1 Crops

1.1 Introduction

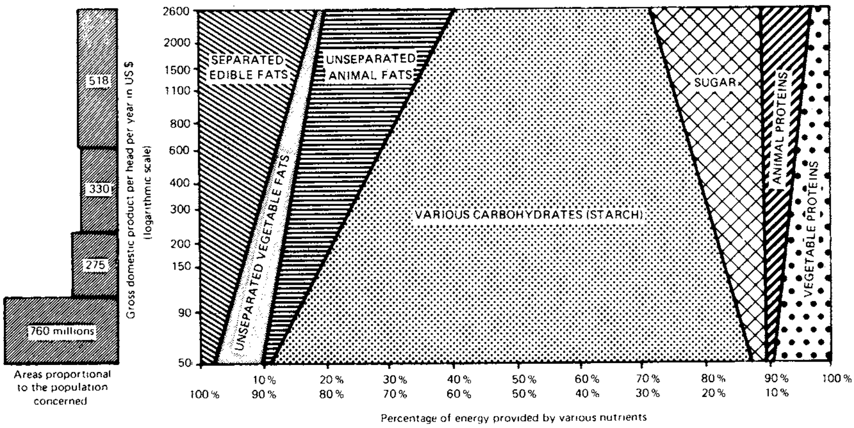
The preface indicated the differences in human energy and protein consumption in different parts of the world. It is important to realise that this energy and protein is supplied by different foods in these different countries. The developed countries enjoy a wide range of foods from a variety of plants and animals. However, this is not the case for many people in developing countries. They rely for a major part of their diet on one food. This food is referred to as a **staple food**. For example, in Central America the staple food is maize; in S. E. Asia it is rice, whilst roots and tubers (e.g. cassava, sweet potatoes) are staples for many in central Africa. There seem to be two reasons for this reliance on one staple food:

(a) the staple food is grown easily by most people in the areas concerned;
(b) the majority of people seem to be too poor to buy other foods.

Certainly Figure 1.1 indicates that diet changes with increase in income.

This figure indicates that generally the poorest people have the highest proportion of **carbohydrate** in their diet (proportion, not necessarily total quantity, because the total food available to them might be restricted). This high proportion of carbohydrate is because these staple foods consist mainly (excluding water) of carbohydrates. Other nutrients (proteins, vitamins, minerals) may not be present in adequate proportions. As income rises, the proportion of carbohydrates in the diet decreases because the higher income allows the purchase of foods derived from animals, which are always more expensive than those derived from plants. This is reflected in an increased proportion of animal fats and the change from vegetable to animal proteins.

Figure 1.1 ENERGY DERIVED FROM FATS, CARBOHYDRATES, PROTEINS AS PERCENTAGE OF TOTAL CALORIES ACCORDING TO THE INCOME OF THE COUNTRIES (1962)



1.2 Staples

In terms of quantity produced and numbers of people fed, the most important staple foods in the world are **cereals.** This is because there are many species of cereals, each with a large number of varieties. This means that cereals are found worldwide in many different habitats. Also the flowering heads of the cereals produce a grain which will keep for a number of years with little deterioration when in the right storage conditions. The main cereals are **wheat**, **maize** and **rice** (approximately 25% each) followed by oats, sorghum and millets which together make up the remaining 25% (in decreasing order of approximate world grain production tonnage). In developing countries these grains will, in the main, be consumed directly by the people. Very little will be used to feed farm animals. The reverse is the case in developed countries. Very little is consumed by the people, but large quantities of cereal grains are used to provide a major part of the food of some farm animals (e.g. pigs, poultry). These farm animals then provide the protein and fats for the higher income peoples as shown in Figure 1.1.

Potatoes, sweet potatoes, yams, legumes (peas, beans, soya, peanuts etc.) and sugar cane are major **non-cereal** staples. Whilst each may be the staple for some peoples, they are not found worldwide because of their specific ecologies.

1.3 Gramineae

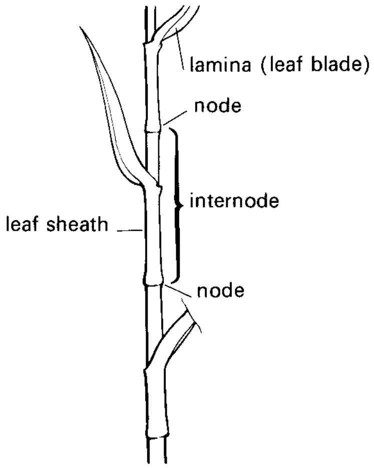
The majority of the cereals mentioned above belong to the plant family **Gramineae**. There are a few very minor exceptions, e.g. buckwheat, a member of the family Polygonaceae. The Gramineae also includes the **grasses**. The term grasses can be used to indicate that the vegetative parts of the plant are eaten by animals (i.e. are **forage** or **herbage**) and so does not include the cereals. Sometimes the word 'grasses' is used colloquially to mean **all** of the Gramineae. In this book the term Gramineae will be used when all members of the family are included and the term cereal will be used for those members of the family Gramineae that are grown for their grains. The term grasses will be used for those members grown primarily so that their vegetative parts can be eaten by animals.

Grasses have worldwide importance as the basic food for all grazing animals. So, either as direct food for humans, or indirectly via farm animals, the Gramineae are very important food suppliers.

The shoot

The Gramineae belong to the **monocotyledons** and so can be recognised by their narrow, parallel-veined leaves. The shoot consists of leaves borne on a stem. The bamboo (Figure 1.2) is a member of the Gramineae and has a shoot which is useful for initial study, although in some respects it is atypical. Each leaf arises at a **node**. The growing part (the **meristem**) of the leaf is at this node, and here new cells are added to the base of the leaf. The leaf grows from the node, and the lower part of the leaf (the **leaf-sheath**) completely surrounds the stem. As the leaf matures, the upper part, the leaf blade (or **lamina**), differentiates from the leaf-sheath. In many species the distinction between leaf-blade and leaf-sheath is quite obvious, and at the junction there may be

Figure 1.2



two **auricles** and a **ligule** (see Figure 1.3). These are often distinctive features useful for recognition.

The bamboo has elongated **internodes** and it is this elongation that is not typical of the agriculturally important grazing grasses, though the flowering

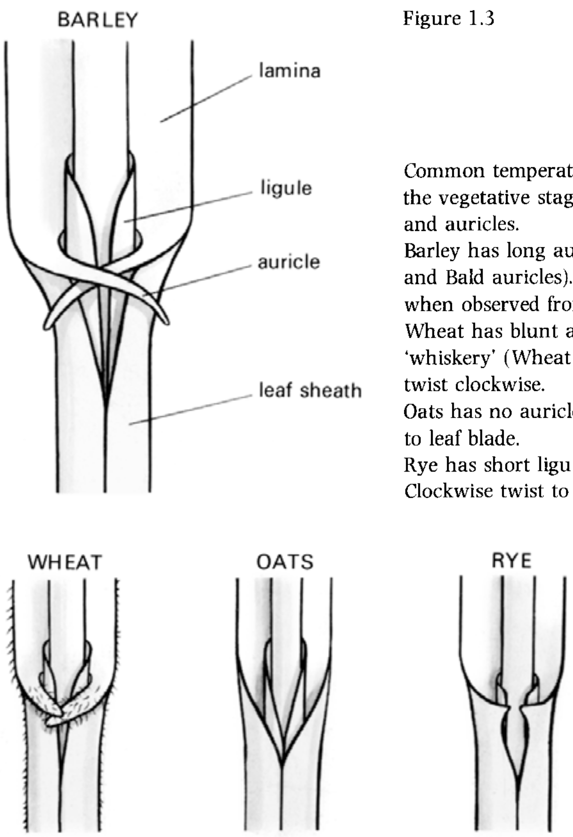
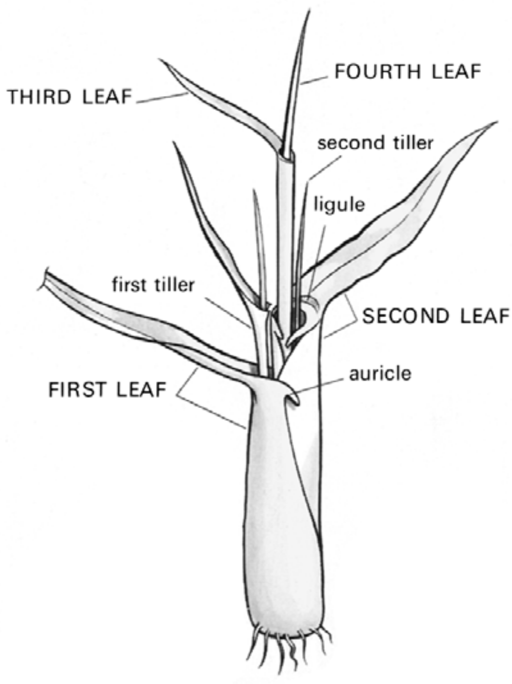


Figure 1.3

Common temperate cereals can be distinguished, in the vegetative stage, by the appearance of the ligule and auricles.
Barley has long auricles with no hairs (Barley: Big and Bald auricles). Leaf blades twist clockwise when observed from above.
Wheat has blunt auricles which are hairy or 'whiskery' (Wheat: With Whiskers). Leaf blades twist clockwise.
Oats has no auricles (Oats: O); anticlockwise twist to leaf blade.
Rye has short ligule and auricles (Rye: Restricted). Clockwise twist to leaf blade.

stems for seed/grain production do elongate (see later). In these grasses the vegetative shoot has internodes which are so short as to be nearly non-existent. The nodes thus appear as concentric rings around a minute stem. The visible part of the shoot of a grass is therefore really a collection of concentric leaves (much like the closed aerial of a portable radio). The leaves thus arise from a very short stem at or near ground level. This fact is of supreme agricultural importance. When the leaves are grazed, this short stem at ground level remains undamaged. Therefore, the **meristematic tissue** of the nodes also remains undamaged, and new growth of leaves (from the bottom) proceeds unhindered. Grazing of the majority of young dicotyledonous plants would remove the main growth point (**apical meristem**) from the stem, probably most of the stem and with it other buds. There would thus be no, or only one or two, growing points remaining and so regrowth would be slow or unlikely. This is why grazing produces the typical **grassland climax** with very few mature dicotyledons. The only dicotyledons likely to survive are those with either a **woody stem** (e.g. trees, bushes) or those with a **prostrate habit**, e.g. dandelion, plantain and daisy, where again the stem is very short and the leaves frequently remain procumbent. In some tropical areas, rainfall is limited and falls in only a short period of the year. Grass growth is therefore very variable – from virtually nothing for several months of the year, to a few weeks of luxuriant growth in the rainy season. It is therefore very difficult to match the feeding requirements of the animals to the growth that actually occurs. This would soon allow far less nutritious dicotyledons, e.g. trees, to become

Figure 1.4a



Sketch of simplified cereal/erect grass to show leaves and tillers.

established and severely reduce the grazing potential of the land. To control these nutritionally undesirable plants, the use of **fire** is an accepted management technique. Particularly in the savanna areas of Africa, controlled burning is used to remove old and dry vegetation of low feeding value. This burning also has the added advantage of stimulating the grass into a flush of growth during dry periods.

Tillers

In the same way that dicotyledonous plants have buds in the angle (axil) of the leaf, so **axillary buds** are present in the Gramineae. These buds grow to produce **axillary shoots** which have the same concentric leaf sheath structure as the main shoot. These axillary shoots are referred to as **tillers**. Grasses will often produce several tillers in rapid succession, which ensures quick vegetative growth, a feature that is particularly important in grasses.

Sexual reproduction in the Gramineae

After a period of vegetative growth, **flower formation** is initiated in the Gramineae. In temperate areas the initiation stimulus is **increasing day length**, though a prior period of cold is necessary for some species or varieties. This cold requirement (**vernalisation**) is particularly important in the cereals as it serves to differentiate the winter cereals from the spring cereals. Winter cereals must be sown in autumn prior to the cold temperatures of winter. Only after this cold

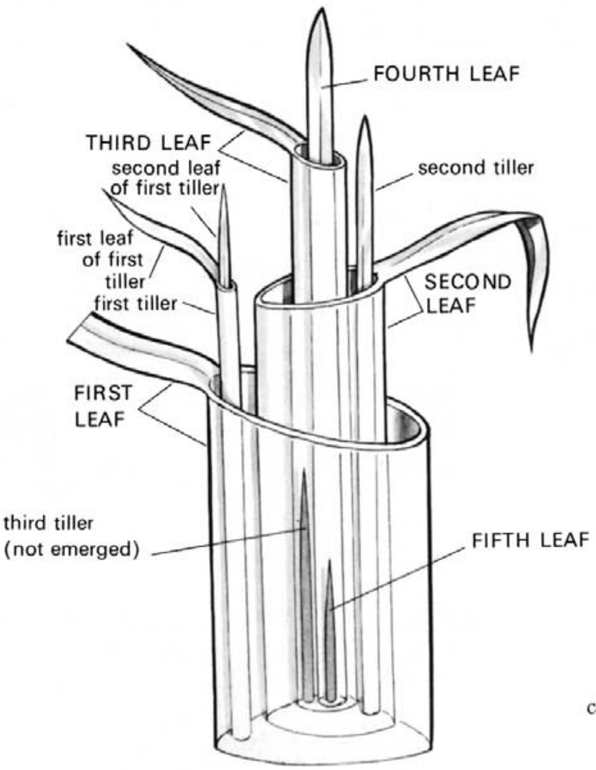


Figure 1.4b

Diagram to show origin of leaves and tillers and the concentric nature of the nodes and leaf bases of sketch opposite.

period will they then be able to respond to increasing day length, and thus flower. If sown in spring, they would receive no (or insufficient) cold and would not produce flowers – they would remain in the vegetative state. (Some winter cereals are really spring cereals which can survive the winter, but do not require cold to flower.) For spring cereals there is no such cold requirement. They are sown in spring and flower just in response to the increasing day-length stimulus.

When increasing day length initiates flower production, the production of new leaves ceases. Instead, an inflorescence is formed. The flowers on the inflorescence are borne above the vegetative shoots. This appears to facilitate **wind pollination** (see later).

Tropical Gramineae may be short-day plants or not sensitive to day-length changes since the length of the day alters very little near the equator.

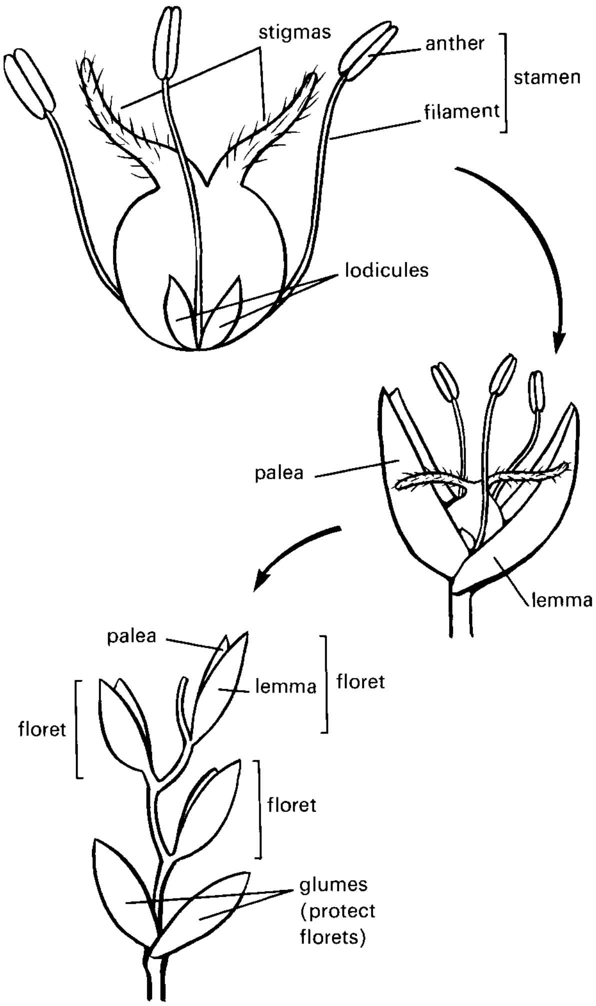
Obviously flower initiation is important in the cereals – it produces the grain which is the prime reason for growing them. In grasses, as just indicated, no new leaves are formed on those shoots that are flowering and whilst those that remain may still grow, this could herald a decline in total vegetative growth as no new tillers are formed. This would mean a reduction in food for grazing animals. However, some vegetative growth will be taking place in those tillers which are too young (immature tillers) to flower. These will provide some grazing during the later months. If the numbers of animals grazing the grasses can be controlled, it is possible for many of the old (or first) shoots to be eaten. This delays or discourages flowering in these old shoots and encourages the formation and growth of new shoots. This type of controlled management is not always possible, hence the use of fire in some tropical areas as previously explained. It should be appreciated that some specialist farmers want, and encourage, the flowering of grasses. They are the producers of grass seed. This will be harvested just like cereals, and subsequently used by other farmers for sowing new grasslands.

Flower structure

The flower of the Gramineae is basically adapted to wind pollination (see Figure 1.5) and, as such, it has a much reduced **perianth** (petals/sepals) and no nectary. In other flowers these might serve to attract insects for pollination. The two small **lodicules** represent all that remains of the perianth.

Most Gramineae have three **stamens** (though six are present in some, e.g. rice). When these stamens mature, the filaments elongate and the **anthers** hang outside the flower. This allows the release of the light pollen for wind cross-pollination, and allergic reactions in sufferers from hay-fever. Most of the cereals, e.g. wheat, barley, oats and rice, are usually self-pollinated, because the anthers **dehisce** before the flowers open. The **gynaecium** is always a monocarpellary single-seeded ovary and has two styles with feathery stigmas – presumably an adaptation for catching air-borne pollen. All the major cereals have this basic perfect (or **hermaphrodite**) flower, except for maize which is **monoecious** (separate male and female flowers on the same plant) and is discussed later. As the lodicules afford little or no protection to the flower, this protective function is performed by two **bracts**, the **lemma** and the **palea**. In

Figure 1.5



Grass flower

Grass floret, open.
A floret consists of a flower together with the protective lemma and palea.

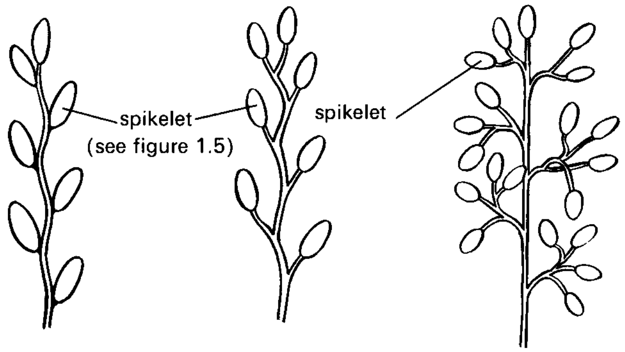
Several florets together form a spikelet:

some plants, the lemma may bear a barbed projection called an **awn**. The flower, plus the lemma and the palea, are together called a **floret**. Several florets may be arranged together into a **spikelet** which will have protective **glumes** (see Figure 1.5). The number of florets per spikelet and the distribution of spikelets on the flower head (**inflorescence**) vary from species to species. (See Figure 1.6.)

The inflorescence

The different inflorescences produced by the Gramineae can be regarded as variations upon a theme (see Figure 1.6). If the spikelets are attached directly to the **rachis** (central stem) with no stalk (**sessile**) the inflorescence is called a **spike**. Wheat, barley, rye and the 'cob' of maize are typical spikes. If the spikelets are attached by a stalk to the rachis, then the inflorescence is a **raceme** (not common in Gramineae). If, however, each of the stalks attached to the

Figure 1.6 Diagrams of some inflorescences of Gramineae



This consists of spikelets arrayed singly on the rachis (inflorescence stalk)

This consists of spikelets with stalk arranged on the rachis

This has groups of spikelets

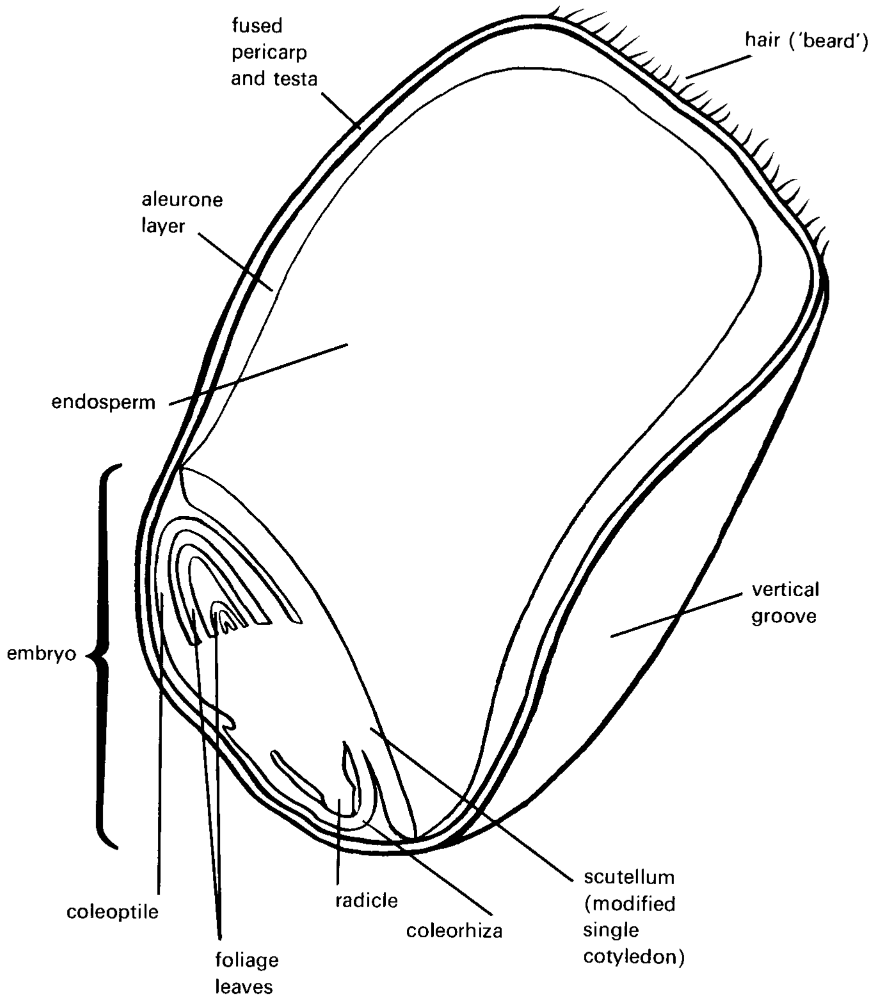
rachis is branched, then a compound raceme is formed which is usually called a **panicle**. Oats, rice, millets, sorghums, the male inflorescence (tassels) of maize are panicles. Oats are an example of a species in which the spikelets are spaced and easily distinguishable – this is a **spreading panicle**. However, some species (e.g. millets, Timothy grass) have very short branches and the panicle then appears like a spike – a **spike-like panicle**. After fertilisation a fruit is formed which is very often referred to as a **grain** or a **seed**. Botanically, it is a fruit called a **caryopsis**. In its formation, the ovary wall (the **pericarp**) adheres as a thin layer only a few cells thick over the true seed, and thus forms the caryopsis (see Figure 1.7). In some the lemma and palea also remain (see later).

Harvesting of cereals

To obtain the grains, the cereals have to be harvested. With little or no mechanisation, this is basically a two-stage process. First, the mature plant stalks are cut, usually low down near to the soil. These are then gathered together (often into bundles, e.g. sheaves) and, after possibly a further period of maturation in the field in groups (sometimes called stooks or shocks), these are collected together in a stack or barn.

The second process (which may take place very soon after the first, or be delayed some time) involves the separation of the grain from the remaining plant material. This involves **threshing** and **winnowing**. Beating with sticks, trampling by cattle or man, and flailing are primitive threshing methods still used worldwide. Throwing the resultant products up in the air, and allowing the wind to remove the lighter parts, is the most primitive form of winnowing. Mechanisation initially brought the **threshing machine** (which also winnows). This separates the grain by the rotation of a cylinder of grooved bars closely adjacent to a static concave reticulate framework. Sieving, and then winnowing (by mechanical fan), separates the grain from the lighter parts (the **chaff**, composed of loose glumes, lemmas and paleas) and the **straw** (flower stalk). The most technically advanced farmers are able to combine these two

Figure 1.7 Diagram of wheat caryopsis (vertical section)



processes (cutting and threshing/sieving/winnowing) in one mobile machine, the **combine harvester**.

The grains produced by these post-harvest operations can be classified into two groups – those with **naked caryopses**, and those with **covered caryopses**. Wheat, rye and maize are examples of naked caryopses, and barley, oats and rice are examples of covered caryopses. The covered caryopses still have the lemma and palea surrounding them which are referred to as the **hull** or **husk**. Before human consumption, rice is dehulled (see later).

Germination and root production

The wheat embryo (typical of many Gramineae) shows the primary root (the **radicle**) enclosed by the **coleorhiza** (see Figure 1.9). Upon germination, the coleorhiza increases only slightly in length before the **primary root** pushes through, followed by the **lateral roots**. Meanwhile the **coleoptile** will have elongated and pushed above the surface of the soil. The first foliage leaves will

Figure 1.8

initially grow up within the coleoptile and then emerge through the coleoptile as the growing shoot. From the nodes of the stem will develop roots, so called **adventitious roots**. Typically, many adventitious roots will form, and produce the familiar **fibrous root** system of the Gramineae. An extreme example of adventitious roots can be seen in mature maize plants, i.e. the prop roots (see Figure 1.8).

Lifecycle of the Gramineae

The cereals are all grown as annuals. (There is some evidence that some plants could persist from year to year – but only in totally uneconomic quantities.) Figure 1.9 shows the life-cycle of wheat.

The grazing grasses of agricultural importance could probably be grown as annuals. If not grazed, they would flower and produce seed within a year. However, they nearly all persist from year to year by vegetative means and therefore could be classed as **perennials**. Perennation in these grasses mainly depends upon the production of tillers which form their own adventitious roots, and the subsequent survival of these tillers over winter. In some varieties of Italian ryegrass, one of the most important temperate cultivated grasses, this ability to survive is poorly developed, and thus these pastures are rarely very productive after the first year. However, foliar production in the first year is excellent and highly nutritious and so the grass has attained importance as fodder for high yielding cows. Some grasses which are only important in