our consideration first is the use of grains for human food.

That grains were an important article of food in prehistoric times we have seen by the antiquity of their cultivation: at the present day, they are the food-staple of more than four-fifths of the human race. No doubt grains were used as food long before cultivation; they are still gathered in some countries from various species of wild grasses. The most primitive method of preparing grains for food appears to have been roasting or parching them, either whole or partially bruised, in glowing ashes or hot sand, or upon hot stones. At a later period, boiling the grains became the universal mode of preparation. From biblical writings (Gen. xviii., xix.), we learn that leavened and unleavened bread was made in very early patriarchal times; the ancient Egyptians baked loaves and cakes, and taught the art to the Greeks.

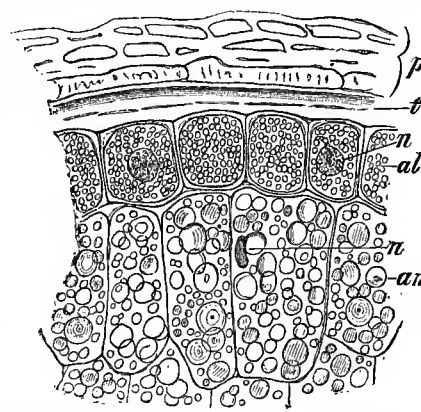

FIG. 40.—Cross-section of part of a wheat grain (× 240): *p* pericarp; *t* testa; remainder endosperm, consisting of *al* aleurone grains in one layer of squarish cells, and *am* starch grains in large rectangular cells; *n* nucleus.

We may consider a grain of wheat, in its structure and composition, as typical of all the other grains. In a transverse section, highly magnified (fig. 40), we see that the interior portion consists of large oblong or rectangular cells filled with numerous granules, some large, others small, with few of intermediate size;

these are starch granules. Outside the mass of large cells is a single layer of squarish cells, containing minute granules of uniform size, known as aleurone grains. Isolated cells of aleurone grains sometimes occur in the central mass of the grain. Investing the row of squarish cells are several very thin fibrous layers which constitute the testa and pericarp, or, in popular language, the skin of the grain. The starch granules, it is hardly necessary to remark, belong to the group of carbohydrate nutrients (heat and force producers); the aleurone grains are highly complex bodies belonging to the group known as proteids or albuminoids (flesh formers), the essential characteristic of which is, that nitrogen enters into their composition. The fibrous layers consist largely of cellulose, indigestible by man, but contain a considerable quantity of oil and mineral matter, the latter chiefly potash and phosphoric acid. The embryo (fig. 1) is rich in all the nutrients. The composition of an average sample of wheat grains is, in 100 parts: water, 14; albuminoids, 12; starch (including about 4 per cent. of dextrine and sugar), 68; fat or oil, 1·7; salts, 1·6; cellulose, 2·7. The sum-total of the nutrients, or nutrient value, is 84 (the oil being expressed in its starch equivalent, 1 part oil = $2\frac{1}{3}$ parts starch). The most important consideration in these percentages is the proportion of albuminoids to carbohydrates and fat; in the above analysis this proportion, or nutrient ratio as it is often termed, is 1:6; in other words, to one part of flesh formers, there are six parts, by weight, of heat or force producers; the nutrient ratio of a standard dietary is 1:$4\frac{1}{2}$. The principal variation in the composition of different kinds of wheat is in the proportion of albuminoids to starch, the former oscillating between 10 and 16 per cent., or even higher in the horny translucent wheats of warm dry climates.

The large amount of starch in the cereal grains gives them a high dynamic value as a food substance. 1 lb. of the crumb of bread, if digested and oxidized in the human body, is capable of producing an amount of force equal to 1333 tons raised one foot high; the dynamic value of wheaten flour, according to Frankland, is 2383 foot-tons; the great difference between these figures is of course owing to the large percentage of water in bread. It is instructive here to compare the dynamic value of some other well-known foods, *i.e.* the amount of energy that 1 lb. will yield: that of pea meal is 2341 foot-tons; fish (mackerel), 1000; potatoes, 618; milk, 390; egg (hard-boiled), 1415; lean of beef, 885; beef-fat, 5640; butter, 4507; the high dynamic value of the last two articles of food being due to the superior heat- or force-producing power of fat, as compared to starch. But when we take into account the cost of these various articles of food, we find that for a given expenditure of money a larger amount of force or energy can be obtained from the cereal grains than from any other kind of food. For example, to raise 140 lbs. to the height of 10,000 ft., 1 lb. of pea meal would be required, costing 4*d.*; or of butter, $\frac{1}{2}$ lb. = 7*d.*; or potatoes, 5 lbs. = 3*d.*; or mackerel, 3 lbs. = 1*s.* 7*d.*; or milk, $6\frac{1}{2}$ pints = 1*s.* 1*d.*; or beef-fat, $\frac{1}{2}$ lb. = $4\frac{1}{2}$*d.*; or lean of beef, $3\frac{1}{2}$ lbs. = 3*s.*; or 1

lb. of wheaten flour, costing only 1*d*. The amount of *external* work that 1 lb. of bread will enable a man to perform is 267 tons raised one foot high, a fair day's work for a labourer being 2 foot-tons per lb. of his body weight. The amount of dry muscle or flesh that can be produced from 1 lb. of bread is about $1\frac{3}{4}$ oz.

Wheat takes precedence of all other cereals as a bread grain, and this is chiefly owing to the glutinous nature of a large proportion of the albuminoids. When carbonic acid gas is introduced into the dough, either by means of fermentation or aeration, the elastic gluten impedes the escape of this gas, and causes it to accumulate in bubbles; the innumerable small cavities thus formed in the dough are fixed by the heat of the oven, and the result is a light, spongy bread. Dough made from the other grains which lack this glutinous property will not rise properly, and therefore makes a heavy bread, or can only be made into cakes. The various processes of milling which the wheat-grain undergoes considerably modify the percentages above given, particularly in the modern roller mills where the operations of grinding and sifting are repeated many times in order to produce a snow-white and almost impalpable flour. During these operations, as will be readily understood on reference to fig. 40, numerous mill-products are obtained—fine and seconds flour, middlings, sharps, pollard and bran; these products having each a different chemical composition and food-value. In the production of the finest flour, this system of high milling eliminates every particle of the coats of the grain as well as the embryo. The removal of the embryo, because its presence would give a yellowish tinge to the flour, is unjustifiable; this is the most nutritious part of the grain, the percentage of albuminoids and diastase in the embryo being 35; oil, 13; mineral matter, 5·5; more than half of the last-named being phosphoric acid, a nutrient of bone and brain. As a result of milling wheat, 75 per cent. of white flour is obtained, and the offal (sharps, pollard and bran) amounts to about 23 per cent. Seconds flour is richer in nutrient matters than the finer grades, the latter containing 2 per cent. less albuminoids than are present in the grain, and about 5 per cent. more starch, while the percentage of oil and salts is in each case reduced to ·8. Bread made from fine wheaten flour contains about 40 per cent. of water, 7 per cent. albuminoids, about 50 per cent. starch, and $1\frac{1}{4}$ per cent. salts (including table salt). Whole meal, only the outermost coat of the grain having been removed, contains all the nutrients of the grain, but also a considerable amount of indigestible cellulose. A finely-ground flour, containing the embryos, but no portion of any of the coats of the grain (this is known in the trade as germ-flour), makes a perfect bread, well vesiculated, sweet, and with a delicate aroma; it keeps moister than bread made from ordinary flour, and is of course more nutritious. 380 lbs. of bread can be made from a 20 stone sack of flour. Macaroni is prepared from the horny wheats of Southern Europe; it is more highly nitrogenous than bread. Semolina consists of the coarse particles of the interior of the grain. The

yearly consumption of wheat in the United Kingdom is about 240 million bushels, three-fourths of which (valued at over £30,000,000) are imported.

Rice is computed to be the staple food of one-third of mankind, and the yearly produce in India, China, and Japan is roundly estimated at 100,000,000 tons. Paddy is the grain in its husk, and the product of milling paddy is the pearled grain familiar to us. A considerable quantity is ground into flour for making puddings, cakes, etc., but the universal method of preparing the grains for food, in all parts of the world, is boiling them. The nourishing constituents of rice are in 100 parts: albuminoids, 7·4; starch, 76; fat, 0·7; salts, 0·5; the nutrient ratio being 1 : 10½, nutrient value 85. The rice-consuming peoples of the East invariably use this grain in combination with some other highly nitrogenous food (beef, mutton, fish, eggs, pulse), which compensates the deficiency of rice in albuminoids and oil, experience having taught them what Europeans have discovered by chemical analysis. Old rice is more digestible than new; the neutral flavour of this grain renders it especially suitable for combination with other kinds of food.

Maize stands in the same important relation to the inhabitants of the new world as wheat does to those of Europe, and rice to those of Southern Asia. Maize is used as human food in various forms: the grains may be broken or split (hominy), or pearled (samp), or roasted until they burst and the starch becomes everted (popcorn), or they may be parched. The usual method, however, of treating this grain is to grind it into meal. Mush, or "corn" meal boiled, is a universal article of diet in the United States, nutritious and easily digested. Ground maize cannot be made into bread, owing to its lack of viscidity when moistened, unless mixed with wheaten flour in about equal proportions. In Mexico, Central and South America, it is baked into thin cakes. The average composition of maize is, in 100 parts: water, 14; albuminoids, 9·2; starch, 68; fat, 5; salts, 1·8; cellulose, 2. So it is poorer than wheat in flesh-formers, but contains more oil than any of the other grains, oats excepted; it has a high nutrient value, namely 88. Various preparations of maize sold in this country as corn-flour, maizena, etc., are used for puddings and blanc-mange, but as they are largely adulterated with starch, the percentage of albuminoids is very low.

One of the most nutritious cereals is the oat. The grains are prepared for human food by being kiln-dried, husked, and ground into meal which is used in the form of porridge and cakes. Oaten flour lacks the glutinous property necessary in a bread grain. The nourishing constituents of oatmeal are, in 100 parts: water, 10; albuminoids, 14; starch, 65; fat, 7; mineral matters, 2; the nutrient ratio being 1 : 5¾, nutrient value 95, or even 100 in some samples. Oatmeal is richer in nitrogenous matters than wheat (the horny varieties of wheat excepted) and is richer in fat than any of the other grains; it therefore approaches more nearly to the composition of a perfectly adjusted food.

Barley, largely used as food by ancient peoples, has now given

place to wheat in most countries. Only a very small proportion of the barley grown in Britain is milled, the products, pot and pearl barley, being used for soups, puddings, etc. Barley is deficient in albuminoids or flesh formers, the nutrient ratio being 1 : 12; the percentages of fat and salts, and the nutrient value, are about the same as in wheat. In some countries barley-flour is mixed with wheaten flour for making bread. Rye-flour makes a dark-coloured, heavy and sourish bread (black bread) or cake, which is the staple food in many parts of Scandinavia, Germany and Russia; it is inferior to wheat in fat, nitrogen, and salts; the nutrient ratio being 1 : 9. The millets are an important food in Southern Asia and tropical Africa; in India they dispute with rice the first place as a vegetable food; some of them are equal to wheat in nutrient constituents, and they usually contain a larger percentage of oil.

Manna kroup, the grains of *Glyceria fluitans*, decorticated and partly crushed, is an article of diet in some parts of Northern Europe. The grains of *Zizania aquatica*, Canadian rice, abundant by streams and lakes in North America, are gathered by the Indians for food.

We have now to consider the cereal grains as the source of the commonest of our food-adjuncts, namely alcoholic beverages. Various kinds of grain are used for the manufacture of fermented drinks; barley is largely used for this purpose in our own country; rye in Russia, maize in America, rice in Japan; some of the millets, too, are used in this way. In the manufacture of beer, the grains are first malted in order to convert the insoluble starch into soluble dextrine (a kind of gum) and ultimately into maltose or sugar, the formula for this chemical action being

$$\underset{\text{(Starch)}}{C^6H^{10}O^5} + \underset{\text{(Water)}}{H^2O} = C^6H^{12}O^6$$

glucose or grape sugar. The maltster causes the grains to germinate for 10 or 12 days, so that a large amount of the starch is dissolved by the diastatic ferment of the cotyledon; he next dries them in a kiln, during which operation a portion of the starch not hitherto acted upon is transformed into dextrine. Only a very small proportion of the proteids is rendered soluble. The plumule and radicle (coombs) are removed, and the screened grain (malt) is ready for the brewer. In the process of brewing, the malt is crushed and infused in hot water (mashed) in order to extract all the soluble constituents; the resulting liquor, called wort, is boiled with hops; fermentation, the next process, takes place to a limited extent, part of the sugar being changed into alcohol and carbonic acid gas, the latter imparting briskness to the beer. One quarter of malt will make 3 barrels of ale (108 gallons). 125,000,000 bushels of barley are annually used in the United Kingdom, mostly for malting and distilling; half of this quantity being imported. Saké, prepared from rice, is the national alcoholic beverage in Japan; one bushel of rice yields 10 gallons of saké.

For the manufacture of spirits, barley, oats, maize, rice, wheat and rye are all employed, but more especially the three first named. The saccharine liquor obtained from these grains, by the conversion of starch into sugar, is by the distiller fermented to the utmost extreme in order to produce as much alcohol as possible, the chemical equation of this fermentative change being

$$\underset{\text{(Glucose)}}{C^6H^{12}O^6} = \underset{\text{(Alcohol)}}{2C^2H^6O} + \underset{\text{(Carbon dioxide)}}{2CO^2}.$$

The enormous quantity of carbonic acid gas evolved is allowed to escape, and the alcohol is separated from the fermented liquor by means of retorts, the vapour that is given off consisting mostly of the more volatile alcohol. 18 gallons of proof spirit (containing 49¼ per cent. of alcohol) can be manufactured from one quarter of barley. Whiskey and gin are for the most part manufactured from this grain, the gin being flavoured with oil of juniper berries or with turpentine. Maize is used most commonly in the United States distilleries, and now largely in this country. 70 million bushels of maize were imported into the United Kingdom last year, valued at £8,000,000. Glucose, prepared from maize by means of a weak solution of sulphuric acid, is now very largely used for strengthening the wort; cane sugar ($C_{12}H_{22}O_{11}$) is used for the same purpose. The juice of the sugar-cane, or more correctly the molasses, a bye-product in the manufacture of sugar, is most generally used for the distillation of rum. The molasses obtained from 100 tons of cane yield by distillation about 20 to 25 gallons of alcohol. Only a very small quantity of the spirits manufactured is used for other purposes than as a beverage. Vinegar is largely manufactured from the fermented liquor of various grains, the alcohol being converted by oxidation into acetic acid.

For our supplies of sugar we were, until recent years, almost entirely dependent upon the grass family; now more than half the quantity of sugar manufactured is obtained from beet. Sugar is present in considerable quantities in the stems of some grasses, notably in those of the sugar-cane (*Saccharum officinarum*), the sap or juice of which contains about 21 per cent. of sugar. *Sorghum saccharatum*, Chinese sugar-grass, yields about 13 per cent. of sugar, and is cultivated in China, and to some extent in Southern Europe, America and Australia. The stems of maize also yield sugar, but the quantity, 7 per cent., is too small to make its extraction profitable. The cultivation of *Saccharum officinarum* is very general in tropical and subtropical countries, and is in many parts the staple industry. This is a handsome grass with culms 10 or 12 feet high, leaves 3 or 4 feet long, and a feathery panicle; it is perennial, and continues productive for 10 or 15 years; it is probably indigenous to India, Cochin China, and the Malay Archipelago, and has spread westward; it reached Europe about the 12th century, the Canaries in 1503, San Domingo 1520, and was well established in America by the middle of the 16th century. The culms or "canes" are cut when about to flower, the yield

being about 20 tons to the acre. The ordinary method of expressing the juice, by crushing the canes between rollers, has now largely given place to the superior diffusion process, the canes being sliced into very thin transverse sections, and these placed in tanks through which hot water is made to circulate until the saccharine matter is entirely dissolved out. The yield of juice from crushed canes varies from 70 to 85 per cent. The juice is boiled down, and raw or brown sugar obtained by crystallization, the uncrystallizable residue being molasses. 100 tons of cane yield 6 or 7 tons of raw sugar, or more, according to the efficiency of the process. The dark-brown colour of this raw sugar is due to each crystal being coated with a film of mother liquor containing various impurities. The elimination of the latter is effected in the refineries, either in the country of production or consumption, the raw sugar being dissolved, purified, and then recrystallized in vacuum pans at a low boiling temperature to avoid the formation of uncrystallizable glucose; the crystals finally obtained are dried in centrifugal machines. Loaf sugar and the large dry crystals are almost quite pure; the moist brown contains a considerable quantity of syrup and is therefore inferior in quality. The liquid residuum of the refining process is treacle or golden syrup, which contains about 35 per cent. of true sugar and 30 per cent of glucose or grape sugar. The world's production of cane-sugar is about 3 million tons, of which 1,300,000 tons come from the West Indies (the Cuban crop being 900,000 tons, valued at £12,000,000); 320,000 tons are produced in Java, while India, China, Manilla, the United States, Guiana, Brazil, Mauritius, and Natal, produce each from 100,000 to 200,000 tons; Egypt, Argentina, Peru, Mexico, Reunion, the Sandwich Islands, and Australia (principally Queensland), 30,000 to 60,000 tons each.

What the cereal grasses are to man, the pasture grasses are to one of the largest and by far the most important of all the groups of the *Mammalia*—the *Ungulata*, or hoofed animals—comprising the equines, and especially the ruminants, namely, oxen, sheep, goats, and antelopes, the *Cervidæ* or true deer, the camel, and llama, which feed almost exclusively upon the herbage of grasses. Various other animals subsist more or less upon grass, *e.g.* some of the marsupials and rodents, and even some of the larger avifauna, such as the struthious and anserine birds; many of the smaller birds feed to some extent upon seedling grasses. The utility of grasses for forage is of course paramount in relation to the domesticated animals which are of greatest service to man, and which, under his especial care, have so greatly multiplied as to far outnumber all other large mammalian forms. The ruminants, or animals which chew the cud, having a compound stomach peculiarly adapted to the digestion of grass-herbage, also an alimentary canal of unusual length, it is this physiological adaptation to environment, namely, an exceeding abundance of grass-herbage, which enables man to rear these animals in such immense numbers,

since they obtain their food for the most part without the necessity of his labour to provide it. The numbers of cattle and sheep which subsist on the vast natural pastures of the world are beyond conception. Of sheep and cattle in our own country there are respectively 30,000,000 and 11,000,000, and very much larger herds and flocks are reared in the United States, the Argentine Republic, and the Australasian colonies. An American writer tries to convey an idea of the number of cattle in the state of Kansas, by stating that if they were all destined for the supply of the city of New York, and were started five abreast, the heads of one rank being just a rod in advance of the next, and they were driven through Missouri, Illinois, Indiana, Ohio, Pennsylvania, and the Empire State, the head of the herd would be crossing Haarlem river before the tail of it had crossed the Missouri at Atchison. 100,000,000 sheep are pastured in Australia (half of them in New South Wales), and 18,000,000 in New Zealand. The live stock of Argentina is estimated to be 25,000,000 cattle, 80,000,000 sheep, and 5,000,000 horses.

The British grasses available for pasturage are few in comparison to the total number of our species. *Alopecurus pratensis*, *Festuca pratensis* and *Lolium perenne* are the three most valuable meadow grasses; they produce a large quantity of nutritious leaves and succulent stems, and are especially suitable for making hay. *Festuca duriuscula* is an excellent bottom-grass, producing abundance of tender foliage. *Poa pratensis* and *P. trivialis* are also valued meadow grasses, the former is particularly esteemed in the United States, where it is known as Kentucky Blue-grass. *Dactylis glomerata* and *Phleum pratense* produce a large amount of nutritious herbage, though rather coarse; the latter yields much heavier crops in North America than in England. *Trisetum flavescens* has only slender foliage, but is relished by cattle. *Arrhenatherum avenaceum* occupies an inferior place to other grasses in our own country, but is largely grown in the United States for its abundant yield. *Anthoxanthum odoratum* is esteemed for the fragrance it imparts to hay. *Cynosurus cristatus* and *Festuca ovina* are the sheep grasses *par excellence*. The latter grows abundantly in hilly districts, and is the chief constituent of the Highland pastures; mutton fed upon it is superior both in flavour and quality. *Agrostis alba*, var. *stolonifera*, fiorin-grass, yields a heavy crop in spongy soil and irrigated meadows. The composition of meadow-hay is, approximately, in 100 parts: water, 16; albuminoids, 13; fat, 1·5; carbohydrates, 40; ash, 6·0; remainder fibre;—of pasture: water, 78; albuminoids, 3·7; fat, 0·4; starch, etc., 10·2; mineral matters, 2. 28,000,000 acres are under permanent pasture in the British Isles, 6,000,000 of this for hay. This is exclusive of grasses sown under rotation, usually in combination with other forage plants. *Lolium perenne* is grown as a self-crop. The cereals are often cultivated as green crops for feeding cattle, more especially in countries where dryness of the climate makes the natural pasturage scanty.

The grains of the cereals are largely used to supplement the

forage of domesticated animals—the oat, for example, is chiefly cultivated for feeding horses; maize, and any kind of damaged grain, the offal of the flour-mills (sharps, pollard, and bran), the spent grain from breweries and distilleries, also the coombs, are all utilized as cattle-food, often in combination with the straw of the cereals. The grains of wild grasses are largely eaten by some kinds of birds, especially the *Gallinæ* or game birds, the *Columbidæ* or pigeons, various waterfowl, and the large family of the finches (*Fringillidæ*) which have a short conical beak adapted for crushing hard seeds and grains. Mill-products, millet-grains (chiefly *Setaria italica*, *Sorghum vulgare*, and *Panicum miliaceum*), and maize-meal, are commonly used for feeding poultry. *Phalaris canariensis* is cultivated in the south of England, on the continent of Europe, and in North Africa, for the grains known as canary-seed, used for feeding cage-birds.

Before dismissing this subject of the utility of grasses in furnishing food for man and the animals he has domesticated, we shall do well to pause for a little reflection upon its relation to the industry, commerce, and wealth of nations, as well as to man's subsistence—our dependence not only upon the cereal grasses for our staple vegetable food, but indirectly upon the forage grasses for our supplies of animal food, viz. beef, mutton, venison, and dairy produce, as well as for various animal substances such as wool and hair, hides and skins, bone and horn, oil and tallow, used for textile and other manufactures (notably woollen fabrics and leather), or for domestic purposes—the large proportion of the world's inhabitants engaged in agricultural (chiefly cereal cultivation) and pastoral pursuits; in some countries 70 to 90 per cent. of the adult male population—the vast internal and foreign trade connected with the distribution of agricultural produce by land and sea—the numerous and important industries concerned in operating upon one or other form of this produce in order to prepare it for consumption; and lastly, the enormous capital employed in all these industrial activities, and the consequent accumulation of wealth. It is only when we take a comprehensive survey, such as we have indicated, that we are able to form some conception of the transcendent importance of the *Gramineæ*.

The uses of grasses in the arts and manufactures, other than the manufacture of sugar and fermented drinks, though not for a moment to be compared to their utility as a source of food, are nevertheless very numerous, and in some cases important.

The stems and leaves of various grasses are utilized for the manufacture of paper, the particular species so employed depending chiefly upon the locality of the manufacture; rye straw, for example, is largely used in Germany; the stems of maize most extensively in the United States, and to a limited extent the leaves of *Saccharum officinarum* and the stems of *Zizania aquatica*; various species of bamboo, chiefly the young shoots, are used in the Indian and Chinese paper-mills, also the stems and leaves of

Saccharum sara and *S. munja*. In our own country, the paper-making material of gramineous origin most commonly employed is the leaves of alfa-grass or esparto, *Stipa* (*Macrochloa*) *tenacissima*. The preparation of pulp from these raw materials consists essentially in the separation of the prosenchyma and the disintegration of the fibrovascular bundles, since it is the individual fibres which, in the process of paper-making, interlace to form a tough felt. This disintegration and the resolution of the fatty, resinous, and silicious matters is effected by boiling in a 10–20 per cent. solution of caustic soda. Straw is largely used for making paper and *papier mâché* in many countries because of its cheapness and the white pulp it yields. In the United States it is extensively used for the manufacture of straw-boards, being first made into stout paper, and then successive layers of the latter glued together and compressed by hydraulics. Coach panels, railway and tramcar wheels, perforated chair seats, etc., are made of strawboards; they are also used for building purposes—sheathing in place of laths and plaster and, when waterproofed, for roofing. Esparto is superior to straw for paper-making; the fibrovascular tissue of its leaves is much more readily isolated than that of straw, the hard nodes of the latter requiring more drastic treatment, which tends to diminish the yield of pulp and to weaken the fibre. The yield of cellulose from esparto is 45 per cent., and it is used either alone or in combination with straw, rags, wood, etc., according to the quality of paper desired. Esparto paper is esteemed by printers for its smoothness, opacity, and mellowness. Esparto grass grows abundantly on the sandy coasts of North Africa (in Algeria, Tunis, and Tripoli), and on the Mediterranean coast of Spain; it is estimated to cover 15,000,000 acres in the plain of the Shotts at the southern foot of the Atlas, growing in and around the marshy lakes; it is the most important article of export from Algeria, but is not at all cultivated. The leaves are rigid, involute, and clothed with microscopic hairs, some of which survive the pulping process and therefore characterize the paper. The fibres are $\frac{1}{16}$ of an inch long, ratio of length to diameter 125; straw fibres have similar dimensions. Esparto grass was introduced into England as a paper-making material 40 years ago, the Ford Works, near Sunderland, being the first to employ it extensively. The quantity annually brought to the United Kingdom is now upwards of 200,000 tons, valued at about three-quarters of a million sterling; three-fourths of it come from Africa, the remainder from Spain. Young bamboo yields an excellent fibre, but the cost of transport precludes its importation into England.

Cordage is made in some countries from the stems and leaves of grasses; in Spain the manufacture of ropes and cables from the leaves of esparto-grass is an important industry; these cables are so buoyant as to float on the water, and are used by the Spanish navy. In the countries of the East the young stems of bamboo are split lengthwise into shreds, which are pounded until soft and made into ropes and string; in India the leaves of *Saccharum*

sara and *S. munja*, 6–8 feet long, are twisted into ropes, which are valued for their elasticity, strength, and resistance to the action of water.

The miscellaneous and mostly native uses to which grasses are applied are exceedingly numerous and varied. The bamboos excel all other grasses in this respect, being employed for every conceivable purpose. In the countries where bamboos abound they furnish the material most generally used for building houses, the stronger stems for posts, rafters, etc., the thin stems (either whole or split) for making floors and walls, thatching, matting, etc. Three-fourths of the houses in India are made entirely of bamboo, and there is hardly a domestic article in India, China, or Japan that is not made entirely or partly of this material. Elegant furniture, beautifully mottled, and taking a high polish, is made of the stems of bamboo, and is now largely imported into Europe. The lightness, strength, and flexibility of bamboo-stems, and their resistance to the action of water, make them peculiarly adapted for many purposes which nothing else could so well serve; for example, bridges, light scaling-ladders (the stems being notched at the sides), which can be carried much more easily than ladders of heavier wood, masts, yards, and oars of boats, rafts, poles of palanquins, etc., lance shafts (*Dendrocalamus strictus* and one or two allied species with solid stems, known as male bamboos, are most commonly used for this purpose), bows, arrows, quivers, clubs, walking sticks, fishing rods. Split bamboo is now largely used in Europe for making fishing rods. The Indians of the Orinoco and Upper Amazon use the stem of a bamboo (*Arthrostylidium Schomburgkii*) as a blow-pipe for their poisoned arrows; the lowest internode, 12 to 16 feet long, with a diameter of 1½ inches, is the part used. Bamboo stems are also used for scaffolding, for making various agricultural implements, and vehicles of every description. Thorny bamboos, when growing, form an impenetrable stockade. The stems of some species are so hard and flinty that they serve as a whetstone, and thin chips of the hard outer portion of the stems are used by the Indians as knives, as well for ordinary purposes as for arming the bottom of pits dug to ensnare wild animals. Owing to their buoyancy, bamboo rafts are very largely used for floating heavier timber down the rivers. Portions of the stems are used for an infinite variety of purposes; when cut into short lengths and the nodes removed they make water-pipes. An internode, together with a node, makes a receptacle for all kinds of small articles, and also serves as a pitcher, or a bottle, or a drinking vessel, and as a trade measure for both liquids and solids. Pieces of thick bamboo, 3–6 ft. long, with the partitions perforated, are used by the hill watermen of India; water can be carried in these long tubes for days without becoming warm or in any way deteriorating. In the internodes of the green stems fresh flowers can be conveyed for hundreds of miles without withering; the eggs of the silkworm were brought in bamboo stems from China to Constantinople in the time of the Emperor

Justinian. Ornamental trinkets, in many instances exquisitely carved, are made by the Indians and Chinese of portions of the thick stems ; also musical instruments, flutes, etc. In the Malay peninsula a curious Eolian harp is made of the live bamboo of a village clump or distant jungle ; the culms are perforated in such a way that when the wind blows through them sounds are produced, "at times soft and liquid like the notes of a flute, and again deep and full like those of an organ." The thin stems, or the larger ones split into shreds, are almost universally used in the East for basket-work, and for making mats, brooms, brushes, window- and sun-blinds, shoes, etc. When bitten into fibres they are woven into a durable fabric for making coarse clothing, sacking, etc. ; the body-cloth of the natives of Celebes is so made. Mats made of the split stems are used all over the East for walls, floors, screens, etc. ; in some of the northern parts of India the houses are almost entirely constructed of these mats, *Bambusa Tulda* being the species most frequently used. The Chinese use the leaves of bamboo for lining their tea chests. The tender shoots of bamboo, either cooked or pickled, are used as food both in India and China, and are cultivated for this purpose. The grains of bamboos furnish immense quantities of food when a general flowering takes place, but this is only at intervals of a great many years ; on some occasions this has prevented a famine. The twigs and leaves of bamboo are largely consumed by the Indian elephant, both wild and domesticated. The uses of bamboo for cordage and paper-making have already been mentioned.

A great many kinds of grasses besides bamboos are applied in different countries to one or other of the uses above-named. Baskets, mats, etc., are made of the culms of *Ammophila arundinacea*, *Elymus arenarius*, and the leaves of *Stipa tenacissima*. The culms of *Arundo donax*, a cane-like grass, 8–10 feet high, native of Southern Europe, are used for walking-sticks, measuring rods, musical pipes, etc. The fragrant roots of *Andropogon muricatus* (cuscus roots), abundant in India, are softened and woven into mats, which are hung over doors and verandahs, and sprinkled with water to scent and cool the heated atmosphere ; they are also largely used for making fans. The roots of another species of *Andropogon* (*A. gryllus*), grown in the south of Europe, are largely imported into Britain for making toilet and other brushes. The roots of *Cynodon dactylon* are used in some parts of India for feeding domesticated animals. The roots of *Agropyrum repens*, the worst weed of British husbandry, when boiled are a nutritious food for swine. In the United States the panicles of *Sorghum vulgare* and *S. saccharatum* are used for making brushes and carpet-brooms, which are very durable, and some are imported into England. The leaves of the larger kinds of grasses are often used for thatching, those of the sugar-cane, for example, in the countries where it is cultivated. The culms of *Phragmites communis* are applied to this and other uses in the fen district of England ; in the early centuries they were used for making pens. The crushed

stems of the sugar-cane (megasse) serve as fuel for the furnaces of the sugar plantations. The straw of the cereal grasses is extensively used for straw plaiting for bonnets, hats, etc., retaining its natural polish for an indefinite time, the culms of *Triticum spelta* (Leghorn straw) being the best for this purpose. The wiry culms of some British grasses, *e.g. Cynosurus cristatus* and *Molinia cærulea*, are suitable for very fine plaiting, and are so used. In many tropical countries the bead-like grains of *Coix lachryma* are used for ornamenting articles of dress. *Hierochloe borealis*, common in Northern Europe, contains an essential oil like that of the Sweet Vernal-grass; it is fragrant in a fresh state, and in Germany, Sweden, and Lapland is strewn about churches on festival days. It is almost superfluous to add that the straw of cereals is used for an infinite variety of purposes other than those already named—for thatching, bedding for animals, stuffing mattresses and many other articles, for matting, basket-work, for packing fragile articles and goods liable to damage in transit, and as a protective covering for bottles, etc.

Starch obtained from the cereal grains is largely used in other ways than as food. It is separated from wheat, rice, etc., by means of dilute caustic potash; the starch chiefly used for laundry purposes is obtained in this way from rice, and is largely used in the muslin manufacture and calico printing, and for toilet powder and adhesive paste; damaged wheaten flour is used for dressing cotton fabrics. In recent years an important industry has been developed in the manufacture of glucose or grape sugar, and of dextrin or British gum, from grain-starch, by means of a weak solution of sulphuric acid. Millions of bushels of maize are thus annually converted into glucose in the United States. The principal use of glucose is in brewing and distilling; it is also employed in the manufacture of tobacco and candles, and very largely in confectionery and as a table syrup. Dextrin is used for dressing textile fabrics, and as an adhesive material for postage stamps, envelopes, labels, etc. The bran of flour-mills is now utilized for the preparation of a superior table salt; the mineral matters contained in bran are separated by a special process and added in certain proportion to chloride of sodium.

The medicinal uses of grasses are not of much importance, save perhaps in India. Some yield an essential oil, *e.g. Andropogon citratus*, *D.C.*, extensively cultivated in India and Ceylon, yields oil of verbena or lemon-grass oil, valuable in rheumatism and cholera; the fresh young leaves are used in some parts of India as a substitute for tea. *Andropogon Nardus*, cultivated in Ceylon and Singapore, yields citronella oil, used for scenting soap, etc. From another species of *Andropogon* (*A. Schœnanthus*), growing both wild and cultivated in India, roussa oil, or ginger-grass oil, is obtained; it is a rubefacient, and applied externally in rheumatic affections; it is largely used in perfumery, and imported into Europe principally for adulterating attar of roses. *Anthoxanthum odoratum* yields a volatile oil called coumarin, similar to that of

woodruff, the Tonquin bean and melitot; it greatly improves the flavour of hay. The leaves and roots of some grasses are used medicinally by the native Indian doctors; an infusion of the leaves of *Andropogon citratus* is used as a stomachic and diaphoretic; an infusion of the roots of *A. muricatus* is a gentle stimulant and febrifuge, and the powdered roots are applied externally, with milk, in skin eruptions, etc. A cooling drink is made from the rhizomes of *Cynodon dactylon*. Tabasheer, a silicious crystalline substance often found in the cavity of the culms of bamboos, is used in native Indian practice as a drug for many ailments, although it is doubtful whether it possesses all the medicinal properties ascribed to it; its chief use is as a stimulant and aphrodisiac. Ergot is a microscopic fungus (*Claviceps purpurea*) which attacks the fruit of grasses; the hyphæ form a purple spur-like body, ¾ inch long. Rye is a common host of this parasite, and ergot of rye is a valuable medicine in obstetrics. The spurs of ergot are highly poisonous, and where rye is largely used as a breadstuff, they sometimes cause terrible gangrenous disease. The only grass that appears to be poisonous is *Lolium temulentum*, supposed to be the tares of Scripture: the deleterious property is in the grain.

Grasses subserve some useful offices in nature. The maritime species with subterranean stolons are invaluable for binding loose sand, and cause the formation of sand hillocks. But for *Ammophila arundinacea*, *Agropyrum junceum* and *Elymus arenarius*, the sea would make serious inroads upon many parts of our coast. In the reign of Elizabeth an Act of Parliament was passed to protect *Ammophila arundinacea*, then largely used for basket-work and matting. This grass and *Elymus arenarius* are cultivated and vigilantly guarded on the Dutch coast. Another important economy of grasses is their action in purifying the atmosphere; every blade of grass is a laboratory in which the carbonic acid gas of the atmosphere, in excess poisonous to animal life, is split into its elements, the carbon being retained for the use of the plant and the oxygen liberated. The utility of grasses in this way is of course most obvious in and around centres of population. Every little grass-plot in town gardens helps to revitalize the vitiated air.

Chief among the ornamental uses of grasses is "the covering of the dark ground by that glorious enamel, by the companies of those soft and countless and peaceful spears . . . the life of sunlight upon the world, falling in emerald streaks, and falling in soft and blue shadows, where else it would have struck upon the dark mould of scorching dust. Pastures beside the pacing brooks; soft banks and knolls of lowly hills; thymy slopes of down, overlooked by the blue line of lifted sea; crisp lawns, all dim with early dew or smooth in evening warmth of barred sunshine, dinted by happy feet, and softening in their fall the sound of happy voices." Thanks to our cool-temperate and insular climate, English lawns are unsurpassed, and rarely equalled, in their perennial verdure, by those of any other country. *Cynosurus cristatus*, *Festuca duriuscula*, and

F. ovina, var. *tenuifolia*, *Poa pratensis*, *P. trivialis*, *P. nemoralis* (var. *sempervirens*), and a fine-leaved variety of *Lolium perenne*, are the grasses most suitable for lawns. *Trifolium minus*, a small-leaved clover, is often combined with these.

Tall tropical or subtropical grasses are imposing objects in the landscape-garden; a clump of bamboos, for instance, with their mottled and polished stems and canopy of light green foliage; unfortunately, these will only thrive in warm countries. Allusion has been made elsewhere to *Gynerium argenteum* as an example of subtropical grasses: it is grown in some English gardens, but the beautiful tints of its large, plumy panicle, varying from the faintest rose-blush to purple and violaceous, are not perfected in our climate. The dried panicles may be seen in nearly every florist's window. The variegated leaved Ribbon-grass (*Phalaris arundinacea*) is familiar to every one as a garden favourite. Many exotic dwarf grasses, such as *Briza maxima*, *Eragrostis elegans*, *Lagurus ovatus*, *Avena sterilis*, *Hordeum jubatum* and *Stipa pennata*, are cultivated by florists for the elegance and airy beauty of their panicles; these are admirably suited for interspersing with bright flowers in bouquets and vases. Nearly every home is decorated with bouquets of dried and coloured grasses, and these would be prettier still if more delicately stained and tastefully grouped. Grasses do not figure so largely in our flower- and landscape-gardens as they deserve to do; but in truth, there is no need for this, when meadow, heath and woodland display such a profusion of beautiful grasses, with graceful ensiform foliage and clouds of feathery and delicately tinted panicles. No effort of the horticulturist could achieve the grand effects of the massing of grasses which we see in Nature.

INDEX TO CHAPTER II. (LATIN NAMES),

Synonyms in *italics*.

N.B.—Where the number of more than one page is given, the first refers to the typical species, the other numbers to its varieties.

INDEX TO CHAPTER II. (ENGLISH NAMES).

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