THE · BOOK · OF NATURE · STUDY

EDITED BY BRETLAND FARMER D·Sc:F·R·S

THE BOOK OF NATURE STUDY

Drawn by Bertha Reid

CLIMBING HEDGEROW PLANTS

1. Woody Nightshade
2. Clematis
3. Honeysuckle
4. Blackberry

THE BOOK OF NATURE STUDY

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THE BOOK OF NATURE STUDY

XEROPHYTIC VEGETATION.

By Charlotte L. Laurie,
Assistant Mistress, Cheltenham Ladies' College.

CHAPTER I

Seashore Vegetation

It would be difficult to find a country with a more varied coast-line than that of our islands. The chalk of Kent, the sandstone of Devon, the granite and serpentine of Cornwall, the limestone of S. Wales,—all combine to produce a variety of coast almost unknown elsewhere in so short a distance. Every type of shore is to be found in these islands: gravel beaches, bold rocky headlands, great stretches of sand, deep bays, wide estuaries; and each has its characteristic vegetation.

It will be most convenient to arrange this great variety of types in the following groups:—

1. The Plant Associations of muddy banks.
2. ,, ,, sandy shores and sand-dunes.
3. ,, ,, pebble banks and shingle.
4. ,, ,, rocky headlands.

The Vegetation of Muddy Seashores.—Mud plants may be studied at the estuary of any tidal river; the shores of the Bristol Channel afford excellent examples of the plants belonging to muddy salt marshes, owing to the fact that the tides are there particularly high, and the channel bed is formed of soft, muddy materials. The vegetation is xerophytic in character, for a muddy salt marsh has great extremes of heat and cold, of moisture and dryness. The plants are characterised by a low growth, a comparatively undeveloped root-system, and fleshy leaves; or by fleshy stems bearing leaves very much reduced in size. At each high tide the waters of such a shallow channel as the Bristol Channel lay down a considerable thickness of mud; thus the formation of a muddy salt marsh begins. Soon there will be a layer of mud, washed by all high tides. Here the Glasswort (*Salicornia herbacea*) establishes itself; often it is the only species found. The accompanying photograph shows the plants some distance apart, not competing in any way with each other. A few green seaweeds may be found in this belt, and sometimes the *Suæda maritima.* When the Glasswort grows thickly it covers the mud-flats with a sheet of vivid green, which changes to brown in autumn; of all the plants growing in salt marshes, it is the one that creeps farthest down to the sea; the first belt or zone of vegetation in these muddy shores is therefore that of the *Salicornia herbacea.* The plant has short, thick leaves, and a stem, succulent above, which bears branches given off in pairs at each node, and these again branch, each ending in a spike. The flowers are very minute, with a green perianth, one or two stamens and two styles projecting from the perianth. The *Suæda maritima* belongs to the Goosefoot family, and is a low-growing plant, sometimes only two or three inches high. It has small, linear, succulent leaves and small, green flowers, two or three together in the axils of the leaves. It forms a sub-dominant species.

Behind the *Salicornia* belt, another Plant Association, that of the grass, *Glyceria maritima*, establishes itself. Here the mud bank is rather higher and the ground is washed by spring tides only in time of storms. This situation is therefore drier than the last. The two plants most usually found with this grass on the shore in question are the Sea Starwort (*Aster Tripolium*) and the Sea Arrow-grass (*Triglochin maritimum*). The Sea Aster is distinguishable from all other British Composites by its large flower heads, with a yellow disc and purple ray. It is seldom more than a foot high.

From Mr. J. H. Priestley, University College, Bristol.

SALICORNIA PLANT ASSOCIATION

Juncus
Gerardii
Associat

lyceria
aritima
Triglochin
aritimum
nd Aster
Tripolium

om Mr. J. H. Priestley, University College, Bristol.

VEGETATION OF MUDDY SHORE

The Sea Arrow Grass is a plant usually abundant in salt marshes, and belonging to the same order as the Water Plantain, namely, to the Alismaceæ. The leaves are succulent, and come up from the underground stem. The flower-stems have no leaves, but bear spikes, from six to twelve inches high, of small yellowish-green flowers. This Glyceria Plant association, as it may be called, is shown in the foreground of the accompanying photograph; it is usually the second association to be formed on muddy sea-shores. In the same photograph, another association is seen occupying the topmost zone. The dominant plant is a Rush (*Juncus Gerardii*), and associated with that are the Sea Thrift (*Armeria maritima*) and the Sea Milkwort (*Glaux maritima*). The Mud Rush (*Juncus Gerardii*) has brown shining bracts. It is marked off from other species of Rush by the leaves of the perianth being about equal to that of the capsule. The Sea Milkwort belongs to the Primulaceæ, but differs from the other genera of that order in having no corolla. The calyx is petaloid and consists of five pink sepals. It is a slender plant, about six inches high, with small leaves. Another plant often found in this belt is the Scurvy Grass, one of the Cruciferæ, with small white flowers and succulent leaves. This topmost zone of vegetation is washed only at very high tides, the ground is therefore far drier. As the salt marsh gets drier and able to support a more fixed vegetation, cattle, sheep, and horses may be turned in to graze on it, and the land gradually becomes reclaimed. The "Levels" of Somerset consist very largely of land of this character. The effect of turning in cattle to graze is to produce considerable change in the vegetation, some plants being kept down altogether. It is interesting, as one walks over a salt marsh pasture, to picture the stages that have followed each other: at one time, it may have been a muddy belt with only patches of Glasswort on it; then as

FIG. 1.—Sea Milkwort (*Glaux maritima*).

the level of the mud rose and only high tides could reach it, other plants were able to gain a footing; the marsh in time got solid enough for animals to be turned in on it, and then the stage is reached in which man's influence becomes the dominant factor. In ecological botany the term Plant Formation is now used to denote the total number of Plant associations which succeed each other in a rapid succession in the way just described; as long as the plants of one association are giving place to another, the association is said to be open; when the final stage is reached and the vegetation is fixed or stable, the association is closed, and there may be intermediate stages. Thus the Salicornia and Glyceria associations are open, the Juncus association is intermediate, whilst that of the salt marsh pasture, showing as it does the influence of man, has been called a "substituted" association.

The influence of a tidal river on vegetation is by no means limited to the formation of salt marshes with their characteristic plants at its estuary. The Severn, for instance, affects the vegetation of Gloucestershire not only at, or near, its mouth, but to a considerable distance inland, with the result that many plants usually found on seashores occur almost in the middle of what is practically an inland county. The following may be mentioned:—

The Sea Milkwort at Beachley Point, 6 miles from Portskewet at the mouth.

The Sea Scurvy grass at Lydney, 14 miles from Portskewet.

The Sea Spurrey at Slimbridge, 16 miles from Portskewet.

The Sea Plantain at Longny, 20 miles from Portskewet.

The Sea Starwort at Newnham on Severn, 20 miles from Portskewet.

The Severn is a particularly good instance of a tidal river. and has a tidal bore, so that the effect on vegetation would be more marked than in many others.

THE VEGETATION OF SANDY SEASHORES.—It will happen that some classes may be able to make observations without much difficulty on the vegetation of sandy seashores. It has

Photo by Dr. Pethybridge, Royal College of Science, Dublin.

OUTER FRINGE OF SAND HILLS

With Triticum junceum (dominant), Salsola, and Atriplex in the foreground: Psamma on hills to the left

From Dr. Pethybridge, Royal College of Science, Dublin.

A CLUMP OF EUPHORBIA PARALIAS (Sea Spurge) AMONG THE MARRAM GRASS

been estimated that nine-tenths of the coast-line of the world are fringed by sands. Sand-dunes which, as will be shown, are largely built up by plants, extend for miles along many parts of our shores, on the coast of Holland, and along the east coast of the United States. To find plants in their natural habitat, it is best to avoid the fashionable seaside resort, and to spend a summer holiday in some primitive spot, if possible, away from esplanades, piers, bands, and trippers. The following observations were made in a little village of Northumberland where the sands stretched for miles and were practically undisturbed. Walking on the sands, one soon realised that there was an area with very few plants, owing to the constant blowing about of the sand by the wind; this may be called the area of shifting sand. The two most common plants of this belt were the Sea Rocket (*Cakile maritima*) and the Saltwort (*Salsola Kali*). The former is a cruciferous plant with fleshy leaves and lilac flowers. The pods are worth noticing. Each divides into two portions, a short lower and a long upper segment. The upper portion falls off in the autumn, the seed gets buried in the sand and germinates the following spring. The leaves of the Saltwort are not only succulent, but prickly. The plant is usually about six inches high, and bears minute flowers in the axils of the upper leaves. In many places the Sea Wheat-Grass (*Triticum junceum*) is the first plant to establish itself on the drifting sand. This is shown in the photograph by Dr. Pettybridge, who has investigated the Plant associations of the Dublin district. The Sea Wheat-Grass is seen in the foreground, and associated with it the Saltwort and the Sea Purslane (*Atriplex portulacoides*). This grass has creeping underground stems (stolons), and these help to fix the loose sand.

Within the area of shifting sand comes a belt of sand in which the wind has not free play, for certain grasses and other plants have begun to bind the sand together, weaving it into a soil of firmer texture than shifting sand can have. The Marram Grass (*Psamma arenaria*) and the Sand-Lyme Grass (*Elymus*) are the two species most commonly found. Both these grasses have long rhizomes, which bind the sand as they spread in matted tufts. The Marram may easily be distinguished from the Lyme Grass by the fact that its spikelets contain only one perfect flower, whilst the Sand-Lyme Grass usually has three perfect flowers in each spikelet. Both have leaves which can roll in, and thus protect the plant from too rapid transpiration. The structure of the leaf is shown in Fig. 2. In wet weather, or in diffuse light, the leaves are spread out flat, but in scorching suns and drying winds the upper surface rolls inwards, owing to the contraction of certain cells.

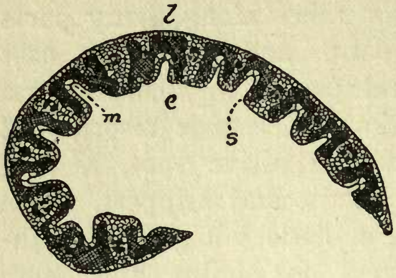

FIG. 2.—Leaf of Psamma (transverse section). *s*, Position of stomata; *m*, motor cells; *l*, under surface; *e*, upper surface.

The stomata are on the upper surface, and are completely sheltered by the inrolling of the leaf. Very often with these two grasses, the Sand Sedge (*Carex arenaria*) is also found; it too has a creeping root-stock and is a sand binder, but undoubtedly the most common binder is the Marram Grass. Other plants soon find a lodgment in the sand which is no longer being blown about; the Spiny Restharrow is often very conspicuous, carpeting the ground to the very edge of the shifting belt; mixed with this may be found the Stork's Bill (*Erodium cicutarium*), a plant belonging to the Geraniaceæ, but differing from the Geranium in having pinnate, not palmate, leaves, and five instead of ten stamens. The long beaks of the fruit are very characteristic; they twist themselves spirally, but the carpels do not open to let out the seeds, as in the Geraniums. A geranium that is very abundant on this part of the Northumberland coast is the Blood Geranium; this has large, purplish-red flowers, which are very striking on the sand mounds and hills against the brownish grass. This is a very local plant, but is usually abundant when it occurs at all. The well known Bird's-foot Trefoil and the Mallow are also common. One more plant must be mentioned as characteristic of this situation, the Sea Purslane (*Arenaria peploides*), which also has a creeping root-stock and is a sand binder. The leaves are thick and fleshy, and the fruits are large compared with those of other species of Sandwort.

The Plant associations to be studied on sandy seashores are:

From Dr. Pethybridge, Royal College of Science, Dublin.

SEA SPURGE AMONGST MARRAM GRASS

From Dr. Peth.bridge, Royal College of Science, Dublin.

SALSOLA KALI (Saltwort)

(1) Those belonging to shifting sands; in different parts of the country, different plants will be found, but the most common are the Sea Rocket and the Saltwort; this may therefore be called a Salsola-Cakile Plant association. (2) The Marram association, situated more landward and characterised by the formation of sand-dunes, owing to the binding powers possessed by the rhizomes of the plants. Here the part played by the wind may be noticed. Coming in contact with sand, the wind drives it onwards, piling it into irregular heaps and ridges called "dunes." Their general direction is transverse to the prevalent course of the wind. The coast of Norfolk is fringed with sand-hills, fifty to sixty feet high. Long tracts of blown sand are found on the Scottish and Irish coast-lines. Sand-dunes extend for many miles along the French coast, and Flanders and Holland; off Holland they are occasionally over two hundred feet, though their average is, as in Norfolk, fifty to sixty. When not fixed by sand binders, the dunes may travel inland. On the low shores of the Bay of Biscay their rate is about sixteen feet per annum, and in their progress they have at times overwhelmed whole districts. This destruction is now prevented by the planting of pine forests.

In making observations on the flora of a sand-dune, the plants found in the hollow between the summits of the dune will be greater in number and variety, for the position is more sheltered, the force of the wind is less felt, and there is more shade. These all help to form a thick sward, which renders the sand less liable to be blown about. The next stage is the formation of a dune pasture. Here there are many more plants present. The most abundant are Centaury, Convolvulus, Thyme, Ragwort, Plantain, and Chamomile.

The following table is an attempt to compare the Plant Formations of muddy and sandy seashores; the figures denote the order of succession.

PLANT FORMATIONS

		MUDDY SHORES	SANDY SHORES
PLANT ASSOCIATIONS	Open . . .	1. Salicornia	1. Sea Wheat-Grass Salsola
		2. Glyceria fluitans	2. Psamma
	Intermediate	3. Juncus Gerardii	3. Sward-forming Plants
	Substituted	4. Salt Marsh pasture	4. Dune pasture

These plants have many features in common; the most important is the structure of the leaf, the organ which more than any other responds to the environment. Some of these plants adapt themselves to their surroundings by the reduction of their leaf surface; others by developing a water-storage tissue which makes the leaf succulent. The reduction of the leaf surface is one of the means by which a plant prevents the loss of water. In the Salicornia the leaves are scarcely distinguishable from the fleshy stem, immediately under the epidermis of which are two rows of cells filled with chlorophyll granules. The same object of restricting the loss of water is attained in the Marram Grass by the inrolling of the leaf, and in other plants by the thickening of the outer skin, or by a covering of hairs, or the formation of a waxy layer, forming the bloom which is so often noticed on seashore plants.

FIG. 3.—Creeping Willow (*Salix repens*).

The stems of these plants also show special modifications of structure. They have much less woody tissue, for there is less conduction of water; on the other hand, they have a greater development of assimilating tissue. Most of them have creeping rhizomes.

The low growth of many of these plants is another noticeable feature; even shrubs are prostrate. The Creeping Willow is a case in point. It is a low, straggling shrub; the stems creep underground, rooting at the nodes, and only ascend above the soil to a foot or more. It has the regular type of Willow leaf, and these are silky on both surfaces.

FIG. 4.—Stork's Bill (*Erodium cicutarium*).

This stunted growth of plants is

characteristic not only of seashores, but of high hills,—of any situation, in fact, where the supply of water is irregular. Some plants frequent both situations: the Stork's Bill is found on hills about eight or nine hundred feet high as well as on sandy shores; the Wild Thyme, and some of the Bedstraws are other instances.

These plants are found not only on the seashore, but inland, in deserts where there is a certain amount of salt. Travellers note in sand deserts, in addition to various species of Cacti and Spurges, the Glasswort or Marsh Samphire, the Sea Plantain, and various members of the Goosefoot family.

THE VEGETATION OF SHINGLE.—Sometimes the beach is covered with shingle, the pebbles of which are derived partly from the cliffs above, and partly from the inrolling waves, which often carry with them sand and stones, depositing them on the shore. The action of seaweeds, as Lord Avebury has suggested, is here of great influence. "They attach themselves," he says, "to the rock, and grow towards the surface, many of them being floated upwards by the presence of innumerable air vessels. The waves as they pass drag the weeds with them, tear up the stones, and throw them on the shore. Some beaches are almost entirely supplied with pebbles in this way by seaweeds." On most beaches two lines of seaweed may be seen, one marking the high-water at the last spring tide, one the high-water line of the last tide. Between these two, other lines of seaweed may occur, showing the high-water level during some storm. There are three main groups of seaweeds: the Olive Brown, the Red, and the Green. The most common species of the first named is the Brown Bladderwrack (*Fucus vesiculosus*). It is like a long ribbon with a thick midrib. Here and there are large bladders filled with air, which enables the plant to float. The whole frond, as it is popularly called, is fastened by a root-like portion to the rock. The size of this seaweed varies very much: in muddy ground it may not be more than an inch or two; in more favourable situations it may be 3 feet long. Little indentations like pimples may be seen at the summit of some of the branches; these cavities contain the reproductive organs. The Brown Seaweeds are burnt for the manufacture of kelp. The Wracks are not the best ones to use for this purpose, only the Oarweeds or Laminaria should be employed. It is these thick Brown Seaweeds that make the rocks so slippery, and necessitate very careful walking. The stem of the Laminaria is very strong, and is used for making handles to knives. When fresh, the stem is soft enough to allow the end of a knife-blade to be thrust longitudinally into it. A portion of the stem, long enough for the knife handle, is cut off, and in a few months it dries, contracting with such force as to fix the blade ; the dried stem has the appearance and toughness of stag's horn.

The Red Seaweeds are particularly beautiful from the variety of their colouring. They are many of them very minute, often only a few inches in length. These are best seen in the shallow pools of water left by the retreating tide on the rocks. In such situations the variety of colouring is enhanced by the background of the rock and the transparency of the water, when the sun is on it, provided the light is not too intense. Some of these Seaweeds are used as articles of food ; the Irish or Carrageen Moss (*Chondrus crispus*) is one of the best known. When boiled it forms a thick, colourless jelly that is said to be very nutritive. The Sea Lettuce and the Purple Laver are often eaten ; they should be gathered in the winter, or early spring, and stewed for several hours.

If Seaweeds are being collected for a herbarium, they should be well washed in fresh water, in order to get rid of the salt ; then pieces of card the size required should be slipped under them as they float in the water. In this way it is possible to spread out all the branches. The Seaweeds have in them a certain gelatinous substance, which usually glues them down firmly to the paper ; if necessary they may be fixed by the gelatine obtained from boiling down the Iceland Moss.

The flowering plants belonging to pebbly beaches have either long tap roots which penetrate between the loose, dry stones, and reaching the subsoil get food material and water from it ; or they have a shallow root-system, adapted to the less dry portion of the bank. To the former group belong the Horned Poppy and the Sea Holly ; to the latter the Sea Purslane.

The Horned Poppy (*Glaucium flavum*) is so named from the long curved pods with two stigmas. These fruits may be even

10 or 12 inches long, and are a very striking feature of the plant. The other characters are those of the common Poppy: a calyx of two sepals, which drop off as the flower opens, four petals and numerous stamens, which in this species are orange. The flowers are very showy, being large and yellow, and the leaves have a silvery tint from the rough, thick hairs which clothe them. The Sea Holly is an equally striking plant. Its foliage is greyish-green, the upper leaves and bracts having an edging of the brightest blue; the flowers are also blue. The leaves are very thick, with a "bloom" on them. They are four or five inches across, and by their great breadth protect the stem and roots from the scorching sun; their spiny margins prevent the plant being eaten by animals. The plant belongs to the Umbelliferæ, and the flower-heads are protected as is usual in umbelliferous plants by bracts, which like the leaves are spiny. Each flower has a prickly calyx, and the fruit is also prickly. The long underground stems are sometimes candied and used as a sweetmeat; if the plant were not well protected by its thorniness it would probably soon be extirpated by animals.

FIG. 5.—Sea Purslane (*Arenaria peploides*).

The Sea Purslane (*Arenaria peploides*) is one of the Sandworts, and belongs to sandy shores quite as much as to pebbly beaches. One or two species of Clover are also common among the stones, and the Viscous Senecio, though hardly common, is found among shingle. This latter is a plant not unlike the Groundsel, but taller and stronger smelling. The accompanying photograph of a newly formed shingle beach, kindly supplied by Mr. J. H. Priestley, is full of interest. It represents an "open" Plant Association, the dominant species of which is the Yellow Horned Poppy, whilst the Viscous Senecio (fruiting in the photograph), has come in along railway embankments during the last ten to fifteen years. Observations of this kind help one to realise something of the migration of plants. A new railway line presents endless opportunities. The plants coming up on the embankments the first season after the line has been laid down will be ousted in succeeding seasons by others, and it is interesting to trace the spread of any particular species along the line, or the extermination of species by successful rivals in the struggle always going on for existence.

CLIFF VEGETATION.—The vegetation of rocky headlands depends mainly on two factors: the nature of the rock and the latitude. Where the rock is hard and massive, as in the case of granite, the vegetation is scanty and far less luxuriant than it is on limestone cliffs. With regard to latitude, the plants which are common in such a southern county as Somerset are scarce off the coast of Northumberland, and are not found beyond the latitude of Edinburgh.

The following table shows at a glance the principal plants of certain typical cliffs.

VEGETATION OF CLIFFS

CHARACTER OF ROCK.	DOMINANT SPECIES.	SUB-DOMINANT.
Rough granite	Very scanty vegetation	Chiefly Heaths and Furze.
Slates and quartzites . .	Sea Samphire Sea Aster Sea Beet	Sea Pink. Sea Campion. Sea Plantain. Scentless Mayweed. Scurvy Grass. Tree Mallow. Sandspurry.
Carboniferous limestone .	Sea Samphire	Sea Plantain, Sea Pink — abundant. Sea Lavender, Scentless Mayweed, Sea Campion, Scurvy Grass — less abundant.

Slate rocks are cut by the action of the waves into all kinds of shapes, and the vegetation in the cliffs and on the ledges of the rocks, where sand or other soil has been deposited, is sometimes luxuriant. The dominant plant is usually the Sea Samphire (*Crithmum maritimum*). This has a short zigzag stem and very much divided leaves, the narrow segments of which stand upright.

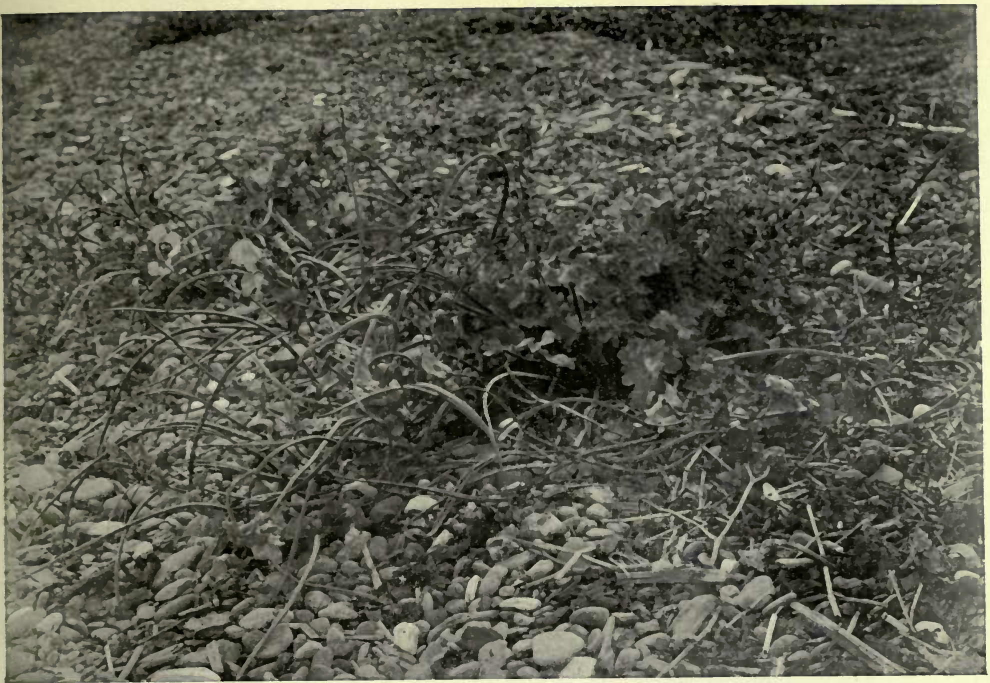

Photo from Mr. J. H. Priestley, University College, Bristol.

HORNED POPPY IN FRUIT AND FLOWER ON SHINGLE

From Mr. J. H. Priestley, University College, Bristol.

OPEN ASSOCIATION OF A NEWLY FORMED SHINGLE BEACH

Yellow-horned Poppy and Viscous Senecio in foreground

It belongs to the Umbelliferæ, and has umbels of greenish-yellow flowers. In many places the plant is not as abundant as it would naturally be, for at one time it was very much used as a condiment, owing to its aromatic properties. In some places the Golden Samphire is found in the neighbourhood of the Sea Samphire, but this is a very much rarer plant, only resembling its namesake in scent and taste. The Sea Samphire used to be found, it is said, as far north as the islands of the Firth of Forth, but it seems now to be quite extinct. The Sea Beet belongs to the Goosefoot tribe, the Chenopodiaceæ, an order which is characteristic of seashore vegetation, and comprises plants with fleshy leaves and small greenish flowers. The Sea Pink (*Armeria vulgaris*) is of all cliff plants the best known, with its cushion of green leaves and heads of pink flowers. It is alpine in its mode of growth, and is found on high mountains, another instance of the similarity existing between the vegetation of high hills and seashores. The Sea Campion is very like the Bladder Campion, which belongs to inland situations. Both have white flowers and a swollen bladder-like calyx, but the Sea Campion is of lower growth and the stems are more numerous and spreading; the petals too are broader. There are four species of Sea Lavender, the one belonging to cliffs is the *Statice auriculæfolia*; the other three frequent muddy seashores. In this species the flowers are arranged in dense spikes, each bearing two rows of spikelets with the flowers all turned one way. Each spikelet contains two or three flowers enclosed by three bracts. The calyx is green, the upper part white, contrasting with the deep purple of the petals. There are five stamens and five long curling

FIG. 6.—Sea Samphire (*Crithmum maritimum*).

white styles. The Sea Plantain (*Plantago maritima*) differs from the Ribwort Plantain of meadows and tennis lawns in its very long, narrow, fleshy leaves. It is also found on high mountains. The Scurvy Grass (*Cochlearia officinalis*) is a Crucifer, easily recognised by its spoon-shaped leaves and white cruciform flowers. The Scentless Mayweed (*Artemisia maritima*) is not confined to rocky headlands, but grows inland; when growing by the sea it is more fleshy. It is one of the Compositæ, with small flower heads, each containing three to five, or six, florets.

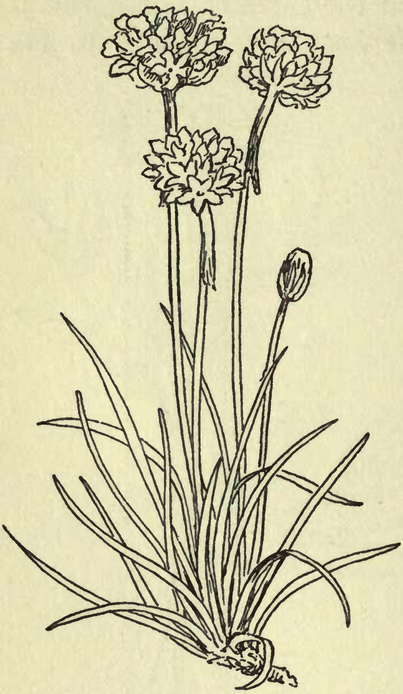

FIG. 7.—Common Thrift (*Armeria vulgaris*).

The Tree Mallow (*Lavatera arborea*) is a very local plant. It is found on the cliffs of Bray Head. There is a certain resemblance to the Common Mallow; the flowers are about the same size, and of a pale purple-red.

The Spurry (*Spergularia rupestris*) is also found in the same locality. This variety has very hairy stipules, looking almost silvery. The Spurry is closely allied to the Sandworts, but differs from them in the presence of stipules. Both the Sandwort and the Spurry have undivided petals, whereas most of the genera belonging to the Caryophyllaceæ have the petals very deeply divided. This character helps in the identification of these plants.

The following description of the vegetation of Brean Down in Somerset, by Mr. Moss, is particularly interesting, as it shows the transition from the Crithmum association of the spray-washed rocks to the Pasture association of the limestone hills. "The promontory is formed of a huge block of carboniferous lime-stone, rising to more than 300 feet above the sea-level. Perpendicular rocks, occupied by the Crithmum association, rise from the sea. At the south-western extremity, as soon as the rocks cease to be vertical but yet remain steep, the rock is covered by a thin marly soil impregnated with sodium chloride. Crithmum has here disappeared, but Armeria (Sea Thrift) is still abundant. As the summit is reached, Armeria dies out; and the remainder of the down is occupied by the Limestone associations." This transitional stage is commonly seen in the downs or pastures near the sea. Off the coast of Cornwall, in the neighbourhood of Mullion and the Lizard, where the Serpentine rocks form bold headlands, the vegetation consists of the Wild Squill, the Sea Thrift, the Lady's Fingers (*Anthyllis Vulneraria*), the Scurvy Grass, and several plants of the Goosefoot tribe. These are not found on the cliffs, but just inland, where a thin layer of soil has been deposited on the rocks. One of the most characteristic plants is the Camomile, which is noted in a history of Cornwall written in 1842. The writer, describing the neighbourhood of Liskeard, says: "Notwithstanding the rocks of granite scattered over the land, the ground was rich in flowers. Purple and gold tints prevailed in the heath and furze blossoms. Beds of Camomile exhaled an agreeable odour, covering many spots on the hillside upon the way to the town of Liskeard, distant only two or three miles." Similarly, the chalk pastures near the sea in such a county as Sussex will be characterised by maritime plants.

SEASHORE PLANTS ARE SALT-LOVING.—Plants adapted for life in salt marshes and by the seashore, where they are constantly washed by the spray of the waves, differ from plants living away from the sea in the percentage of common salt found in them. The amount of salt in plants growing inland is not usually more than 5 per cent.; it is far greater in seashore plants.

In the Sea Thrift it varies from 12·69 to 15·10 per cent.
,, Sea Aster it varies from 43 to 49 per cent.
,, Sea Artemisia it reaches 26·68 per cent.
,, Sandwort (*Arenaria media*) it reaches 36·55 per cent.
,, Sea Plantain it reaches 45·53 per cent.

These plants seem to have a craving for salt, so much so that if grown in ordinary soil they extract as much as they can from it. A species of Scurvy Grass grown on sandstone, when analysed, was found to have 41·70 per cent. of salt; a Sea Rocket grown on manured land had 15·46, and the Sea Holly as much as 19·30 in its ash.

On the other hand, plants which do not tolerate salt die if grown in soil watered with a solution of only 2 to 3 per cent. of common salt. This is true of all plants except those which belong to saline habitats—Halophytes, as they are called,—and of a few Non-Halophytes. If the structure of these salt-loving Non-Halophytes be compared with that of Halophytes, the chief resemblances lie in the arrangements for preventing transpiration. They have either a very thick epidermis, or abundance of hairs, or incurved leaves with sunken stomata, or a reduced leaf surface. They may have special arrangements for the storing of water, and in this case the leaves will be succulent. Facts of this kind help to explain the resemblance that undoubtedly exists between the flora of high hills and that of the seashore. It is true that there may not be salt in the air blowing over hills that are inland, but this situation resembles that of the seashore in one particular, namely, in the irregularity of the water supply. It has already been noted that some few plants, like the Sea Thrift, belong to both localities; but even where the plants are not the same there is a similarity of habit; they are plants of low growth, and generally of reduced leaf surface.

The colour of plants by the sea is often deeper than that of the same species growing inland in valleys. This is perhaps due to the greater number of hours of sunshine which seaside places have. It is well known that the colour of flowers is much more brilliant in deserts, at high latitudes and on mountains where the sunlight is intense and continuous. The dark blue of the Squill off the Cornish coast, the golden yellow of the Gorse, the pink of the Sea Thrift, seemed deeper than that of inland plants. It has been suggested that the blue-purple colour needs the greatest amount of sunlight energy, and white or yellow the least. From this point of view the colours of the plants of successive seasons might be observed; many spring flowers are certainly yellow or white, whilst the bluish-purple flowers belong to June and July. The Daffodil, the Celandine, the Colt's-foot, the Buttercups are yellow; the Wood Anemone, the Starwort, the Daisy (*Bellis*) are white, and these belong to spring; the Cornflower, the Knapweed, the Self-heal, the Vetches, and many another are bluish-purple, and flower in the summer months when sunlight is not only intense but of longest duration. There are, however, many exceptions, and the Violet and Bluebell will occur to every one.

Many of our cultivated plants are derived from Halophytes. The Cabbage, Cauliflower, Broccoli, Kale, etc., are cultivated varieties of the Cabbage Brassica (*Brassica oleracea*), a plant belonging to the maritime cliffs of the Mediterranean region. Thence it spread to the coasts of northern France and of southern England, and is now found on many of the cliffs of our islands, in some cases being probably an "escape" from cultivation. The Beet and Mangel Wurzel are cultivated varieties of the Wild Beet (*Beta maritima*), whose natural habitat is the muddy seashore. It is possible, though this is not certainly known, that the Radish comes from a seacoast variety of the Wild Radish, *i.e.* from *Raphanus maritimum*. The Horse Radish (*Cochlearia Armoracia*) is not an indigenous plant, but it has become naturalised near the sea. The Carrot is probably an original native of the seacoasts of Southern Europe.

The Asparagus has its natural home in the maritime sands, or sandy plains, of Central and Western Asia, whence it spread to the Mediterranean and western coasts of Europe. At the present time the Wild Asparagus is confined in Britain to the south-western shores of England and to one or two counties of Ireland.

Lastly, the Coconut tree (*Cocos nucifera*), so much cultivated in the tropics, grows under natural conditions only on the saline soil of the seashore.

PRACTICAL WORK.—On *sandy seashores* note the effect of the wind. If the most prevalent winds are those that blow towards the shore, the sand is heaped up into dunes; on the other hand, if the predominant winds are generally off-shore, the sand is continually blown back into the sea and dunes are not formed.

Look for "ripple marks," which may often be observed on blown sand. The sand grains, pushed along by the wind, travel up the long slopes and fall over the steep slopes. Not only do the particles travel, but the ridges also follow each other more closely.

On sandy seashores the following belts may be observed :—

1. The foreshore. This is the strip between the ordinary high-tide mark and low-tide mark. This is periodically washed by the waves, and presents alternately terrestrial and aquatic conditions. It is almost constantly exposed to the spray; evaporation goes on rapidly, and the temperature is constantly changing. The vegetation is in consequence limited, consisting mostly of annuals or perennials with long creeping rhizomes.

2. The midshore comprises the belt of sand between ordinary high tide and spring tides.

3. The upper shore is the strip between the middle beach and the sand-dunes, if these are formed. There is more humus in the soil, because there is more vegetation. The spray of the waves reaches this belt, and sand is constantly being blown by on-shore winds from the midshore.

4. If sand-dunes are formed they will occur to landward of the upper beach, but dunes are not always present. The sandy coast may rise quite gradually without any sharp line of separation into woodland or grassland. The formation of dunes depends very largely on the direction of the prevalent wind.

The influence of the wind is also very evident in the distance to which the spray of the waves may be carried, making the atmosphere salt ; this is very well seen off the Cornish coast, where the storms are often very violent. The branches of the trees grow with an inclination towards the opposite direction from that whence the wind blows, so that the trees seem one-sided.

5. On *pebble beaches* the following observations are suggested.

The larger stones are heaped up on the higher part of the beach, forming a ridge, the smallest pebbles being nearest the sea.

The shape of the pebbles is flat, not round, as in rivers. This indicates that they have been pushed, not rolled along.

The shingle is very generally arranged in festoons or scallops, sometimes for miles in length. This arrangement has been attributed to the crossing of waves.

The effect of a strong on-shore wind, or of a heavy ground swell on the shingle, should be noted. It may be almost entirely carried away.

The two lines of seaweeds are clearly seen on shingle beaches; one line marks the high water at the last spring-tide; the other is the high-water line of the last tide.

The pebbles which have seaweeds attached to them have probably been pulled to their position by the seaweeds.

The characteristics of plants belonging to the shingle may be ascertained by comparing them with each other.

6. In observing the vegetation on *cliffs* the geological character of the rock should be ascertained before it is possible to compare one flora with another. It is easy to distinguish stratified from unstratified rocks. Granite is unstratified, limestone stratified. To some limited extent it is possible to recognise rocks by their colour. Chalk is white; unweathered clay is blue, but the action of the atmosphere on it gives it a yellow tint, and the effect of burning it is to convert it into a brick-red. The old red sandstone is red in colour, but red may also denote the presence of iron; it is not therefore safe to depend on colour alone. Limestone may be detected by testing with a strong acid; a piece of limestone rock effervesces when hydrochloric acid is poured on it. A geological map of a district will give the geological formations, and enable any one to ascertain the nature of the cliffs.

The plants belonging to each kind of cliff can only be a matter of gradual observation. Lists should be made of the plants found at different seaside places, and compared with each other. It is impossible to generalise until a great many places have been visited. It will be found that some plants are common to all shores; for what they want is salt. To determine in any particular case whether the plant requires salt or not, it may be transplanted to ordinary garden soil and watched. If it thrives without any addition of salt to the soil, it is independent of salt; but the majority of plants growing by the sea will not flourish in an inland garden unless the soil is watered with a solution of common salt.

Observations of Plant Formations.—The Plant associations occurring in the different belts of the shore should be carefully noted in this order: 1. Those nearest to the sea, whether on cliff or in mud or on sand. These are open associations. 2. The Intermediate associations, which may be two or three in number, and are on the landward side of the open associations nearest the sea. 3. The Pasture associations. These comprise the plants of—(*a*) The sand-dune pasture ; (*b*) the salt marsh ; (*c*) the cliff. In all these pastures, many seashore plants will be found, for the spray is blown by the wind some little distance inland and the plants thus get the salt they require.

The best way of getting an idea of the way in which a Plant formation arises is to watch the colonising of a new piece of ground, as, for instance, a railway embankment along a newly made line. The first plants to appear should be recorded ; then their destruction by other plants. The gradual migration of plants into a new district from an adjoining area is an observation full of interest.

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CHAPTER II

Aquatic Vegetation

Aquatic vegetation includes both salt and fresh-water forms. These two groups are connected by the plants, few in number, belonging to brackish water, which is found at the mouths of rivers, in salt marshes that are gradually being reclaimed, and in inland saline lakes.

The flora of the sea, as distinct from that of the seashore already described, consists mainly of Algæ, red, green, and brown. In fresh water the predominant plants are flowering, and only the green Algæ are usually found. In addition to flowering plants, certain Mosses, some few Ferns, and other Cryptogams occur in fresh water, but are absent in salt water. Among Mosses may be mentioned some species of the Fern Moss (Hypnum), and the Bog or Sphagnum: The Marsh Fern (*Aspidium Thelypteris*), the Pillwort, the Quillwort, and the Bog Equisetum are instances of fresh-water Cryptogams; these groups are entirely absent from the sea flora. There is thus a striking difference in fresh-water vegetation compared with marine.

The flora of the seashore, with the exception of the Seaweeds, is mainly terrestrial, not aquatic; at the same time, it is profoundly influenced by the sea, for the sea water bathes at every high tide the belt of vegetation growing on the shores, and the spray, containing salt, falls on the cliffs and gives salt-loving plants some of the food material they require. The effect of this perpetual motion of the waves on vegetation may be compared with the effect of flowing water on fresh-water plants. The flora of a stagnant pond is different from that of a stream or river. Water in motion makes great demands on the resisting power of plants; in structure it will be seen that they have far more highly developed strengthening tissue than those which merely float on the surface of the water.

SUBMERGED AQUATIC PLANTS.—Some aquatic plants live an entirely submerged existence: they even flower, and are pollinated under water; they form seed, which is dispersed by water. The habit of life of such plants is naturally very different from that of land plants, and also from those aquatic plants which have their roots and some of their leaves in water, but otherwise lead a terrestrial existence. In some ways life is easier for these plants. To begin with, they are not exposed to the rapid changes of temperature that are often so trying to plants that live under atmospheric conditions. The temperature of water is more uniform; even when a hard frost occurs, the submerged vegetation is protected, for the ice floats to the top and the plants are sheltered in the less cold water flowing beneath. Again, they are not exposed to the frosts of early spring, which affect the blossoms of land plants. Then the whole surface of a submerged plant is able to absorb water and the substances dissolved in the water, and this facilitates nutrition. Plants that live an entirely submerged existence can only do so when the water is sufficiently clear and the upper surface free enough of vegetation to allow the rays of light to penetrate. The Alga, Nitella, for instance, is found in Lake Constance at a depth of about thirty yards; in more turbid waters it is only found at a depth of twelve yards. Below a depth of six yards it is unusual to find Flowering Plants. Some of these submerged plants have more or less upright stems with cylindrical leaves, as the Quillwort and the Pillwort, found on the edges of lakes in clear water; others have their stems parallel to the surface of the water; they have long shoots, adapted for floating in the water, *e.g.*, certain species of Pondweed (*Potamogeton*).

Submerged plants are usually very rapidly propagated. Many do not form seed, but multiply vegetatively. A twig of a water plant, broken off from the parent stem, is able to lead an independent existence and form a new plant. It is in this way that the American water-weed, *Elodea canadensis*, has spread in the short space of sixty years through Western Europe; it was first observed in Britain in 1847, in Yorkshire, Leicestershire, and near Berwick and Edinburgh; now it is found in most ponds, canals, and slow-flowing streams.

The structure of an aquatic plant differs from that of a land plant mainly in four respects :—

1. The root-system is either absent or very much reduced. The main function of the root is to fix the plant in the bed of the stream, or on some stone or wood, etc. ; it is not engaged to any appreciable extent in the absorption of food material and in its conduction, as in the land plant.

2. The length of the shoot is very much longer in a water plant, for the light is less intense, and strong light retards growth in length. A transverse section of the stem of a submerged plant shows a comparatively undeveloped vascular system. There is often very little of the woody tissue which helps to support a land plant (Fig. 8).

3. The cuticle of the leaves is usually thin, or even absent ; the whole surface is engaged in absorption, and there are no stomata in submerged plants, although they are naturally present in large numbers on the upper surface of the leaves of floating aquatic plants.

4. Water plants have air spaces, which make them light.

Submerged aquatic plants may be arranged in the following groups :—

(*a*) Plants fixed to stones in running water. These include some Mosses and a few tropical plants with very much reduced flowers.

(*b*) Rosette plants, rooted in the ground, generally with cylindrical leaves. These belong to the more or less shallow and still waters of pools and lakes. The Cryptogamic plants, Pillwort and Quillwort ; and the flowering plants, Awlwort and the Water Lobelia, are the best known instances.

(*c*) Plants rooted in the soil, or free swimming, with long flowing shoots. The Slender Naiad, common in N. America, but found only in a few places in Britain ; the Hornwort, a free swimming form, belonging to pools, and adapted for pollination in water, and the Whorled Milfoil may be mentioned. One or two other plants, as the Water Soldier (*Stratiotes*), are almost entirely submerged, and in general habit may be grouped with these.

The Pillwort (*Pilularia globulifera*), is not a flowering plant, but bears spores which, unlike those of the fern, are of two sizes, large and small. These are situated in bags or sporangia, which are contained in receptacles that look like little pills covered with short hairs; hence the name of the plant. The stem creeps under water, rooting at every node. The leaves are very narrow, and grow upwards; they are bright green, from one to three inches in length, and rolled inwards at the top, just as the frond of a fern is.

The Quillwort (*Isoetes lacustris*) is found in the shallow water by the edges of lakes, as, for instance, near a boathouse. The easiest way of getting it is to go out in a boat a yard or two, to a spot where its dense, dark green tufts can be seen through the water, and then to pull it up from the bed of the lake. The root-stock is very short indeed, and bears tufts of leaves. The spore-cases are enclosed within the base of the leaves, and the spores are of two sizes. These plants with two sets of spores form a link between the Ferns on the one hand and the Flowering Plants on the other. The small spores may be compared with the pollen grains of the flowering plant, and the large spores with the embryo-sac of the ovule.

The Awlwort (*Subularia aquatica*) also belongs to the shallow edges of ponds and lakes, more especially to alpine districts. It is found in the mountainous regions of Scotland, North-western England, North Wales, and Western Ireland, but is by no means common. It is usually entirely submerged, and is about two inches high. The leaves are radical, the flowers have minute white petals. The pod is short and broad, and dehisces from the base upwards, as in the Crucifers generally.

The Naiads—the nymphs of waters and springs in classical lore—are slender submerged plants with linear leaves often crowded into clusters; the flowers are small and sessile in their axils. There are three species occasionally found in this country: the Slender Naiad in Perthshire, Skye, and Connemara; the Holly-Leaved Naiad, found only in Hickling Broad, Norfolk; and the Grassy Naiad, in Lancashire. This fresh-water genus is not nearly as common as the marine herb, the Grass-Wrack, which belongs to the same order. This latter has a creeping stem, which roots in the sand or mud and is found most abundantly at or below low-water mark. The Hornworts have no roots, the absorption of food taking place entirely from the surface of the leaves, which are cut up into thin, linear segments. Pollination takes place under water. Each staminate flower has from twelve to twenty anthers. When mature they contract slightly, and squeeze the pollen into the water. Being of the same specific gravity as the water it does not sink, but is almost sure to reach the stigma, as it is very plentiful. The Hornwort is very fairly common in pools, or slow streams, or ditches near a river, or on the shallow edges of lakes.

The Whorled Milfoil (*Myriophyllum verticillatum*) has even its flowers in water, and it inhabits deep, clear water. The Spiked Milfoil creeps and roots in the mud under water, its flowering spike coming above the surface. Both plants have very fine whorled leaves; the latter is the more common species in Britain. In general appearance the Milfoils are not unlike the Hornworts.

The Water Soldier (*Stratiotes*) leads during the greater part of its life a submerged existence. During the winter it remains at the bottom of the pond. When spring comes it rises to the surface, producing fresh leaves, floating roots, and as the summer comes on, flowers. After flowering it sinks again, to mature its fruits and seeds and to develop buds for the production of young plants. Towards the end of August it rises again, the young plants having now grown up, though not yet as large as the mother plant. For a time the parent plant, not unlike an American Aloe in appearance, floats on the surface with the younger plants attached; then the connecting stalks die and decay, each little rosette is liberated and sinks to the bottom, and all hibernate till the following April. This plant is common in the fens of eastern England, and has been found in Lancashire and Cheshire.

The Water Violet (*Hottonia palustris*) has the creeping habit of entirely submerged plants, the flowering stems alone coming out of the water. The leaves are submerged and cut up into fine segments, as those of water plants often are The flower-stem bears three to five or six pale purple flowers. This plant belongs to the Primulaceæ, and frequents central and eastern England rather than the west. The Water Lobelia (*Lobelia Dortmannii*) is another aquatic plant that flowers above water. It has tufts of hollow, radical leaves, the dense green carpet of which can be seen through the clear water at the edge of a lake. The leaves may be recognised by their backward curve, and by being composed of two tubes, clearly seen when the leaf is cut across. The tall flower-stem arises from the centre of the rosette, and lengthens until the lowest flower is well above the water. The flowers are pale blue; the corolla is inclined to be two-tipped, and the five anthers form a ring round the style. In the irregular corolla and the union of the anthers the Lobelia differs from the other members of the Campanulaceæ with which it is associated.

The Pipewort (*Eriocaulon septangulare*) grows in certain districts with the Water Lobelia. The root stock is creeping, and bears on its under surface long, white fibrous roots, and at its extremity grass-like leaves. The flowering stem rises above the water, and is usually marked with seven raised lines, whence the name "septangulare." The flowers are mottled white and black, and arranged in a dense tuft, those in the centre being staminate, those at the edge pistillate. The distribution of the plant is limited in our islands to the Irish lakes, where it is often very abundant, and to Skye and the neighbouring islands.

THE VEGETATION OF STILL WATER: (*a*) PONDS AND LAKES.—Ponds are abundant in pastures, especially if there is a substratum of clay. They are often found where two hedges at right angles to each other join, and on the shady side of the hedge, for in such a situation the cattle can get shelter from the noonday sun whilst quenching their thirst. If the pond is not under the shelter of the hedge it is generally planted round with Hawthorn, or Willow, or some other shrub, gaps being left for the animals to gain easy access to the water. In early spring a pond of this kind, with the Hawthorn hedge just coming into bud, perhaps a Willow bough overhanging, and the weeds just beginning to show their green leaves on the surface of the pond side by side with some of the old autumn ones that still float on it, makes a restful spot in the monotony of the pasture. The Duckweed may cover the whole surface, or only bits here and there near the edge; tangles of yellowish-green Algæ, which have been engaged during the winter in propagating themselves at the bottom of the pond are now rising towards the surface to get as much light as possible for the new growth which is to take place during the spring and summer. Patches of the Common Reed border the banks, which may be almost covered with the glossy yellow blossoms of the Celandine and the pale lilac of the Cuckoo-flower. Even as early as the middle of April, after a severe winter, the Water Crowfoot may be in bloom, its white flowers above the water making it conspicuous. This plant has two sets of leaves: those in the water are very much cut up, presenting a large area to the water; those above the water are not cut up, but float flat and dry on the surface, enabling the plant to hold its flower-stems well up out of the water. After flowering, the flower-stalk curves downwards, and the fruit ripens beneath the water. There are several varieties of this species: some are found in running streams, others in deep still waters; it varies very much with the situation in which it is growing.

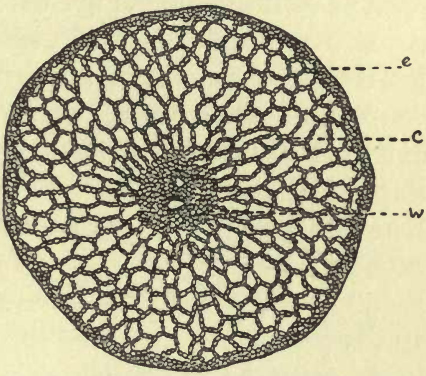

FIG. 8.—Stem of Potamogeton (transverse section). *e*, Epidermis; *c*, cortical tissue with air-spaces; *w*, conducting tissues.

In summer most ponds have some species of Potamogeton or Pondweed. There are a large number of these Pondweeds, which mostly resemble each other in having a root-stock that creeps in the mud, very narrow leaves in the water, and usually much broader leaves that float on the surface. The chief variation is in the leaves: the majority of species have both submerged and floating leaves; in others the broad leaves are borne under the water, and occasionally the floating leaves are not broad, but narrow. A comparison of the plants found in still water undoubtedly shows that their habit is to float; not only the leaves, but the stems can float. A transverse section of a Potamogeton (Fig. 8) shows the structure of a stem adapted for floating. The cortex has very large intercellular spaces, filled with air; these make the plant very light, enabling it to float, and they also serve to convey the air to the lower parts of the stem growing in the deeper water, or creeping in the mud. The woody tissues which support land plants are in these water plants very much reduced, and are placed in the centre—not midway, as in land plants—for the weight of the plant as it floats is supported by the water, and the strain in still water is very slight. The structure of the leaf is also adapted to the floating habit. Leaves of this kind are usually round, or entire, or very slightly lobed; they bear stomates on their upper surface, which is usually very glossy owing to the wax that covers it and prevents it getting wet. Kerner gives 11,500,000 stomates for the average-sized leaf of the Water Lily.

The water of ponds, is, as a rule, shallow enough to be penetrated by the rays of light throughout its whole extent; in freshwater lakes the depth may be considerable, and in these, three regions of illumination are distinguished:—

1. The bright region, in which the intensity of light is sufficient for the development of flowering plants.

2. The dim region, where most flowering plants can hardly exist. Below a depth of two yards the green alga Chara forms an important part of the vegetation; below seven or eight yards Nitella takes the place of Chara, and a few Mosses may be found with it.

3. The dark region, where vegetation is very scanty indeed, and is practically confined to plants without green leaves.

It must be remembered that the depth to which light penetrates water depends on the clearness of the water, and that varies with locality and season. In Lake Geneva, in September, a photographic plate became slightly dark at a depth of 170 metres, and very dark at 120; whilst in April, even at a depth of 250, light was not altogether absent.

The following regular succession of plants has been observed off Scotch lochs:—

(*a*) Marsh plants, such as Sedges and the Lesser Spearwort, mix with the Meadow Clovers and Grasses, where the soil is water-logged.

(*b*) A narrow belt of Rushes.

(*c*) Iris or Sweet Flag, where the water is less than eighteen inches.

(*d*) Reeds, such as Scirpus, from two to four feet.

(*e*) Water Lilies, the rhizomes of which may be at a depth of nine feet.

(*f*) Pondweeds, chiefly *Potamogeton natans*.

(*g*) Open water, with Diatoms and other Algæ, chiefly Chara and Nitella.

Of these, the Reed association is the one that varies the most. With the *Scirpus lacustris*, sometimes the dominant form, may be associated the Common Reed, *Phragmites communis* (a true grass), or a species of Equisetum (E. *limosum*). The Common Reed, with its horizontal stem and vertical branches, is of great service in enabling the plants to get out from the edge into more open water. Other plants commonly found with the Reed association are the Flowering Rush, the Water Plantain, and the Arrowhead—plants which also belong to running water. With regard to the Water-Lily association, it is found in Switzerland and Germany that the Yellow Water Lily succeeds the White. The Quillwort may also be found in this belt. It is interesting to note that the Duckweed, characteristic of ponds is not found in lakes.

Fresh-water lakes, to which the sea may have had access in past geological ages, often have a flora of peculiar interest. The shores of Lough Neagh yield the following maritime plants: the Sea Scirpus, Field Cerastium, Stork's Bill, Hare's-foot Clover, and Sandspurry. Many water plants, such as the Awlwort, the Water Parsnip, the Elongated Carex, used to be found there, but seem to have disappeared with the lowering of the level of the lake.

Many of the plants mentioned as characteristic of the edges of lakes are also found in very gently flowing water in canals and in back waters. The Creeping Scirpus, the Water Plantain, the Arrowhead, Sweet Flag, the Flowering Rush are instances. It would be easy to make records of the plants found by the side of any of the numerous canals which intersect the country; they should be visited early in the summer, before vegetation begins to decay, as they are not then very pleasant.

(*b*) Bogs and Fens.—It is not always easy to distinguish a bog from a marsh, the transition from one to the other being sometimes very gradual. To most minds the term "bog" recalls soaky, peaty ground in the midst of a heather moor; but bogs may be formed on other soil than peat, provided it is a soil that does not allow the water to percolate through, as on Fuller's Earth. The character of the vegetation in marshy and boggy ground depends on whether the soil is peaty and the water rich in mineral substances such as lime. The water of peat bogs is poor in lime, and the plants are mostly slow growing and dwarfy. A marsh usually has water rich in mineral substances, and plants grow rapidly. Bogs may be found at any height, from a few feet above the sea level to several thousands; but a marsh is more usually on low ground, on the outer margins of ponds and streams and in hollows where drainage is deficient; it may even mark the position of a former pond which has been filled up and drained. Plants living on marshy ground will be superseded by other species if the ground is drained. This is very well seen in deserted brick ponds. As the water gets less and less, different plants begin to appear on the sides, which are drier than they were when the pond was fuller; by degrees plants which do not care for a moist soil establish themselves, and in a few years the vegetation may seem almost xerophytic. The following plants were gathered on the slopes of a deserted brick pond in April: Colt's-foot, Groundsel, Rockcress, Stinging Nettles, Purple Deadnettle. There was very little water left in the pond, and only some algæ in it. What time has elapsed since that pond was first deserted is not certainly known, probably at least ten years.

Insectivorous plants are characteristic of peat-bogs; these plants get the nitrogen necessary for their life from the insects on which they feed. A great many experiments were tried by Darwin, in order to ascertain whether these plants would absorb non-nitrogenous fluids. He placed drops of distilled water on the leaves of Sundew, but the tentacles which are situated on the edge of the leaf remained motionless; then he tried solutions of gum arabic, sugar, starch, alcohol, even tea, but in experiments on sixty-one leaves no effect was produced; the tentacles would not respond to the stimulus of non-nitrogenous liquids. The case was very different with nitrogenous foods, such as milk, albumen fresh from a hen's egg, saliva, isinglass, etc. In the case of milk he found that the tentacles took forty-five minutes to become inflected; that in two cases the blades of the leaves were so much curved inwards that they formed little cups enclosing the drops of milk; that the leaves expanded on the third day. Altogether, Darwin experimented with nitrogenous fluids on sixty-four leaves, and found that sixty-three responded. Care has to be taken to select young and active leaves, as old ones have not sufficient power of response. These experiments certainly seemed to show that non-nitrogenous matter did not stimulate the leaves of the Sundew; to place the matter beyond a doubt, Darwin tested the same leaves with bits of meat, and found they did respond, though not so readily as fresh leaves, for their powers had been somewhat impaired owing to the experiments with non-nitrogenous material. Other experiments were performed to ascertain the nature of the process. Darwin found that the glands in the knob of the tentacles of Sundew have the power of secreting a ferment analogous to the pepsin contained in the gastric juice of animals; this ferment in the presence of an acid dissolves nitrogenous compounds. The length of time during which the tentacles remain inflected depends partly on the quantity of the substance given; they remained inflected longer over large bits of meat than over small ones, and only the tentacles on the same side as that on which the meat was placed bent in, whilst those on the opposite side remained distended. To repeat some of Darwin's experiments as recorded in his book on Insectivorous Plants would give a far better idea than any description of the response of these plants to the stimulus of nitrogenous objects.

Insectivorous plants may be arranged in two groups: (1) Those that catch insects by means of traps; (2) those that perform movements in the capture of their prey. To the first belong the Bladderwort; to the second, the Sundew and Butterwort. There are three fairly common species of Bladderwort. The most common is the *Utricularia vulgaris*, which is found in deep pools. It has not true roots, but root-like floating branches, sometimes nearly a foot long. The leaves are very much divided, and bear bladders. The flower-stem is six to eight inches high, bearing a few large yellow flowers, which are generally over by the end of August, or even earlier. The smallest Bladderwort (*Utri-*

cularia minor) has much smaller floating branches, not more than three inches long, and the leaves have few bladders; the flowers are pale yellow and much smaller. This is a commoner species than the other. The Intermediate Bladderwort (*U. intermedia*) differs from these two species in the fact that the bladders and leaves are borne on different branches; it is a rarer species than the other two, and does not often blossom. The bladders are modified leaflets, each attached by a little stalk to the submerged floating stem. At the upper end of the sac-like bladder there is a small opening, around which are a number of stout forked bristles (Fig. 9). The opening is closed by a valve, which opens inwards, and shuts like a spring door against the thickened rim of the aperture. By means of these bladders the plant captures an immense number of small aquatic animals. Darwin found four, five, eight, or even ten, minute crustaceans in the bladders he examined. What attracts these animals to the bladder is not positively known; they may be seeking a hiding-place from larger animals, and the bladder being transparent may attract them. They push against the valve, which yields at once, then as soon as the animal has entered closes again, so that it cannot escape. The bladder is lined with cells adapted for absorbing the products of the decaying body, but there does not appear to be any special digestive juice, as in the Sundew.

FIG. 9.—Bladderwort (*Utricularia*). A single flower and bladder on the right.

It is easy to recognise the Sundew from the long bright red hairs, or tentacles, on the edges of the leaves. The three species may be distinguished from each other by the following characters. The Round-leaved Sundew has round leaves, lying almost flat on the ground; this is the most common species. The Long-leaved Sundew (*Drosera anglica*) has upright leaves, about six times as long as they are broad, and a flowering stem which rises erect from the centre of the leaves. The Intermediate Sundew may be recognised by the flowering stem, which is horizontal in its lower part, then erect. These plants perform movements by which the insect is caught. The tentacles, as already described, bend over, the leaf curves over, and the animal is digested by the juice secreted by the gland of the tentacle.

FIG. 10.—Sundew (*Drosera anglica*).

Another insectivorous plant that performs movements by which insects are entrapped is the Butterwort, which thrives on damp spots, the neighbourhood of springs, banks of brooks, peat-bogs. Very often it is found in company with the Sundew. The Butterwort has its leaves to some extent permanently incurved; insects washed down by the rain are thus caught by these incurved margins. The leaves are covered with two sets of glands, which secrete mucilage and an acid digestive fluid. It has been calculated that there are 25,000 mucilage secreting glands on a square centimetre of a Butterwort leaf, and that six to nine leaves will have about half a million of them. The body of the insect is digested by the acid juice. It has been found by experience that inorganic material, such as grains of sand, do not stimulate the secretion of either the mucilage or the digestive acid. The Butterwort bears slender flower stems, each with a single two-lipped purple flower, which is spurred. The Butterwort bears transplanting very well, and will flower in a window box, provided it is on the shady side of the house and that the soil is kept moist with bog-moss. The number of insects that these plants will catch is almost incredible. Darwin relates that 142 insects were found on thirty-two leaves, which had also entrapped leaves of such plants as Heather, Sedges, and Rushes. The insects included small flies, some ants, a few small beetles, spiders, and even small moths.

Another feature of most bog plants is their xerophytic character, perhaps owing to the fact that the peat-water can be tolerated by plants of this habit. The Cotton Grass, several species of Carex, the different heath-like plants found in the drier parts of peaty bogs are instances of this. It is in the Lake district and in the Scotch Highlands that bog plants are seen in their perfection. One gets to associate certain flowers with the Wordsworth country, as, for instance, the Bog Asphodel with Blea Tarn on the Langdale Pikes. The Grass of Parnassus, Bog Orchids, the Bog Myrtle, Bog Cinquefoil, Buck-bean, Bog Pimpernel are all characteristic of peat-bogs. The Grass of Parnassus is in flower in August. When in bud the flower looks like a round ball, the white petals of which may be seen through the green calyx. There are five stamens with perfect anthers, and five bearing instead of anthers a tuft of filaments with yellow glands that answer to nectaries, though they secrete no nectar. The pollination of the plant should be watched. The anthers liberate this pollen one at a time ; if an insect in search of honey alights in the middle of the flower it is certain to brush itself against the anther which has dehisced that very day. If, however, an insect crawls in from the edge of the petals, it has to climb over these yellow knobs to get the honey, and in so doing must almost reach the centre of the flower, and thus it comes in contact with the anther. Thus the Grass of Parnassus can be pollinated by different insect visitors, by those which alight from above as well as by those which crawl in from the edges. The greater the number of insect visitors, the more certainty is there of pollination taking place in seasons, in which insects are few. The Bog Myrtle (*Myrica Gale*) grows to a height of three or four feet ; the leaves are fragrant when bruised. Generally the stamens are on one plant, the carpels on another. This shrub is wind-pollinated.

In exploring a bog it will soon be noticed that some plants are found in the little pools formed on the surface of the peat ; others cling to the sides of the pools, others again belong to the drier parts. The Buckbean is not confined to bogs, but is also found in shallow ponds, it belongs to the wetter soil of the bog ; it has densely matted roots which creep along in the black peat, or in the mud of a pond. Its flowers are pure white within, but fringed with pink on the outside, the petals are fringed with white

Photo from Mr. J. H. Priestley, University College, Bristol.

DITCH IN A PEAT MOOR, COMPLETELY FILLED WITH BUR-REED
(Sparganium ramosum)

filaments, which form a contrast to the red stamens within. There are long-styled and short-styled forms, as in the Primrose, to ensure cross-pollination, and the fringes on the petals keep out insects that would be too small to pollinate the flower. In the month of August the Buckbean is in fruit, and the flowering spikes stand some six inches or more erect above the surface of the bog, bearing brown, withered-looking capsules. The name Buckbean is due to the leaves bearing some resemblance to those of the Broad Bean.

The Bog Pimpernel clings to the sides of the pools. It has very delicate leaves and pale pink flowers. The stamens are joined together by the bases of the filaments, and are densely clothed with long white hairs to protect themselves from small insects. The Marsh Pennywort often covers the boggy ground with its large green leaves in the shape of a penny. It is one of the smallest of the Umbelliferæ, with very minute greenish flowers tinged with pink.

FIG. 11.—Bog Pimpernel (*Anagallis tenella*).

The Bog Cinquefoil (*Potentilla Comarum*) is often softly hairy on both sides, a xerophytic character. The outer side of the calyx is brightly coloured,—in fact, the whole plant is often a bluish-purple, and the stem is, as occurs frequently among bog plants, creeping. Among Bog Orchids may be mentioned the Bog Malaxis, which flowers late in summer and is not easy to find. It inhabits spongy bogs, and is only three or four inches high. From the root-stock a small bulb is produced out of the ground, and there are three or four radical leaves. The flowers are very small, of a greenish-yellow. The "labellum" is short, and arches over the stamen and carpel; the place usually occupied by the labellum is taken by the central sepal, which acts as a platform for insects.

The Plant associations most common in bogs are:—

1. The Sphagnum association, in this the Bog Moss is the dominant species.

2. The Cotton Grass or Eriophorum association, with the Cotton Grass dominant.

FIG. 12.—Lesser Spearwort (*Ranunculus Flammula*).

Both these have already been fully treated in connection with the vegetation of moorlands (Vol. IV.)

3. The *Juncus Sphagnum* association. This is found at an altitude of nearly 2000 feet. The Sphagnum and the Hair Moss (*Polytrichum*) form a dense undergrowth, sometimes a foot in height, whilst the Common Rush (*Juncus communis*) and sometimes other species form a thick overgrowth. In this association the Rushes and the Mosses are equally dominant; it is not developed on thick peat, but rather in soil which contains plenty of humus material and water which is not stagnant but slowly moving. The sub-dominant plants are: Lesser Spearwort, Ling, Red Rattle, Sheep's Sorrel, some Carices, Bedstraws, and Grasses. Sometimes the insectivorous plants, Sundew and Butterwort, occur; it depends, in part at any rate, on how water-logged the ground is.

The vegetation of the Fen country affords considerable material for observations of all kinds. In no part of England has the influence of man been greater. Hardly any of the original fen remains untouched; only at Wicken is it possible to see the flora that used to cover the whole district. Nearly all the Fen country has been drained and reduced to cultivation, each field, be it potato or corn, now has the weeds that belong to cultivated areas. The introduction of roads, usually mended with chalk, accounts for another set of plants not natural to the Fen region. Apart from the plants due to the influence of man, the Fen district offers a great variety of vegetation, for it is possible to trace at least three distinct deposits in this region. There is the gravel brought down by the rivers; the peat formed by the flooding of the district and accumulation of vegetable matter, now reaching a thickness of twenty feet in parts; the silt deposited by the sea, as it burst in behind the Alluvium, is laid down in considerable quantity over the level ground on which a river spreads when in flood, for the water in spreading out on the plain loses velocity and consequently power of transport, and the mud, soil, etc., held in suspension falls on the plain. This must have happened over and over again in the Fen country, and accounts for the presence of gravel and peat in this region; the villages usually stand on gravel beds, which are nowhere higher than 56 feet, and slope down in some parts under the peat and silt. The peat has ceased to grow, probably because the climate is getting drier; it occupies a larger area of fenland than the gravel, and is characterised by an almost even surface and the absence of hedges. Ditches lined with the Common Reed—a true Grass —*Phragmites communis*, take their

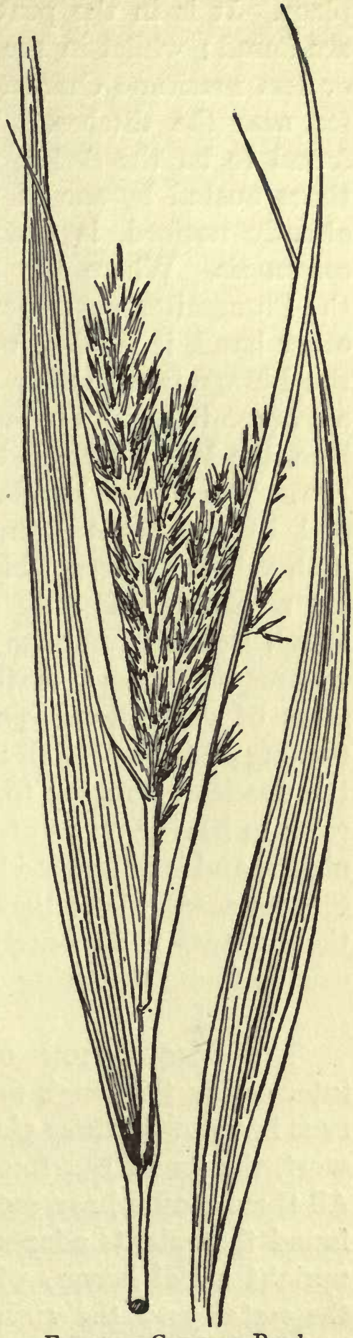

FIG. 13.—Common Reed (*Phragmites communis*).

place. It is in the peat area that the characteristic Fen plants are found; whilst in the silt land there will be plants of a more or less maritime character. The Fen plants should be looked for near the ditches. The dominant species will probably be found to be the Sedge, *Cladium germanicum*; but this is sometimes ousted by one of two Grasses, *Molinia cœrulea*, which, as already noticed, is characteristic of wet moors, or *Phragmites communis*. Where the ground is subject to frequent flooding the Phragmites ousts both the Molinia and the Cladium; on the other hand, if flooding occurs but rarely, the Cladium drives out the Phragmites. Other plants belonging to what may be called a Phragmites, or a Cladium association, are: The Yellow Meadow Rue, the Marsh Marigold, the Larger Convolvulus, and the Marsh Pea. The Yellow Meadow Rue grows from two to four feet high, and has, like the Ranunculaceæ generally, numerous stamens with yellow anthers, which make the flower conspicuous, as there are no petals and only small sepals. The Convolvulus and the Marsh Pea are climbing plants that make use of the Sedges and Grasses as support, matting the whole together into a luxuriant mass of vegetation. The Convolvulus climbs by means of its twining stem, the Marsh Pea by tendrils. The Larger Convolvulus, the species belonging to the Fen ditches, differs from the Bindweed in having no scent. The flower remains open on moonlight nights, and is pollinated by the Convolvulus hawkmoth; it seldom sets its seeds where that does not occur. The shade formed by these plants is so dense that certain Ferns and Liverworts are usually found sheltering under them.

THE VEGETATION OF RUNNING WATER.—In the ditches intersecting the rough meadows of the Fen country, where water runs but slowly, three plants are usually found, the Greater Spearwort, the Small Bur-Reed, and the Sedge (*Carex Pseudo-cyperus*). All these plants have more or less grass-like leaves, and it will be found that plants adapted for life in running water usually have upright aerial leaves, which enable them to stand the flow of the water and the rush, often considerable in time of floods. This type of leaf is more usual in monocotyledons than in dicotyledons, the parallel veins of monocotyledonous leaves suit the vertical habit better than the net-veined leaf of the dicotyledon; a large number of the plants growing in or by running water are monocotyledonous. Where the running water is very shallow, and the plants are to some extent submerged in it, the leaves are not vertical; the plant is on the whole creeping. In most rivulets and brooks the Brook-Lime, the Apium, and the Water-Cress are to be found. The Brook-Lime is one of the Veronicas, and has the characteristic bright blue flowers of that genus; in this species they are not as large as in the Germander Speedwell, a common weed that flowers early in spring on roadsides and hedgebanks. It is a smooth shining plant with succulent stems and oval glossy leaves. Like the Brook-Lime, the Apium or Marshwort has a creeping stem and erect flowering branches. The whole plant is smooth as water plants generally are. Each leaf consists of from three to ten pairs of leaflets; the flowers are white. This is a very variable plant; in certain situations it may be several feet in length, but it is usually very much shorter. The Water-Cress (*Nasturtium officinale*) is a cruciferous plant, now very much cultivated, especially in the southern counties. Great care is now taken that the water in which it is grown should not be contaminated by sewage. It is important that the beds should be near the source of the water supply, in order that the temperature may vary as little

FIG. 14.—Marshwort (*Apium nodiflorum*).

as possible; a gravelly loam is the best soil; loose sandy loam, pure clay and peaty soils are to be avoided. The Cress is propagated by division of the plants: this is done between hay-making and harvest, and is continued until the end of October. The top of the plant is cut out, the length of the cutting averaging one foot, but this varies according to the depth of the water. Some growers cultivate stocks for planting in smaller streams isolated from the main bed, in order to get more robust plants. The beds should be thoroughly cleaned out and replanted each season. The growing of Water-Cress is not a very remunerative industry, but it does give employment during the great part of the year to those engaged in it.

The presence of a stream has great influence on the vegetation of the adjoining hedge. A country lane with a stream along the lower hedges, woods bordering its upper end and pastures beyond, will afford at least three types of vegetation. The hedges by running water will luxuriate in such plants as the Rosebay Willow-Herb, the Hemp Agrimony, the Purple Loosestrife, and the Meadow-sweet; while underneath, in the shade afforded by them and at the edge of the water, will be found the Golden Saxifrage and a species of Bitter Cress (*Cardamine flexuosa*). The Willow-Herbs are a large genus, and have been thus named from the resemblance of their leaves to those of the Willow, which is often associated with it on the banks of streams. The Rosebay is one of the largest species, reaching even four feet in height; unlike many of the other species, it is not hairy. The flowers are purplish-red and very showy, and the stigma is deeply four-lobed. In identifying the different species of Willow-Herbs, one of the first things to examine is the stigma; some have a four-lobed stigma, others a club-shaped one. This plant is very much visited by insects, and as the stamens mature before the ovules, cross-pollination usually takes place.

The Purple Loosestrife (*Lythrum Salicaria*) has long spikes of rose-coloured flowers, which are very interesting, for there are three types of these flowers. Each has two sets of stamens, the position of which varies with regard to the stigma. The style is also of different length. In one type it is short, and the two rows of stamens, six in each row, are then above the stigma; in the second type the style is of medium length, and the stigma has one row of stamens below it and one above it. In the third type of flower the style is long, and both rows of stamens are below the stigma. This plant is therefore said to have trimorphic flowers, and in this particular may be compared with the Primrose, which has dimorphic flowers. The Purple Loosestrife must not be confused with the Yellow Loosestrife, which is a Lysimachia and has the Primrose type of flower.

The Hemp Agrimony is one of the simplest of the Compositæ; each apparent flower is a small flower-head consisting of four or five pale reddish-purple florets contained by an involucre of about ten bracts. Each of the little flowers is in structure similar to a single disc floret (the yellow florets) of the Daisy, except that the two styles are in this plant much longer. The florets contain honey, which collects in the long narrow tube of the corolla, where it can be obtained by butterflies. The Meadow-sweet is a rosaceous plant with creamy flowers massed together. The fruits are not so well known; they are very minute, five or six together, as each flower consists of five or six carpels which are not joined to each other and therefore form the same number of fruits; each contains one seed and opens to let it out in the autumn, and is therefore a follicle, not an achene, as the fruits of many of the Rosaceæ are. The Golden Saxifrage (*Chrysosplenium*) likes a wet habitat, and is found not only in ditches by the side of streams, but on rocks kept wet with the spray of waterfalls or trickling rivulets. It differs from the true Saxifrage in having no petals. The stamens,

FIG. 15.—Purple Loosestrife (*Lythrum Salicaria*).

usually eight in number, are inserted on the four-lobed calyx. The flowers are small, apparently almost seated on the leaves. There are two species, distinguished from each other by the arrangement of the leaves on the stem; the one with opposite leaves is far more abundant than the alternate-leaved. The Cardamines all like damp situations. The best-known species is the Cuckoo-flower, which flowers in early spring. The *Cardamine flexuosa* is the one found at the edges of streams; it may be recognised by the wavy stem. The different cresses are puzzling; but the Nasturtiums, or Water Cresses, and the Cardamines are almost the only two genera of the Cruciferæ which have pinnate leaves. The genus Nasturtium is quite distinct from the garden Nasturtium, a genus of the Geraniaceæ. Another plant very characteristic of slow running water is the Fleabane (*Inula dysenterica*). It is found in ditches on the roadside and in wet pastures. All the florets are yellow, the outer ones very spreading and very bright. The leaves are rough above and downy underneath. This is one of those plants growing in damp situations with cottony instead of smooth leaves. More observation is necessary before it is possible to give any explanation of this fact. A comparison of the different species of Inula shows a variety of habitat and a corresponding diversity in regard to this character of hairiness. *Inula Helenium* belongs to rich hilly pastures, and has leaves which are nearly smooth above and downy underneath. *Inula Conyza* (Ploughman's Spikenard) is a still more downy plant, belonging to dry situations. *Inula crithmoides* (Golden Samphire) is a seaside plant with smooth succulent leaves, whilst *Inula Pulicaria* (Small Fleabane) resembles *Inula dysenterica* in having leaves with a smooth upper surface and a downy under surface. It would be interesting to compare as many different plants as possible of these two species, with a view to discovering whether the under surface of the leaf is more or less downy the farther the plant is growing away from water.

THE VEGETATION OF SWIFTLY FLOWING WATER.—RIVERS.—The plants growing on the banks of a river lead a semi-aquatic existence: their roots and stems are in the water; their leaves are partly in and partly out of the water; they flower out of the water. Such plants have to accommodate themselves to a rush of water, and to changes in the level of the water which may be considerable during flood. The organ by which the plant is able to meet these conditions is the leaf. Plants floating in more or less still water have, as already noticed, more or less round leaves with air spaces. This type of leaf would be useless here; it would be swamped during floods. The long, narrow, upright leaf is the kind required. Leaves of this type bend with the water, and, being a foot or more above the surface, are unaffected by the changes of level in the water. The Sweet Flag, Bur-Reed, Bulrush, Reeds all have long, narrow, upright leaves, and are all monocotyledons with the veins of the leaf parallel. The Sweet Flag must not be confused with the Yellow Flag or Yellow Iris. It belongs to the same order as the Common Arum, which grows under shady hedges. The Sweet Flag has narrower and brighter green leaves than those of the Yellow Flag, with an aromatic odour when bruised, and their margin is slightly crimped. The flower-stems are

FIG. 16.—Branched Bur-Reed (*Sparganium ramosum*).

flattened, and the dense spike of sessile flowers, which is the termination of the stem, looks like a projection by the side of the leaf-like bract, which in this genus does not enclose the inflorescence as the bract (spathe) of the Arum does. The spike contains many hundred flowers, which do not produce ripe fruit, probably because there are not the right insects to pollinate it in this country, as it does produce fruit in Asia, its native continent. The Bur-Reeds and the Bulrushes belong to the Typhaceæ. There are three well-marked species of Bur-Reed (genus *Sparganium*) in the British Isles. The largest, *Sparganium ramosum*, is easily recognised by the flower stem branched near the top; the branches are given off alternately on each side, each bearing six or more heads of flowers protected by a leafy bract. The upper heads contain staminate, the lower, pistillate flowers. The Simple Bur-Reed (*S. simplex*) has an unbranched flower stem; the flower-heads are fewer and at considerable distances from each other; the lower stalked ones produce fruit, the upper ones are barren. The Small Bur-Reed (*S. minimum*) is a very much smaller plant, with narrow leaves that float on the surface. It is not as common as the other two species, and belongs to still water rather than to rivers.

The Bulrushes are, strictly speaking, Reed-Maces (genus *Typha*). The Great Reed-Mace (*T. latifolia*) has a short root-stock which creeps in the mud and from which erect stems, three to six feet in height, ascend. The leaves may be as much as ten feet in length, though five or six is their usual height. The spike of flowers is often more than a foot in length, the staminate flowers being above the pistillate. In the smaller species of Reed-Mace (*T. angustifolia*) there is a distinct interval between the two sets of flowers. When the flower-spikes first appear among the sheathing leaves they are wrapped in long bracts almost lace-like in their delicacy; as the flowers develop, these bracts float off in the air. It is well worth watching them. The fruits are brown, and persist during the winter. When they become detached from the spike, the hairs borne by the stalk of each fruit act as wings to disperse the seed; the hairs fluff out into downy masses, so that the whole spike looks about a hundred times as large, for a single head will contain about a quarter of a million of these flying seeds, according to Professor Lloyd Praeger's estimate. Another plant, sometimes called Bulrush, is the Sedge, *Scirpus lacustris*. This, unlike most of the Sedges, is a leafless plant. It has tall, smooth stems, sometimes six or eight feet in height. The length of the stem varies with the habitat of the plant. When growing by the edges of lakes it is short, sometimes not more than six inches high; in the water it grows very much taller.

The Arrowhead (genus *Sagittaria*) and the Greater Water Plantain (*Alisma Plantago*) are often found growing in rivers, not as near the banks as the upright plants. Both these plants belong to the Alismaceæ, and have rather a different type of leaves from the upright type. They are not long and narrow, but more lobelike and ovate in shape, approximating towards the floating type. The Arrowhead is easily recognised by the shape of the leaves, which develop in the following order. The first leaves are submerged; then come linear leaves, the upper part of which floats on the water. Next floating leaves, in which an ovate blade is developed, and lastly the triangular, deeply sagittate leaves from which the plant is named. The leaves of the Water Plantain have a somewhat similar development. The flowers of the Arrowhead have three small, green sepals and three large white petals, with a deep purple spot at the base of each. The lower flowers are pistillate, and are on shorter stalks than the upper staminate ones. The flowers of the Water Plantain in general appearance are not unlike those of the Arrowhead, with this distinction, that each flower contains both stamens and carpels. The Flowering Rush may also be mentioned here, as it is a semi-aquatic plant belonging to the Alismaceæ, but it frequents still rather than running wtaer. It is not a Rush at all, but was probably thus named from the rush-like, leafless flower-stem. It has rose-coloured flowers. With these plants there will be certain Grasses, such as the Common Reed—as it is called—(*Phragmites communis*) and the Reed Poa (*Glyceria aquatica*), and other well-known plants, such as Docks, Spearworts, Yellow Loosestrife, etc.

The vegetation of the banks of a river is therefore very varied, so varied that it is difficult to fix on one dominant plant. The Bur-Reed and the Reed Mace are generally about equal in numbers, whilst *Phragmites communis* often disputes the predominance with them. Under these circumstances the name of the Plant association is based on the type of leaf, and it is found best to speak of the Upright-leaf, the Floating-leaf, and the Submerged-leaf associations, and under these headings the different plants are arranged as dominant and subdominant species.

The marshy ground within the banks of the river has also its characteristic vegetation. The plants in this belt, though hardly aquatic, are distinctly hydrophytic ; that is to say, they live in soil which has a very high percentage of water, without being constantly bathed by water as the banks of a river are. The Butter-Bur, the Wild Angelica, the Yellow Meadow Rue, Water-cresses, the Water Starwort, certain Willow herbs and certain species of Orchis are among the most common in this situation.

An account of the vegetation by river sides is hardly complete without some mention, however slight, of the trees that most frequently border their banks. Pollard Willows (*Salix alba* and *S. fragilis* generally) are very common ; the trees are kept cut down to a particular height to thicken the growth at the top, from the stool-shoots thus produced osier-rods are obtained, although in some parts of the country another species of Willow, *Salix viminalis*, is specially cultivated for this purpose. The ground vegetation of an osier plantation is a combination of marsh and meadow plants.

Another tree, belonging to the same order as the Willow, and commonly planted near streams, is the White Poplar, which reaches a height of sixty or even a hundred feet. Its branches spread horizontally, and the leaves are on long, slender stalks. The catkins appear in March and April ; the staminate ones are about four inches in length, each flower consisting of six stamens with purple anthers. The pistillate catkins are much shorter, and the bracts are less hairy than in the staminate flowers.

The Alder is even more generally associated in one's mind with streams than the Poplar. It likes not only the moist loam which is usually to be had near a river, but it enjoys the damp mist which rises from it. The flowers of the Alder and Willow have already been described (Vol. IV.)

Rivers, it must be remembered, affect vegetation not only through the influence they exert on the degree of moisture supplied to the plants on their banks, but also by the débris and humus they deposit in their course. A river that is flowing at the rate of only three inches per second will bring down fine mud; a velocity of six inches per second supplies enough force to carry down fine sand; twelve inches will move fine gravel along; twenty-four inches will roll along rounded pebbles an inch in diameter, whilst a velocity of three feet is required to move stones about the size of a hen's egg. Rivers flowing through calcareous districts carry down a great deal of matter dissolved in the water; it is estimated that the Thames carries down no less than 450,000 tons of salts in solution annually.

Amphibious Plants

Some few plants are able to live equally well in water as on land; they are sufficiently plastic to adapt themselves to either medium. The best known instance of this is the *Polygonum amphibium*, which flourishes equally well on the top of a bank or in ten feet of water; but the character of the plant varies with the habitat. When growing in dried-up ponds, or muddy ditches, the stems are creeping at the base, then shortly erect, and the leaves are often downy. On the top of a bank the plant sends up erect leafy stems, usually without flowers. In water, the long stems reach the surface; the thick, leathery leaves, three to six inches long, float on the surface of the water, and dense spikes of rose-coloured flowers project out of the water. The Polygonums are closely allied to the Docks, but are less stiff plants, and some species are creeping or floating. The Water-Pepper Polygonum is a slender plant, sometimes

FIG. 17.—Amphibious Polygonum (*Polygonum amphibium*).

creeping, with flowers in slender spikes, and the perianth of the flowers dotted with small glands. It is found in wet ditches and on the edges of ponds and streams.

It seems probable that aquatic plants have originated from land plants, which, crowded out by competition with each other, may have lived an amphibious life for a time, and eventually taken refuge in the water altogether. Now they are so perfectly adapted to life in the water that they would find it difficult to live on land; it is easier for land plants to adapt themselves to an aquatic existence than for water plants to return to a mode of life determined by atmospheric conditions. The influence of change in external conditions on land plants has been investigated in the Cuckoo flower (*Cardamine pratensis*), plants of which were found submerged on the banks of a pond that had overflowed. These submerged forms differed from the terrestrial forms in the following respects: the cauline leaves, which are usually sessile, had developed long stalks; their segments were narrower; the epidermis thinner. The fibro-vascular bundles of the stem were nearer the centre, and the cortex was much thicker. Some of these changes would take place if the plant were grown in a medium of moist air instead of water; the two changes which appear to be specially associated with the liquid condition of the water are the displacement of the vascular bundles and the narrowing of the leaf segments. Similar results have been observed in one of the Water Crowfoots, *Ranunculus fluitans*, and in other

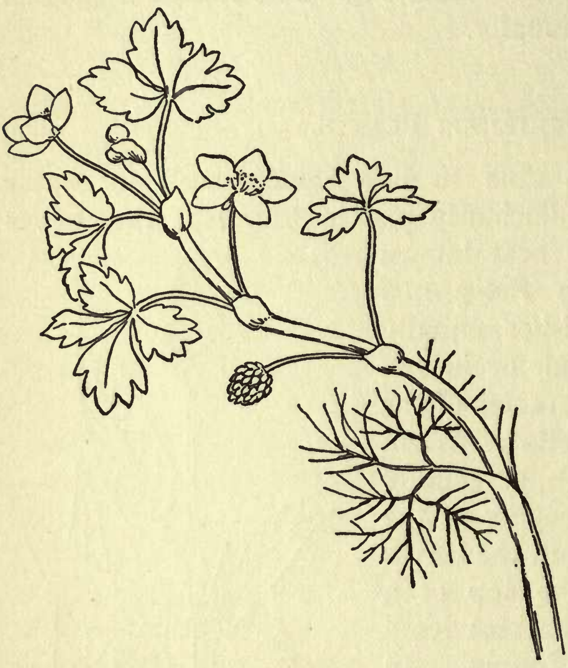

FIG. 18.—Water Crowfoot (*Ranunculus aquatilis*).

plants; it is therefore considered that these two modifications are the first stage towards the transformation of a terrestrial plant into an aquatic plant. It is clear from the observations on the *Cardamine pratensis* that these changes were brought about by the influence of external conditions; but this plant does not appear able to hold its own as an aquatic plant,—probably the changes thus brought about by the pressure of environment are not handed down, in the case of this plant at any rate, by natural selection.

THE REPRODUCTION AND DISPERSION OF AQUATIC PLANTS

Life in the medium of water is favourable to vegetative reproduction. The rapid spread of the *Elodea canadensis* has already been noticed (p. 22), the growth of the Frog-Bit, a closely allied genus, may be given here. This plant sends out long runners, which give off at intervals tufts of floating leaves above, and roots hanging down in the water. This method of multiplication is similar to that of the Strawberry. In the autumn, buds form at the end of the shoots, sink to the bottom while the rest of the plant decays, and the following spring they rise to the surface and grow into new plants. The distribution of this plant is not as wide as that of the Elodea, but it does belong to both Europe and Asia and is common in many parts of England and Ireland.

FIG. 19.—Frogbit (*Hydrocharis Morsus-Ranæ*).

The Algæ are usually fertilised in water, but Flowering Plants are not as a rule. The Brown and Red Sea-weeds, the Green Algæ of ponds are all reproduced, not only by vegetative processes, but by fertilisation. In the case of Flowering Plants, however, seed is not usually formed in water. The majority of aquatic plants protrude their flowering stems above the water in order to produce flowers and make seed; the Water Plantain, the Arrowhead, and many others will not flower if completely submerged, whilst the Awlwort when completely submerged forms cleistogamous flowers, *i.e.* flowers which never open and are self-pollinated. There are only about fifty Flowering Plants adapted for pollination and fertilisation in water. The Grass-Wrack (*Zostera*), a marine plant abundant in the brackish water of lagoons and off muddy seashores, has peculiarly formed pollen. The outer coat characteristic of the pollen grains of land plants is absent; the anthers open under water, and as soon as the pollen cells are liberated they take the form of long cylindrical tubes, which are carried by the water to the stigmas of the pistillate flower. The Naiad have pollen of the same character. Those aquatic plants which discharge their pollen above the surface of the water have pollen grains with the usual outer coat, and they are round or elliptical, not cylindrical or tube-like.

For the dispersion of their fruits and seeds, aquatic plants are frequently provided with means of floating. Schimper mentions a definite floating bladder in the case of the *Morinda citrifolia*, but the majority of these aquatic plants merely have fruits with tissues containing plenty of air spaces, which make them light and buoyant and able to float great distances. The double coco-nut of the Seychelles Islands has been found on the coast of Sumatra 3000 miles distant; the fruits of the Soap-Berry (*Sapindus Saponaria*) have been brought to Bermuda by the Gulf Stream from the West Indies, and the West Indian bean, *Entada scandens*, has travelled as far as the Azores, about 3000 miles. Facts of this kind are of peculiar interest, as they explain the resemblance of the shore flora of such widely separated land as the Malay Archipelago and the Central Pacific islands.

The coco-nut bought in England gives no idea of the tissue by which the fruit floats. The fibrous covering has been stripped off to be made into ropes and other articles of commerce, and what is bought is usually the hard shell with the white endosperm inside. It is this husk of fibrous tissue with plenty of air spaces in it which enables the nut to float these immense distances;

the sea-water cannot enter the coco-nut, because the outside of the husk is coated by a layer with fatty contents, which prevents the infiltration of water.

The number of fruits or seeds capable of floating on the water for any length of time is small; most sink at once, and sooner or later, undergo decomposition at the bottom of the sea. It has been ascertained by experiment that the seeds of several plants can be immersed in sea-water for over a year and yet not lose their power of germination.

Fresh-water plants, such as the Sedges, Water Plantains, Flowering Rushes, Bur-Reeds are dispersed by the wind blowing them as they float on the surface of the water. The fruit of the Sedge is enclosed in a bag, called the utricle; this acts as a bladder, the space between the utricle and the nut being filled with air; by this means the fruit is able to keep afloat, and is blown along from bank to bank, or from marsh to marsh. The seeds of the Arrowhead are not wetted by water, and therefore float; the fruits of Water Plantains, Bur-Reeds, and other water plants are furnished with a cortical tissue containing a great deal of air that makes them light.

In the Yellow Water-Lily the walls of the carpels separate into two layers; the outer one is green and succulent, the inner is white and charged with air, which keeps the fruit afloat. In the white Water-Lily each seed has a coat (arillus) round it, the space between this and the testa is filled with air, enabling the seed to rest on the water until it is driven along by the wind.

Fruits or seeds which have structures enabling them to keep afloat may be dispersed not only by the wind blowing them along the water, but by adhering to the beak, legs, or feathers of birds which come to the water's edge to drink. Even seeds that do not float, but sink into the mud, may be dispersed in this way, as the mud sticks to the feet of the birds. Darwin's experiments on the number of seeds imbedded in mud gave some very striking results; as many as 537 plants were obtained from the seeds contained in 6¾ ounces of mud. Now, many birds fly at the rate of forty miles per hour, swallows about one hundred miles an hour; seeds adhering to them may therefore be dispersed at considerable distances from the parent plant. Kerner in his investigations found seeds of the Purple Loosestrife, the Water Cresses, Rushes, Sea Milkwort, Sedges, Grasses, the Brook-weed (*Samolus*) in the mud taken from birds. Cattle convey the seeds of marsh plants through the mud which sticks to their hoofs.

A large number of water plants, perhaps the greater proportion, have their seeds dispersed by the wind. These plants flower and seed well above the surface of the water, and their fruits or seeds are provided with appendages which allow them to be wafted about by the wind. Others are provided with hooks, or bristles, which adhere to the rough coats of sheep, goats, oxen, and horses that come down to the river, or marsh, and are thus dispersed.

Although most fruits and seeds are provided with structures for dispersion, it is conceivable that they may not be carried any distance from the parent plant; but under certain circumstances, such as the absence of wind or the non-visits of animals, may fall in the immediate neighbourhood of the mother-plant. Nature allows for great loss of seeds through many failing to germinate for want of right conditions. When a plant sheds its seeds in its own spot of ground the seeds on germinating must choke each other, and only a few will grow into adult plants. The number of seeds produced yearly by a single plant is enormous, and may reach several thousands, but in order to keep up the present number of plants, only a very few of these need grow up into adult plants, and unless there were great loss of seeds the earth would soon be too small to contain all the descendants of any one plant. The loss of life, however, in seeds, in seedlings, and in adult plants is immense, owing to changes of temperature, to floods, to destruction by animals and by man; and unless there were contrivances for dispersion, as well as an immense quantity of seed produced, many plants would soon die out; as it is, certain water plants belonging to the Fen district are much rarer than they used to be, owing to better drainage.

The Colour of Water influenced by Vegetation

Many Algæ give a distinct coloration to water, snow, and ice. It is a matter of common experience that the rain-water in a cistern is sometimes green or red. This is due to one of the simplest of our Algæ, the Protococcus, an organism consisting of one cell, in the protoplasm of which red and green colouring matter is suspended.

It is another Alga, very similar in structure to Protococcus, that makes snow red, as travellers have often noted. The red colouring may extend to the depth of two inches, and appears to occur on most mountains with perpetual snow. This phenomenon has been observed both in the Arctic and Antarctic zones; on the Alps, Scandinavian mountains, and on the Andes. Ice has sometimes a superficial brown layer, due to those organisms which can thrive on fine dust.

The colour of the water in lakes has been the subject of some experiment. As every one knows, many lakes have a distinct colour of their own, independently of the tints due to changes in the sky. Some are intensely blue, others green or yellowish, some almost colourless. The natural colour of pure water in sufficient quantity is blue; the crevasses in glaciers are blue; why, then, should the water of some lakes be green? It is suggested that blue is turned into green by minute quantities of organic matter in solution. The blue water of the Lake of Geneva was turned into a green colour, similar to that of the Lake of Lucerne, by adding to it an infusion of peat. Forel, who tried these experiments, instances in support of his theory the two lakes of Achensee and Tegernsee in the Tyrol. The former is blue, the latter green; the basin of the former is free from peat, that of the latter is covered with peat mosses.

This does not account for the greenish tint of sea-water near the shore. Shallow water over yellowish sand would look green from the reflection of the yellow light at the bottom of the water. The constantly varying tints of river, lake, and sea are, however, due above all to the sun, and to the changes in the intensity of the rays of light.

Suggestions for Practical Work on Aquatic Plants

I. Note the Plant associations—

(*a*) In bogs. There are at least three well-marked associations (p. 35).

(*b*) By the banks of streams, rivers, and lakes. The Upright-leaf association.

(*c*) In ponds, lakes, and in the river. The Floating-leaf association.

(*d*) In marshes. Often a combination of pasture and aquatic plants will be found.

(*e*) Submerged plants, found in ditches and shallow pools.

The special organ to observe in detail is the leaf, the structure of which varies considerably.

II. The difference in the leaves of the same plant when in water, and when out of water. The Brooklime and the Water Crowfoot are typical plants to observe in this connection.

III. The absence of hairiness in water plants. There are a few plants growing by water which are undoubtedly hairy. A list should be made of these, and compared with the same species growing inland, in order to ascertain whether the plants growing by the water are more or less hairy than those inland. The Meadow-sweet and the Forget-me-not give good results.

IV. The effect of growing land plants submerged in water. This may be observed under natural conditions, as in the over-flowing of a pond or river; or under artificial conditions. The seedlings of plants, which normally grow in damp places, might be grown in an aquarium or large tank, and the results noted. Similarly, the result of growing water plants out of water may be tried, and the one set of results compared with the other.

V. The influence of man, seen in—

(*a*) The draining of marshy districts, with the result that certain species are becoming extinct.

(*b*) The altering of the level of lakes; or the creation of lakes.

(*c*) The pollution of rivers, especially in country districts, where sewage arrangements are sometimes non-existent.

(*d*) The abandoning of mills and of brick-ponds. Under these circumstances, nature is left undisturbed, and there will probably be a succession of Plant associations. This kind of observation is practicable for class work in those localities which have mills, or brick fields, within easy reach of them.

VI. The effect of running water on Hedgerow vegetation.

(*a*) Note the dominant shrub, or tree, in hedges with a stream running by them. Some species of Willow will be often found.

(*b*) Note the tall, upright plants, such as Rosebay Willow-herb.

(*c*) Note the herbaceous vegetation at the bottom of the hedge; examine the stems and leaves of these plants as regards their hairiness, their succulence, the thinness of their epidermis, and their reduced fibro-vascular tissue (bast and wood). Compare these plants with those found in a hedge by the side of which there is no water. The observation of hedges is also work that can very easily be done by classes of students.

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CHAPTER III

The Vegetation of Meadows and Pastures

Meadows and pastures have much in common as far as their vegetation is concerned, and are of special interest from the fact that, more than any other natural area, they show the effect of man's influence. For this reason the Plant Associations found in them are artificial, not natural. In a good meadow, or pasture, the ground is covered with a compact growth of Grasses, forming so thick a carpet that the colour of the soil is often entirely concealed. Such a grass carpet consists of the densely interwoven rootlets and rhizomes forming a sod, and is rich in humus from the accumulation of years. In temperate climates, such as our own, the meadow is characterised by its fresh green tint, which is preserved even in winter, for the grasses are practically evergreen in their habit, young green leaves being ready to take the place of the yellow old ones almost immediately.

Grasses Dominant.—Grasses may be distinguished from all other plants by having their leaves arranged in two rows alternately up the stem ; and by the circular outline of the cut stem. The leaves have no leaf-stalk, but a blade and a sheath, which is nearly always split. In many Grasses there is an outgrowth from the blade where it joins the sheath ; this is the ligule, which prevents the water that falls on the leaf running down the sheath and rotting the stem. Grasses have fibrous roots, and many of them long creeping underground stems, which break up stiff soils. The end of May, or the beginning of June, is the best time for observing their inflorescence, and the Oat is one of the easiest with which to begin, on account of the large spikelets. Each spikelet consists of scales, known popularly as "chaff," and of three flowers. Some grasses have only one or two flowers in each spikelet. When dissected out, the following structures are seen (Fig. 20).

1. Two large scales, at the bottom of the spikelet; these are the glumes, situated one just above the other. The tip of the glume may be extended into a stiff, long, bristle-like structure, called the awn.

2. Three flowers, each in the angle of a pair of minute scales, called pales.

3. Each flower consists of three stamens and an ovary with two plume-like stigmas.

In June, when the Grasses are ripe, the anthers may be seen almost covering the spikelets, and swaying with each breath of wind; for the flowers are wind-pollinated. It has been observed that they have as a rule definite hours for opening: some begin as early as four or five in the morning; the majority about six or seven; Seashore and Moor Grasses between twelve and one, and some few species not until afternoon.

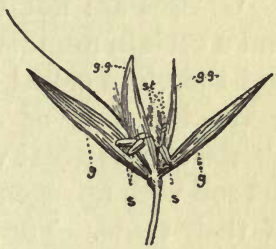

FIG. 20.—Flower of a Grass: *g*, outer glumes; *gg*, inner glumes; *s*, stamens; *st*, stigmus.

As many as twenty or thirty species of Grasses may be found in a meadow. Those most commonly sown for hay are: the Rye and Oat, the Cock's-foot, the Foxtail, the Sheep's and Meadow Fescue, the Sweet Vernal, and the Meadow Grass. Of the Rye Grasses (genus Lolium), the one most commonly planted in meadows is the Italian Rye Grass. The genus may be identified by the red colour of the sheath and the arrangements of the spikelets. They are opposite each other, and each has only one, not two, glumes.

The Cock's-foot (*Dactylis glomerata*) is easy to recognise, for the spikelets are crowded together, and the inflorescence in shape is not unlike a cock's foot. The leaves are bluish-green in colour. It is a perennial, and forms dense tufts. It is a valuable grass for a meadow, because after it is mown and made into hay it grows again rapidly, and gives an abundant second growth, or aftermath. The Foxtail (*Alopecurus pratensis*) has a brown, or black, sheath. It is one of the earliest grasses to flower; the spike has much the appearance of a round tail ending in a point, and is soft to the touch; it flowers from the middle of April to June.

It is, unlike the Cock's-foot, one of the best Grasses for producing an even sward, by means of its short creeping stems, or stolons. The Sweet Vernal (*Anthoxanthum odoratum*) also flowers early. It is mainly this grass which gives the sweet scent to newly mown hay. The spikelets cover the entire surface, and each has but one perfect flower, with two, instead of three stamens.

The Meadow Fescue (*Festuca elatior*) is a large grass, often over three feet high. The sheath is red, and there is no ligule. It may be distinguished from the Brome Grass, which in some respects it closely resembles, by the split sheath. The Meadow Grass (*Poa pratensis*) is a perennial with long stolons. It is of great value for "bottom grass," but yields only thin hay. It has four to five flowers in each spikelet.

Grasses are not the only plants found in meadows. Clovers and a certain number of plants, useless as far as food is concerned, and therefore called "Weeds," form a certain proportion, though a varying one, of all grassland. The Clovers are leguminous plants, and of great value from the power they possess of enriching the soil with nitrogen, through the bacteria present in the tubercles of their roots. These bacteria have the power of "fixing" the free nitrogen of the air. The four Clovers most common in meadows are—

1. The White Clover, which flowers from May to October, and is most abundant in soil containing lime.
2. Broad or Red Clover, which is found practically everywhere.
3. Perennial Clover or Cow Grass, also very common.
4. Alsike Clover, which is found in moist soil.

The structure of the Clover flower differs from that of the Bean or Pea in the fact that the petals and stamens are united to each other.

Effect of Manures on Grassland.—At the Rothamsted Experimental Station, experiments on the effect of certain manures on grassland were begun in 1856, and have been continued without intermission. These have been tried on some twenty plots of ground, each about a quarter of an acre in extent. The land chosen has been under grass for some centuries, and as far as is known no fresh seed has been sown. Since 1874 there has been no grazing on these plots, and the grass has been cut twice in the year. The hay made has been weighed, and exact records have been kept of the manure given to each plot and the yield from each. Two of the plots have been left without manure during the whole period ; other plots have been given nitrogenous manures entirely, namely, ammonium salts and nitrate of soda. Others again have been dressed with mineral manures alone ; a fourth set have had nitrogenous and mineral manure. The unmanured plots do not show any great diminution in the weight of the hay, but the character of the grass has very much deteriorated during the fifty years, and the weeds form a larger percentage than they formerly did ; in 1902 they reached the high figure of 50 per cent. The Quaking Grass, the Sheep's Fescue, Bird's-foot Trefoil, Black Knapweed, Burnet, and Hawkbit are among the most prominent weeds in these unmanured plots.

The plots dressed with nitrogenous manures have given different results according to the manure used. The average yield of hay was 35 cwt. per acre when nitrate of soda alone was used, and only 26 cwt. in the case of ammonium salts. On the plots manured with nitrate, deep-rooting Grasses such as the Meadow Foxtail and the Downy Oat Grass were conspicuous ; on the plots with ammonium salts, the Sheep's Fescue and the Common Bent, which have a shallower root system were dominant, for the nitrate of soda sinks down into the soil, whilst the ammonium salts are retained by the surface layers. Leguminous plants are practically absent from these plots.

The plots to which mineral manures alone have been given have not suffered from the want of nitrogen, owing to the fact that leguminous plants can use the free nitrogen of the air ; the yield of hay per acre was 38 cwt. One plot to which mineral manure without potash was given has shown some striking results. The yield per acre is much less, owing, it is thought, to the reduced percentage of leguminous plants which seem to require potash. The most productive manure has proved to be, as might be expected, a combination of mineral and nitrogenous substances, when the yield per acre has, in some cases, reached as high a figure as 72 cwt.

Another especially interesting result is the effect of a change of manures on the composition of the herbage. The effect of changing to mineral manure from ammonium salts was to increase the percentage of leguminous plants to 35 per cent., to lessen the weeds by 20 per cent. and the grasses by about 15 per cent. A change from nitrogenous to mineral manure without potash reduced the leguminous plants from about 20 to 5 per cent.

One practical conclusion that has been drawn from these experiments on grassland is, "that it is better to lay up the same land for hay each year, grazing the aftermath only, and in the same way always to graze other land, rather than graze and hay in alternate years." This is an important conclusion, which should be more widely known than it apparently is, for in many parts of the country it is usual to use the same meadow for mowing and pasture in alternate years. The Rothamsted experiments also show that "land which is growing hay requires a manure which is mainly nitrogenous, whilst pasture requires a mineral manuring." (*Rothamsted Experiments*, by A. D. Hall.)

WEEDS COMMON IN MEADOWS.—Some of the more common weeds in meadows are: the Common Bent Grass, the Yorkshire Fog, the Quaking Grass, Clovers, the Bird's-foot Trefoil, Burnet, the Beaked Parsley, the Ribwort Plantain, Yarrow, Sorrel, and many others. The Common Bent Grass (*Agrostis vulgaris*) is characteristic of poor land; it has thin dry leaves, rough on both sides, and the sheath is colourless. The Yorkshire Fog (*Holcus lanatus*) is a perennial, with an upright woody stem; it is a widely distributed weed. The Black Knapweed, or Hardheads, is easily recognised by the bracts of the involucre, which are brown, or black, and deeply fringed. The outer florets are purple, and without stamens or ovules. The Yarrow is also a Composite, with about five or six ray florets, generally white or pink, and with yellow disc florets. The plant has very finely divided leaves. The Sorrel is a dock-like plant; in poor pastures, where it is often abundant, it forms a sheet of red. The Beaked Parsley (*Anthriscus sylvestris*) is an umbelliferous plant with umbels of small white flowers. The Salad Burnet (*Poterium Sanguisorba*) belongs to the Rosaceæ. It is one of the few genera without petals. Each head contains both staminate and pistillate flowers; the former have stamens with long filaments, so that the anthers swing in the air, and the plant is wind-pollinated. The pistillate flowers have tufted stigmas, reddish purple in colour.

Certain of these weeds are characteristic of particular manures. It is found at Rothamsted that the Beaked Parsley is a prominent weed when nitrate of soda has been used; the Buttercup, the

FIG. 21.—Black Knapweed (*Centaurea nigra*).

FIG. 22.—Salad Burnet (*Poterium Sanguisorba*).

Black Knapweed, Plantain, and Yarrow were characteristic of the plot which had been deprived of potash, and the Bird's-foot Trefoil was the most marked of the leguminous plants in the same plot, because Clover and other taller leguminous plants which usually keep out the Bird's-foot Trefoil had not grown owing to the want of potash. Sorrel is found to be characteristic of those meadows where nitrogenous manures, such as ammonium

FIG. 23.—Meadow Saxifrage (*Saxifraga granulata*).

salts, have been used without mineral manure; it is a weed indicative of sour ground. The Quaking Grass, the Bird's-foot Trefoil, the Burnet, Hawkbit, and Black Knapweed may also be considered characteristic of poor land.

In meadows, where there is a certain amount of moisture, the Meadow Saxifrage may be found. It is abundant in several parts of England and southern Scotland, but is rare in Ireland. The stems are six inches to a foot high, the leaves are kidney-shaped, and the flowers are large and white. It is a perennial.

A plant characteristic of meadows or pastures on clayey soil is the Self-heal, one of the Labiatæ. The stem is creeping, the flowering branches vary in height from two or three inches to six or eight; they are seldom a foot high. The flowers are a deep purple.

FIG. 24.—Self-heal (*Prunella vulgaris*).

It is hardly necessary to remark that Buttercups and Daisies together with Grasses and Clovers are the dominant plants in a meadow. In moist meadows the Bulbous and the Creeping Buttercup are the two most common species of Ranunculus: the former may be recognised by the turned back sepals; the latter by the middle lobe of the leaf, which projects beyond the others and by the creeping stem. The Small Daisy (*Bellis perennis*) grows very close to the ground, and flowers nearly the whole year round; the large Ox-eye Daisy flowers with the hay.

The plants growing in a meadow have certain resemblances in structure; these may be regarded as the characters by which they have adapted themselves to their surroundings.

1. They are mostly perennial. This is true of most of the meadow grasses, and it is interesting to note that where a grass is naturally an annual, as the Italian Rye Grass, it may become a perennial. The red and white Clovers, the Bird's-foot Trefoil, the Buttercup, the Knapweed, the Yarrow are all perennials.

2. Many meadow plants have something of the nature of creeping underground stems,—stolons, or rhizomes, which produce a carpet of vegetation.

3. The leaves are thin, flat, broad, and smooth; those of the meadow grasses have stomata on both sides, and they never roll up as those of xerophytic grasses do. This structure of the leaf allows of free transpiration and assimilation.

In Switzerland the Meadow Plant Communities have been classified by Schröter according to the type of meadow; thus "dry meadow," "wet meadow," etc. Another classification—and one to be preferred—is based on the dominant grass or dominant plant other than the grass; thus there is the Festuca, the Poa, the Agrostis associations among the grasses, and the Carex, the Orchis among other flowering plants. In Gloucestershire, where these meadow plant associations have been now observed for some few years, it is found that in certain parts of the county the Cowslip is almost absent; whilst in other parts it may be considered the dominant plant, and associated with it in many meadows is the Early Purple Orchis. In these meadows we should have a Cowslip-Orchis association; in some parts of the county the Daffodil is the dominant plant, not the Cowslip. One great difficulty in mapping out Plant Communities in meadows lies in the fact of the succession of plants. For instance, the Early Purple Orchis may be dominant in spring; a month or two later the Green-winged Orchis may be the dominant species, and in late summer yet another group of plants will be in flower. In England, very little work has as yet been done on Meadow Plant Communities.

Pasture Land.—It is difficult to draw a hard-and-fast line between a meadow and a pasture, especially in this country, where the same land may be grown for hay in one year and the next left for grazing. There seems to be a general consensus of opinion that land which is mown should be called a meadow and that a pasture is, strictly speaking, land which is grazed; the terms "mowing meadow" and "grazing meadow" have been applied to land that is both mown and grazed. Speaking generally, a pasture is higher and drier, and its vegetation is shorter and more open than that of the meadow.

Farmers often speak of permanent and temporary, or seed, pastures. Soil which is too light to maintain a good pasture for any length of years is very often devoted to seed pasture, and in the present condition of agriculture it is considered that the best system of farming is to have from one-sixth to a quarter of the land thus laid down. Permanent pasture is land which is always under grass. In ecological work the terms "artificial" and "natural pasture" are more generally used. Natural pasture has been defined as primitive grassland without heath plants; it is permanent pasture, for it has never been anything else but grazing land. Where, however, a permanent pasture has been artificially made, as when land originally a heath or moor has been converted into pasture, it would from the ecological point of view be considered artificial pasture. All those grazing lands, with the ridge and furrow, which indicate ploughed land, would come under the term "artificial pasture." The fact is, that there is comparatively little natural pasture in our islands, especially in Scotland. The chalk downs of Wiltshire, the oolitic limestones of the Cotswolds, and the Permian limestones are the best examples in England.

A good grazing pasture should have its surface covered with a level and uniform turf of nutritious Grasses and Clovers; there should not be clumps of brown herbage here and there. Grasses which form a leafy underground, such as the Sheep's Fescue and the Meadow Grass, should be planted, in order to secure a thick "bottom growth," as it is called. Great and regular attention has to be paid to the manuring of grazing land. If the grasses are so manured as to produce a coarse growth they

A MEADOW

Drawn by Bertha Reid

will be less nourishing. Nitrogenous manures should not be applied to permanent grazing pastures. If the animals grazing on them are fed with corn and oilcake, then it is sufficient to supplement the animal droppings with some non-nitrogenous artificial manure, such as kainit, or basic slag. Thistles ought to be cut down twice in the year, directly they appear above ground in the spring and before the time of flowering in the late summer; if they gain a footing in a pasture they deprive the grass of nourishment. The ox pastures of Leicestershire are some of the best in the country. It is stated that all the manure they receive is five to six hundredweight of common salt to the acre, applied in the autumn about every seventh year. Care is taken to spread the animal droppings constantly, in order to prevent uneven grazing.

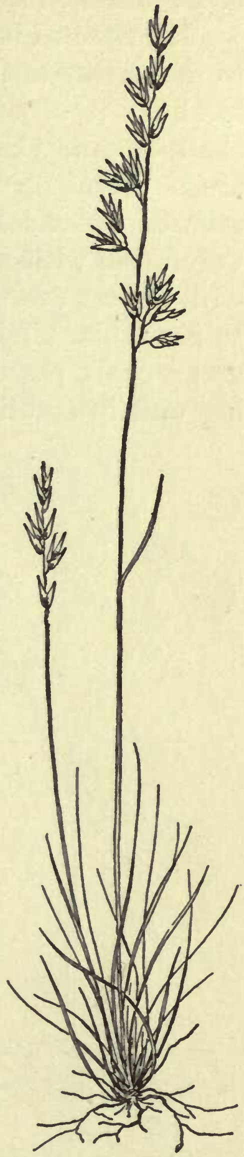

FIG. 25.—Sheep's Fescue (*Festuca ovina*).

Natural pasture can often be distinguished from artificial by the wild plants growing on it. Several different grasses are found in it, and each season has its own appropriate flora, so that there is a regular succession of plants replacing each other. Further, in wet years certain plants are prominent; in dry ones certain others. There is consequently a great deal to observe in the vegetation of any bit of natural pasture. The nature of the soil, whether hard limestone, or chalk, or sand, etc., should be noted; then the dominant grass together with the sub-dominant species; and lastly, the other plants belonging to each season of the year. The plants that flower at the same time should be recorded, and it will be found on comparing one year with another that the chief plants succeed each other in a regular order. The colouring of the pasture at each season is worth noting: in the spring, the bright green of the closely cropped grass contrasts strongly with the sombre colouring of a heather moor, or, it may be, with the rough appearance of a grass heath.

The natural herbage of pastures differs considerably, according to the nature of the rock or soil on which it is growing. In many localities it is possible, for example, to contrast the pasture of chalk or sandy land with the alluvium or clay of the lower levels. Much useful observation may be made and intelligent interest aroused by endeavouring thus to correlate the character of the vegetation with that of the soil. Of course, some plants spread with almost every type of soil, but others will be found restricted to particular kinds. The study of a sandy field on the one hand, and a chalk pasture on the other, will not fail to prove interesting and instructive.

FIG. 26.—Lady's Mantle (*Alchemilla vulgaris*).

LIMESTONE PASTURE.—The vegetation of dry limestone pastures includes the following plants: the most common grasses are the Sheep's Fescue, the Fine Bent Grass, and the Cock's-foot. Besides these, Agrimony, the Woodrush, Thyme, Milkwort, Eyebright, Salad Burnet, Knapweed, Hawkweeds, Flax, Yellowwort, and certain Orchids occur. Ladies' Fingers (*Anthyllis Vulneraria*) is very characteristic of the chalk districts.

The Sheep's Fescue (*Festuca ovina*) is the most common grass on elevated natural pastureland and mountain slopes. It varies considerably according to situation and exposure, being sometimes not more than two or three inches high, while under more favourable circumstances the flowering stems may reach a foot in height. It is a densely tufted grass, with very slender leaves, the upper ones of which are rolled. The spikelets are sharply pointed, or they may have very short awns. There are several varieties of this grass, and it is not easy to differentiate them (see Fig. 25). The Hard Fescue grows taller than the others, and belongs to moister soils; the Red or Creeping Fescue has red sheaths to the lower leaves, and belongs to poor, stony land.

The Field Woodrush (*Luzula campestris*) is found in almost every kind of pasture land. It differs from the Common Rush (genus Juncus) in its grasslike leaves, which are often fringed with a few long white hairs. The flowers of this species are six or eight together in clusters, the perianth is brown with bright coloured shining edges. This is one of the first plants to flower in pastures in spring; it grows low, and is easily distinguished from the surrounding grass by the brown colour of the inflorescence. The Lady's Mantle is a perennial with large radical leaves, which form, as it were, a small cup or saucer that contains drops of rain or dew. The rain does not wet the leaf, but touches it at the base, where a tuft of hairs prevents it running down the leaf-stalk. The flowers have no petals.

FIG. 27.—Cathartic Flax (*Linum catharticum*).

The Wild Thyme is also a low growing plant, readily recognised by its characteristic scent and the dense tuft of purple flowers covering the wiry stems. The flowers are two-lipped, resembling those of the Deadnettle in structure, but they are very much smaller. The leaves are small with a few hairs on each side. It flowers the whole summer from about June onwards.

The Flax (*Linum catharticum*) is a very characteristic pasture plant. It has a slender stem, not more than six or eight inches high, with small leaves opposite each other, and small, pure white flowers on slender stalks. There are other species of the genus, such as the flax from which linen is obtained, which have pale blue flowers, but these are less common, although they too belong to limestone.

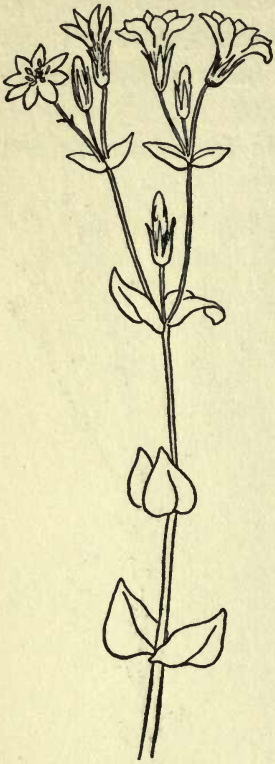

FIG. 28.—Yellowwort (*Chlora perfoliata*).

An interesting plant, on account of the arrangement of its leaves, often found on oolitic limestone, is the Yellowwort. The two leaves join at the base to form a ring round the stem, which thus appears to pass through them. They are greenish grey in colour, and the flowers a bright yellow. The blossoms are closed when the sun is not shining, and they remain on the plant long after they have faded,—in fact, until the seed vessel splits them up.

Certain Orchids belong to pastures, and very often to a limited area of the pasture. This seems to be a characteristic of Orchids as a rule; they are often abundant, but local. The Spotted Orchis (*O. maculata*) is common in early spring; in summer the Frog Orchis (*Habenaria viridis*) and the fragrant Habenaria are found in hilly limestone pastures. The flower of an Orchid differs in many respects from other flowers. It has one stamen which is united with the ovary; this latter structure is usually twisted, and appears to be at first sight the stalk of the flower. The pollen grains are united together in masses, which adhere to the insect's proboscis as they are touched. This is easily seen by inserting a sharp pointed pencil into the spur of the corolla. In this way cross-pollination takes place. The Frog Orchis has brownish green flowers, and grows about eight inches high; the lip petal (*labellum*) is three-lobed and hangs straight down; the other leaves of the perianth arch over like a hood. The Fragrant Habenaria is bigger, and may be even two feet in height. The purple flowers are borne on a long spike, and the spur of the lip is

FIG. 29.—Flower of an Orchid. *l*, Lower petal; *p*, petals; *s*, sepals; *pl*, pollen bags.

slender. A very small Orchid found in September on limestone pastures is the Autumnal Lady's Tresses (*Spiranthes autumnalis*). The flowers are white with a scent of almonds; the leaves are rosette-like, and not more than an inch long.

In pasture land lately reclaimed from muddy salt marshes, as in the Levels of Somerset, many maritime aquatic plants occur. In older, drier pastures the aquatic plants will be fewer, and the Field Thistle becomes a troublesome weed.

SANDY PASTURE.—On sandy pastures the Restharrow, the Stork's Bill, the Stonecrop, the Heath Bedstraw (*Galium saxatile*) and patches of Gorse are the most characteristic plants.

The Restharrow is a very variable plant. In sandy soil it is more thorny than when growing inland; in these dry situations many of the small branches end in a thorn. The flowers are of a beautiful pink colour; the "standard" is large, and the filaments of the stamens are all united in a sheath.

FIG. 30.—Restharrow (*Ononis spinosa*).

ALPINE PASTURE—The term "Alpine Pasture" is usually applied by botanists to natural pasture which is situated at an altitude of over 2000 feet. The most abundant grass is the Blue Moor Grass, so called from the colour of the spikes, which get a bluish tinge in a congenial habitat. The roots descend very deeply into the soil, in order that the grass may get a footing and not be blown or washed away; the stems are six inches to a foot high, and the spike of flowers about an inch long. The stamens have orange-yellow anthers, tipped with purple; the stigmas are very long. The time of flowering varies from April to May or June, according to the altitude. Alpine plants are found along the sides of streams in Alpine pastures; but above 2000 feet, where Alpine pastures are situated, vegetation is at the best scanty.

Sometimes plants which belong distinctly to the lowland are found in Alpine pastures, in sheltered spots under the lee of rocks. Those who are within reach of the fells in the Lake district might keep records of the lowland plants found above 2000 feet. The following list is given by Mr. Lewis.

Adoxa	at 2480 feet.
Wood Sorrel	,, 2500 ,,
Herb Robert	,, 2300 ,,
Water Avens	,, 2250 ,,
Wild Angelica	,, 2100 ,,
Slender St. John's Wort	,, 2200 ,,

THE DRAINAGE OF GRASSLAND.—The level of the ground water is of great importance to plants. By ground water is meant the layer of water situated above some impermeable layer; for instance, a sandy or gravelly pasture may be situated on a geological layer of clay, there will be a layer of ground water between the pasture and the clay. The level of this ground water varies with the nature of the soil, and to some extent with the season, and it is found that vegetation varies with the level of the ground water. Warming quotes Feilberg's observations on the sandy plains near Skagen in Jutland. When the ground water in summer is at a depth of three inches, Juncus vegetation and meadow-moor prevail; at six inches Mosses and Sedges are dominant, but Grasses begin to occur; at nine inches these are dominant; cereals thrive when the water is at a depth of from eighteen to twenty-four inches; at from thirty to forty, Xerophytes reign.

Drainage is essential for several reasons. If soil is water-logged the roots are confined to the surface layer; they cannot penetrate, for they must have air, and if the spaces between the particles of soil are filled with water they cannot be filled with air. The following experiment shows how much air dry soil may contain. Estimate the volume of a glass vessel by noting how many cubic centimetres of water are necessary to fill it. Dry the vessel thoroughly, and fill it with soil which has been thoroughly dried in the sun or in an oven. Then pour water into it, noting how many cubic centimetres the soil will soak up. If the soil is dry it will be found that it takes up about one-half of the water that was poured into the empty vessel, and the bubbles of air can be seen coming out on the surface as the soil gets thoroughly soaked. Roots cannot penetrate into a waterlogged soil, on account of the want of air. It follows that in a season of drought, when the level of the ground water will be altered, that plants whose roots do not extend below the surface will suffer, perhaps even die, from want of water; whereas in a thoroughly drained soil they would have penetrated some three feet, and would therefore suffer less from the drought. Drainage also increases the temperature of the soil. The attention paid to drainage is of comparatively recent date in many districts. Up to the end of the eighteenth century, what is known as the "open-field" system existed. In Traill's *Social England* an open-field farm in Wiltshire is thus described: "In shape it was generally long, narrow, and oblong, hemmed in between the downs and the stream, and often stretching three miles in length. At one end stood the cluster of mud-built, straw-thatched cottages, each with its yard, or small pasture, for horses, calves, or field oxen. In the lowest part of the land, if possible along the banks of the stream, lay the permanent meadows. These were fenced off in strips and balloted for by the tenants, and held in separate ownership from Candlemas or from Lady-Day to Midsummer Day or hay harvest. As soon as the grass was mown and the hay carried, the meadows once more became open common pasturage, and so remained till they were once more allotted and put up for hay. Beyond the meadows lay the three great tillage fields. Each of the three fields was cut up into acre, or half-acre strips, divided from each other by narrow, rough, bush-grown balks of unploughed turf. The complete holding of each village was so distributed that each man had a third of his holding in each of the three fields. Drainage was impossible, for if one man drained his land or scoured his courses his neighbour blocked his outfalls. . . . The scab was rarely absent from the common fold, or the rot from the ill-drained field" (vol. v. pp. 102–105).

The celebrated grazier Bakewell was one of the first to irrigate his meadows about the middle of the eighteenth century. The work of Arthur Young practically put an end to the open-field system. It is estimated that between 1830 and 1870 some three million acres of heavy land were drained.

The present appearance of rural districts with pastures and meadows separated from each other by hedges is entirely different from the type of scenery that must have existed when the "open-field" system was prevalent. In early writers there is no mention of hedges, now so characteristic a feature of our landscape. Under the Saxons, meadowland used to lie open from hay harvest to the following spring. When the grass began to grow the cattle were driven out and the meadow *fenced* round and divided into as many equal shares as there were families in the village; each man had his own haytime and housed his own crop; that done, the *fences* were thrown down and the meadow became again common. Under the Normans, the open fields were merely roughly marked off by turf balks, not by hedges. The first attempt at enclosing the waste lands of the manor was made in Edward III's reign, but not at all generally, and it is not until the sixteenth century, with the publication of Fitzherbert's *Book of Surveying*, that the recommendation to cut up the land into small fields, each surrounded by its separate hedge, is definitely recommended. The two counties that adopted this advice were Essex and Suffolk; outside these, England remained almost totally unenclosed until the eighteenth century. The state of things is very different to-day. The fields are often so small and the hedges and the hedgerow trees so numerous, that a good deal of land is incapable of profitable cultivation. In very small fields with large trees the roots of the trees may penetrate so far as to rob the crops of the manure intended for them. They may screen the sun and wind too much from the hay or corn that is being harvested. They prevent satisfactory drainage. It was calculated about thirty years ago that the hedgerows in England and Wales occupy not less than one million and a quarter acres; if the estimate included the area occupied by the roots, it would be three millions.

The references to hedges in the poetry of Wordsworth, who wrote many of his nature poems during the last years of the

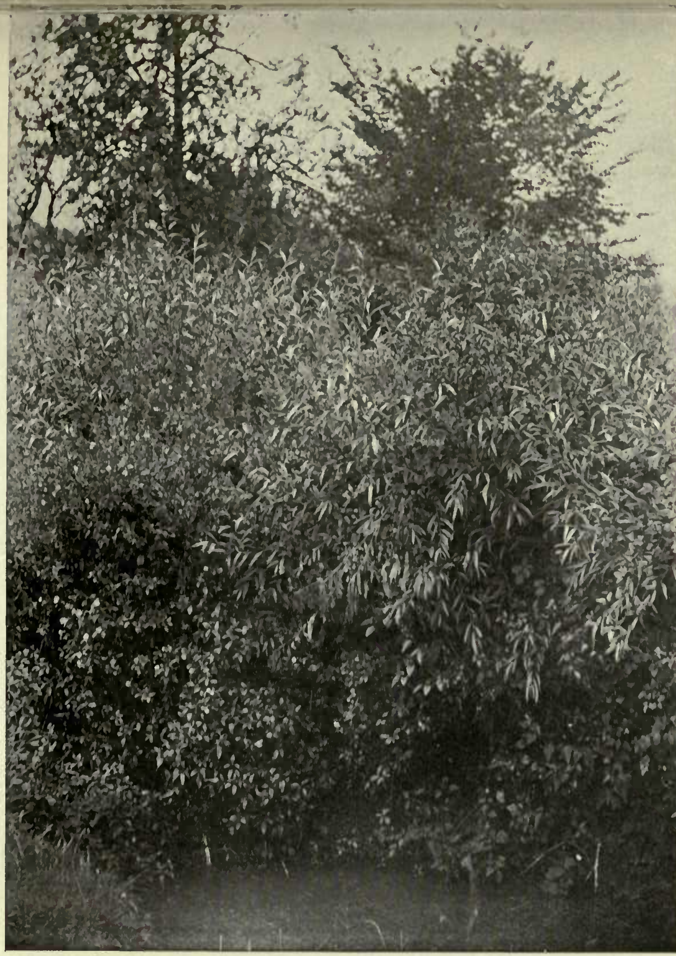

Photo by Miss E. Tidman.

HEDGEROW VEGETATION BY A STREAM

Willow in the background; Rose-bay Willow-herb in the foreground

A HAWTHORN HEDGE

Overgrown with Hazel, Roses, Grasses, &c.

eighteenth century or the beginning of the nineteenth, are therefore of special interest. In "Tintern Abbey" he writes—

"Once again I see
These hedgerows, hardly hedgerows, little lines,
Of sportive wood run wild."

Does this denote that these hedges had but lately been planted in 1798, the date of the poem? In "Margaret" he speaks of "two tall hedgerows of thick alder boughs," and in "Lucy Gray" of "a broken hawthorn hedge."

At the present time the Hawthorn is the shrub most commonly planted in hedges; the Privet is also common, and amongst hedgerow trees and shrubs may be mentioned the Elm, the Ash, the Hazel, the Crab Apple, Elder, Guelder Rose, Dogwood, Spindletree, Rose. In autumn the berries of many of these are conspicuous from their bright colouring, which attracts birds, and thus the seeds are dispersed. The haws of the Hawthorn, the hips of the Rose, the dark red berries of the Guelder Rose, the red pod of the Spindle-tree, which on opening exposes the orange-coloured coat of the seeds, are well known hedgerow fruits. Hedges are sometimes so overgrown that it is difficult to say whether the dominant plant is Hawthorn or some other shrub, such as Hazel; but it is generally possible to decide if a sufficient length of hedge is examined. The plants that conceal the original hedge are mostly climbing The Blackberry, the Clematis, the Convolvulus, the Vetches, the Woody Night-shade, in order to get light, clamber up to the top of the hedge, which in those parts of the country where hedges are not too frequently trimmed is a regular tangle of climbing plants. Many an observation may be made on the manner in which the plant climbs, whether by twisting its stem or its leaf-stalk, or by prickles or by the development of tendrils. The direction of twining plants, such as the Black Bryony, should be noted.

The herbaceous vegetation of a hedgerow depends on several factors:—

1. The degree of moisture. If a ditch or a stream is situated at the bottom of the hedgebank, plants which like a damp situation will be found. (See p. 40.)

2. The degree of shade. In walking along a country lane the hedgerow plants on each side are often very different. In the month of June, on the shady side of a lane, the following plants were noticed: Germander Speedwell, Herb Robert, Hedge Garlick, Black Bryony, Red Campion, Buttercup (*Ranunculus acris*), Bedstraws, Stinging Nettle, Dog Rose; whilst on the opposite side it was only possible to find the Mouse-Ear Hawkweed, Thyme, a species of Geranium, and the common Bird's-foot Trefoil.

3. The position of the hedge with regard to the pasture or field and the road. The vegetation of a hedge between two pastures does not vary as much as that of a hedge between arable land and a road. The weeds of arable land will be found on one side of such a hedge; on the other the material with which the road is mended will affect the plants in the hedge, for it alters the nature of the soil. Thus it has been found in the Fen district, where the roads are often repaired with chalk, that plants foreign to the district have been introduced. As a rule there are no hedges in the Fen country, but where there are hedges along high roads, as in the western and midland counties, it is easy to note the difference in the vegetation of the two sides of the hedge. Where pastures and meadows are separated by stone walls instead of hedges, the vegetation is xerophytic in character. In Cornwall, the wall flora contains many not very common plants, such as Valerianella, Subterranean Clover, Field Madder, and Trigonella.

In conclusion, the following observations on pasture and meadow vegetation may be suggested:—

1. The succession of Plant Associations.

2. The difference of the time of flowering. In meadows, kept for hay, the plants flower more or less together; in pastures, the time of flowering is different, one species succeeding another.

3. The general character of the vegetation in each case. On the whole, that of the pasture, especially if natural and not artificial, is more xerophytic than that of the meadow.

4. The hedgerow vegetation. The difference in the flora of hedges situated between two meadows or pastures, and between a road and a pasture or meadow, is worth noting.

Bibliography.—A. D. Hall, *Rothamsted Experiments*; Buchanan, *A Country Reader*. Part II.

Photo by Miss E. Tidman.

A HEDGEROW IN SPRING

The most conspicuous plant is Jack-by-the-Hedge or Garlic Mustard (*Alliaria officinalis*)

CHAPTER IV

The Weeds of Cultivation

In walking over such tracts of country, as the South Downs, it is possible to notice traces of the ridge and furrow, which possibly point to the fact that at one time the land was under the plough. In the thirteenth and fourteenth centuries there could not have been much less Wheat grown than there is at present, and there may have been more ; for in those days the population was fed on the food grown in England and wheaten bread formed a considerable part of the peasant's diet. Towards the end of the fourteenth, and during the fifteenth, century, when wool was very much in demand and labour scarce, the acreage of land devoted to pasture increased considerably. Sheep-keeping was at that time the most profitable part of farming. In 1436 the growing of corn had so decreased that politicians became alarmed, and an Act was passed to keep up the price of corn and thus encourage tillage. Up to the end of the eighteenth century, wool was one of the chief sources of profit to the English farmer, and England was then mainly a pasture country.

The work of Arthur Young in agriculture, coinciding as it did with the industrial revolution that was taking place owing to the introduction of machinery in manufacturing districts, rapidly changed the methods of farming. Waste land, and much of the land that had been held in common, was brought under wheat cultivation. Prices fluctuated during the Napoleonic wars from about 63s. to 115s. the quarter. In those days it paid to grow wheat. With the beginning of the nineteenth century may be compared its closing years, which witnessed a remarkable shrinkage in the amount of wheat grown. In 1871 there were in England three and a quarter million acres under wheat ; in 1901, only about a million and a half. England is now dependent on other countries for her food supply, and is again mainly a pasture country.

Wheat is grown successfully when the average July temperature is at least 56° F. and the rainfall below thirty-three inches. More wheat is grown in England than in Scotland; more in the south than in the north. The line of the northern limit of wheat passes through Britain. There is also a well-marked limit in altitude, but this varies with the slope of the hills. Mr. R. Smith gives five hundred feet as the limit on the northern slopes of the Pentlands near Edinburgh, and seven hundred on the south-eastern slopes; in Yorkshire, wheat grows well at an altitude of six or seven hundred feet.

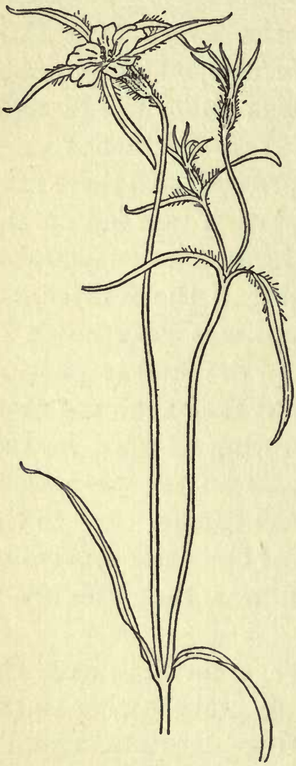

FIG. 31.—Corn Cockle (*Lychnis Githago*).

WHEAT, AN "INDICATOR"-PLANT.—In ecological observations Wheat has been taken as an indicator-plant. It is found, for instance, that certain trees and weeds do not ascend higher than the Wheat line. It has been observed that the lowland oak woods within the Wheat zone have a richer vegetation than oak woods above the Wheat limit. The same holds good with the weeds of arable land. Of sixty-three out of one hundred weeds found in Yorkshire to be common to arable land, only forty-two occur above the Wheat line. The Common Poppy, the Wild Radish, Field Pansy (*Viola arvensis*), the Corn Cockle, Sow-Thistle, Spurge, Shepherd's Needle are some of the most prominent in the wheat zone. Certain aquatic plants, such as the Bur-reed (*Typha latifolia*) and the Common Reed (*Phragmites communis*) are distributed over the same area; whilst others belong entirely to marshy ground, where wheat cannot be grown. The Corn Cockle (*Lychnis Githago*) is a remarkably handsome plant, with a peculiar calyx, which has long, green linear lobes projecting beyond the petals. The fruits of the Wild Radish and the Pansy are worth noticing: that of the Radish is jointed by transverse partitions into as many portions as there are seeds, and it dehisces transversely; that of the Pansy also opens to let out its seeds, and splits at the midrib into three valves, each containing a row of seeds, which are forced out several feet by the walls of the valve coming together as the fruit gets dry. The Shepherd's Needle is in some respects unlike most of the Umbelliferæ. It is sometimes called Venus' Comb, from the shape of the fruit, which is nearly two inches long and resembles a comb, the edges being fringed with teeth.

FIG. 32.—Shepherd's Needle (*Scandix Pecten*).

FIG. 33.—Black Medick (*Medicago lupulina*).

In discussing the weeds of arable land it is almost impossible to say which weeds are associated with any particular crop, for at the present time there is a regular rotation of some three or four crops on all cultivated land. At Rothamsted Experimental Station, however, a certain field has been grown continuously in wheat for more than fifty years, and the weeds that havegiven most trouble on the unmanured plots are the Black Bent Grass (*Alopecurus agrestis*) and the Black Medick. Of those two, the Bent Grass is by far the greater pest; the Black Medick, indeed, is of some use, for being a leguminous plant it enriches the soil with nitrogen, and may in this way help to supply the want of manure. In appearance it is not unlike the small yellow Clover, but may be distinguished from it by the fruit, which is black and spirally twisted. Another difficulty in associating certain weeds with particular crops is caused by the impurity of seed. Weeds are constantly introduced with the seed sown. Thus Charlock, so common in Potato, Corn, and other fields, has a seed very like that of the turnip or rape, and might be easily introduced with either crop; the Dodder is so often mixed with Clover that in England an ounce of Dodder in a ton of clover is considered permissible. In most continental countries there are seed-testing stations under Government control, in order to test the germinating power of the seed, and to ensure its purity and genuineness. This is of great practical use to the farmer, for if he knows that the seed he is sowing has only a germinating value of 75 per cent. instead of 95, he can increase the quantity sown in a given area and thus save loss. At the seed station in connection with the Royal College of Science, Dublin, some fifteen hundred samples a year are tested, and the quality of the flax seed sown in Ireland has distinctly improved since the establishment of the station.

Rotation of Crops.—The rotation of crops in farming is due to the fact that different plants make a different demand on the soil. There are certain substances that all plants require for food; some are obtained from the air, others from the soil, but the quantity required by each plant varies. Clover needs a great deal of potash, wheat comparatively little; on the other hand, wheat needs silica. As long as the "open-field" system lasted it was impossible to have a rotation of crops, in which roots, such as Turnips, should form an element. Up to the end of the eighteenth century each village farm had attached to it three great tillage fields, and the usual practice was to sow one with Wheat or Rye; the second with Barley, Oats, Beans or Peas, whilst the third lay fallow. Thus, even then, there was a rotation of crops, but a limited one. Arthur Young, writing in 1768, remarks that Clover and Turnips were unheard of in many parts of the country, and even as late as 1811 they were still almost unknown in Wiltshire.

Now roots form a regular element in the rotation of crops; the order, however, varies in different parts; in Norfolk, Turnips are followed by Barley, Barley by Clover, and Clover by Wheat.

In order to ascertain the substances that a plant requires for food, its ash may be analysed. Then the soil in which it is proposed to grow it should also be analysed, and any deficiency of the substances necessary to the plant should be made good by appropriate manure. The amount of humus in soil may be ascertained by first drying and weighing the soil, then burning it, and weighing again. By means of sieves, with meshes of a different size, the amount of silt-clay, gravel, and sand can be roughly estimated. Silt-clay passes through a mesh of 0·05 mm., leaving the sand and gravel in the sieve. This residue is then sifted in a sieve with a mesh of 1 mm., the sand passing through whilst the gravel remains. A definite weight of dried soil must be taken to begin with, and at each stage the residue must be dried and weighed. In this way the percentage of sand, clay, etc. can be determined. The terms "marl" and "loam" are constantly used in any rough classification of soils. A marl is a mixture of lime and clay; a loam, of clay and sand.

All good soils contain a certain amount of clay, which is richer in plant food than any other part of the soil, and it also has the power of fixing certain substances required by the plant. Clay also retains water, and needs good drainage and admixture with sand, or lime, or ashes, etc. to increase its porosity.

CERTAIN WEEDS CHARACTERISTIC OF CERTAIN SOILS.—The majority of plants seem able to grow on most soils, provided they can get the water they require. This seems to show that it is the physical, rather than the chemical, properties of the soil which are of the greatest importance to the plant. The one exception to this rule is lime, which many plants appear either to love or hate; it is for this reason that it is preeminently possible to speak of a chalk flora. On light calcareous soils it is found that Sainfoin and Lucerne are valuable crops for purposes of fodder. Amongst the weeds, which are commonly found on soils with a good proportion of calcium carbonate, may be mentioned Fumitory (*Fumaria officinalis*) and the Dove's-foot Geranium (*G. molle*).

Fumitory is characteristic of cornfields, and is easily recognised by the very delicate leaves and irregular, curiously formed pink flowers, tipped with purple. The leaf-stalks act the part of tendrils, and coil round the stems of adjacent plants. Each flower has two sepals, which soon fall off. There are four petals, the upper one being prolonged into a spur, the two inner ones being joined together at the tip. The six stamens are arranged in two bundles of three each. *Geranium molle* has downy leaves and small pink flowers with deeply notched petals; the flower-stalks are shorter than the leaves, and each bears two flowers.

FIG. 34.—Fumitory (*Fumaria officinalis*).

Many leguminous plants do not grow well on sandy soils; Lupins and Gorse are exceptions. The barren sandy heaths of East Prussia have been reclaimed and rendered fit for cultivation by growing Lupins and ploughing in the green crop. At the Royal Agricultural Society's farm at Woburn the experiments made with Gorse on the coarse sandy soil seem to show that it might become a valuable fodder crop. In ecological work, the presence of Gorse may almost invariably be taken as indicative of a sandy layer of soil, even where the underlying geological layer is of a different character. Amongst crops, Potatoes and Carrots are best adapted for sandy soils, provided sufficient manure is given. The most common weeds of these soils are the Poppy, the Spurreys, and the Cornflower. The bright scarlet blossoms of the Poppy, the blue Cornflowers, and the pink Sand-Spurrey form a striking contrast to the yellow Corn. There are two species of Poppy: the Common Field Poppy (*Papaver Rhœas*) has flowers of a deeper colour than those of the long-headed species (*P. dubium*); but the chief difference is in the fruit, which is much shorter and stouter than that of *P. dubium*. The unfolding of the petals, which have been crumpled in bud, is worth watching; they look so tumbled when the sepals first open, yet they spread themselves out perfectly smoothly. The opening of the fruit by pores just below the lid formed by the stigmas should also be observed; the seeds are thrown some distance from the parent plant, and thus dispersed.

The Cornflower has very large outer florets, whose work it is to attract insects. The inner disc florets are the perfect ones, making both pollen and seed. Another of the Compositæ, common in cornfields on sandy as well as calcareous soil, is the Corn Marigold, in which all the florets are of a deep golden yellow. This belongs to the same genus as the Ox-eye Daisy, but does not grow as large and has not white florets. The Corn Spurrey (*Spergula arvensis*) grows about six or eight inches high. It has very narrow leaves, apparently whorled, and very minute white flowers with undivided petals. The Sandwort Spurrey (*Spergularia rubra*) is found near the sea. It is a more creeping plant than the other, and usually has pink flowers.

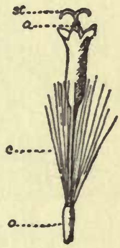

FIG. 35.—A floret of Groundsel. *c*, calyx; *o*, ovary; *st*, stigmas; *a*, staminal tube.

Certain weeds are characteristic of rich loams. The most common are the Groundsel, the Chickweed, the Sowthistle, two or three species of Veronicas, a species of Spurge (*Euphorbia Peplus*), and the Pimpernel. Every one knows the Groundsel, which is practically ubiquitous. There are seldom any ray-florets, all the flowers being tubular. The involucre consists of two rows of bracts tipped with black, the outer row being shorter than the inner one. The calyx, as in most of the Compositæ, is represented by hairs, which form the feathery pappus after the flower has withered. The petals and stamens are five in number, and the stamens, being joined together by their anthers, form a tube through which the stigmas pass. Self-pollination takes place as the stigmas are pushing their way up through the staminal tube; the stamens dehisce inwards and the pollen grains fall on the stigmas. Small, inconspicuous flowers of this kind are not, as a rule, dependent on cross-pollination, although this may take place occasionally.

The Chickweed (*Stellaria media*) is almost as common as the

Groundsel. It is found in allotments, and practically in all fairly rich cultivated ground. It may be distinguished from other Chickweeds by the ovate leaves and by the hairy line which runs along its stem, shifting from side to side at each node.

The Sowthistle (*Sonchus arvensis*) is common in cornfields, and may be recognised by the long, lanceolate leaves, curved downwards and bordered by small prickly teeth. The flower-heads are large, of a bright yellow. A still more common weed of arable land is another species (*Sonchus oleraceus*), which has rather smaller flower-heads with pale yellow florets.

FIG. 36.—Germander Speedwell (*Veronica Chamædrys*).

The Speedwell most commonly found in cultivated ground is *Veronica agrestis*, which may be distinguished from other species most closely resembling it by the narrow sepals and the white lower petal of the corolla. In allotments the Germander Speedwell, the largest of the Veronicas, is common. The structure of the flower should be examined, for in many respects it differs from the other genera of the Scrophulariaceæ. There are only four petals and two stamens, which are placed laterally. The complete number of stamens in this order is five, as in Mullein ; many genera, however, have only four, and in some cases, as in the Figwort, a scale represents the fifth stamen. The reduction of stamens, from six to two, reaches its lowest limit in the Speedwells. The lower petal is generally larger than the others, and forms a landing-place for the flies which pollinate the flower. The stigma stands straight up in the middle of the flower, and is touched by the fly before the stamens, and by a different part of its body. In trying to get the honey, which is secreted by the gland below the ovary, the insect comes in contact with the stamens, from which it gets the pollen to carry to another flower. The Scarlet Pimpernel (*Anagallis arvensis*)

FIG. 37.—Fruit of the Scarlet Pimpernel.

is found in cornfields, creeping along the ground. When the corn has been cut, the plant is in fruit, and its dehiscence should be noted. It splits transversely, allowing the top to be lifted off like a lid. The majority of capsules split longitudinally, therefore this transverse dehiscence is interesting. The bright scarlet flowers expand only in fine weather, hence the name Poor Man's Weather-glass has been given to the plant. The Petty Spurge (*Euphorbia Peplus*) is an annual. The peculiarity of structure in the Spurges is that each apparent stamen is a flower, for each has a minute scale at its base. The cup-shaped structure, which at first sight may easily be taken for a corolla, is an involucre furnished with four or five teeth and with brownish yellow glands. The pistillate flower in the centre has a three-celled ovary; the styles are three, and the whole flower hangs down. In the Spurges then, what appears to be a single flower is an inflorescence. All the Spurges have a milky juice which is often poisonous. Many well-known foods are prepared from plants belonging to this order. Tapioca comes from the West Indian Cassava. There are two species of Cassava common in the West Indies. The root of the Sweet Cassava is eaten as a vegetable; the Bitter Cassava is highly poisonous, but a flour is prepared from it by extracting all the poisonous juice, and out of this the thin Cassava cakes, which visitors to the West

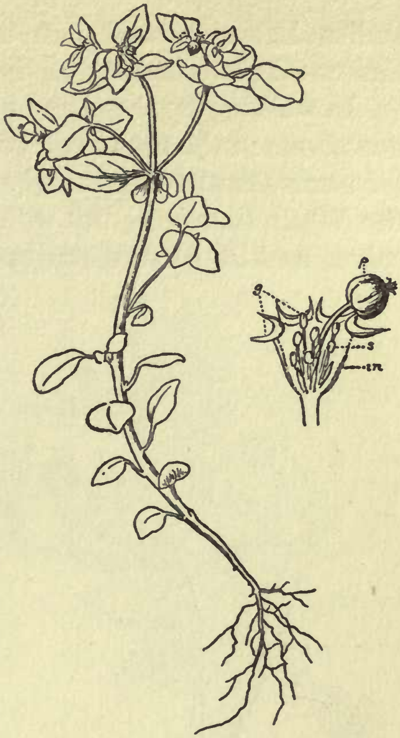

FIG. 38. — Petty Spurge (*Euphorbia Peplus*). *s*, Staminate flowers; *p*, pistillate flower; *g*, glands; *in*, involucre.

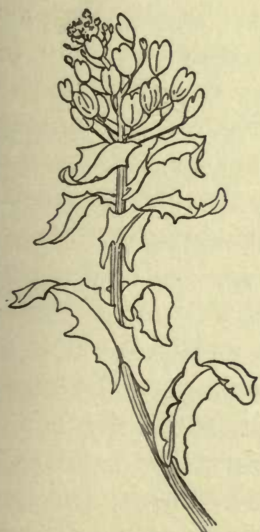

FIG. 39.—Field Pennycress (*Thlaspi arvense*).

Indies know so well, are made. The Croton plants and the Castor-oil plant belong to the same order, the Euphorbiaceæ.

In walking by the edge of an oat-field one of the most conspicuous plants in the month of June is the Bladder Campion; its white blossoms stand out strikingly against the yellow Corn. It resembles the White Campion, but differs from it in the swollen bladder-like calyx, and its flowers are open during the day, whilst the White Campion (*Lychnis vespertina*) does not open until the evening.

FIG. 40.—Corn Buttercup (*Ranunculus arvensis*).

The Pennycress (*Thlaspi arvense*) is also a denizen of cornfields. The fruits are massed together in a long raceme, each capsule has a very broad wing, reminding one a little of the garden Honesty. The wing is deeply notched at the top, and there is a minute style in the notch. (See Fig. 39.)

On clay soils the Corn Buttercup (*Ranunculus arvensis*) is very common in cornfields; it is also found abundantly on calcareous soils. The special feature of this plant is its fruit, which distinguishes it from all other species of Ranunculus. The carpels are prickly. The Field Mint (*Mentha arvensis*) is also troublesome on clay soils. As a rule weeds are not so numerous on clay soils as on many others, owing to the close texture of the soil. In good seasons, that is, when there is a certain amount of rain, so that the clay does not get hard and dry, some crops, especially Beans, Mangolds, and Wheat, do very well. If the season, however, is very dry the plants are in danger of not getting enough water from the subsoil, and then their growth is stopped and the crop is poor. A weed that is often found in great quantities along the edge of a Bean-field is the Gromwell (*Lithospermum arvense*). This plant grows about a foot high, and is covered, as the majority of the Boraginaceæ are, with hairs. The flowers are small and white, and the nut-like fruits very hard.

The number of weeds found in cultivated land is said to be about 280. Of these, only about 100 are found above the limit of Wheat cultivation, *i.e.* above 500 feet in the Highlands. Many of the species which belong to the Wheat zone cease to be prominent above the Wheat line, and become casuals. If seed grain from another district is used, weeds are often imported with it, and may, under these circumstances, spread from a lower to a higher altitude, holding their own for a time, but they cannot stand the stress of competition and soon die out. Light, calcareous soils are apt to be more weedy than clay, or sandy, soils.

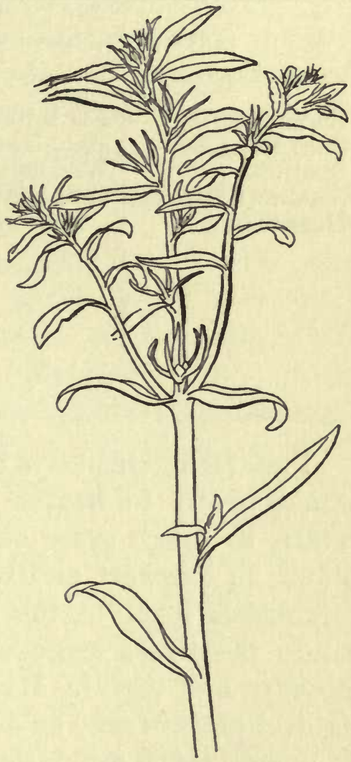

FIG. 41.—Corn Gromwell (*Lithospermum arvense*).

The only classification of weeds of arable land that can be given in the present state of our knowledge is based on soils; for, as has been already said, the only way of ascertaining whether there is a relation between the crop and the weeds would be by having experimental plots, planted year after year with the same crop, to which the same kind of manure was given season after season. It is, indeed, possible to give the weeds belonging to the Wheat zone; but it must be remembered that this includes at least two or three crops in addition to Wheat.

The following lists are not meant to be mutually exclusive; some weeds, such as Groundsel, Shepherd's Needle, and Chickweed

(*Stellaria media*) grow almost everywhere. Many of those given as belonging to calcareous soils are also found on loams, and *vice versa*. Of course, in actual practice the result of adding lime and manures to arable soils is to modify the "weed flora" that they bear.

CLASSIFICATION OF SOME COMMON WEEDS ACCORDING TO SOIL.

Sandy Soils.	Clay Soils.	Loams.	Calcareous Soils
Cornflower	Black Bent Grass	Chickweed	Fumitory
Corn Marigold	Field Mint	Groundsel	Dove's-foot Geranium
Spurrey	Wild Carrot	Stinking Mayweed	Convolvulus Polygonum
Sandwort Spurrey	Corn Buttercup	Sowthistle	Bladder Campion
Horsetail		Goose Grass	Scabious
		Field Speedwell	Shepherd's Needle
		Wild Poppy	Radish
		Petty Spurge	Poppy
		Pimpernel	Chicory
		Henbit	

Practical Observations.—Arable land, if left uncultivated, would revert to heath. The first stage would probably be a return to rough grass occurring in patches, together with such plants as Ragwort and Crosswort. The former plant sometimes establishes itself to the exclusion of any other. If the soil is sandy the Grass associations might in time be conquered by Bracken and then by Heather. As was seen in the last chapter, natural pasture may be defined as grassland without heath plants. If uncultivated arable land reverts to grassland it is practically only a step further back to grass heaths, and thence to heather moors, or woodland. Thus the vegetation of a district, if undisturbed by man and animals, is always changing, one species after another being ousted, until at last the one best adapted to the environment creeps in from elsewhere, establishes itself, and holds its own. It is the purpose of vegetation maps to register some of these changes.

In making observations on arable land, the extent to which Wheats and Oats are cultivated should be noted. In Scotland, Oats are grown wherever land is cultivated at all. An altitude of 1250 feet is reached in the Highlands, and in some parts there are traces of former cultivation as high as 1500 feet. A list of weeds in the Wheat zone, and of those in the Oat zone, might be made ; it will be found that some are found at the higher altitude of the Oat belt which are not present in the lower Wheat area. A map, with the height above the sea level marked, could be drawn and the Wheat and Oat fields inserted, and coloured to show the difference in the altitude at which the two crops will grow.

The effect of farming operations on weeds and their influence on the Plant Associations that occur would form an interesting series of observations from year to year. To get approximately accurate results, it would be necessary to keep records of the ploughing and manuring of the field, the kind of manure given, and the rotation of crops. A complete list of the weeds found each month should be kept and compared from year to year, or from season to season. After four or five years it would be possible to note whether the same weeds occurred year after year, if the same manure was used. Where the crop and the manure vary from year to year, it would seem likely that the constant presence of certain weeds is due to the character of the soil. The presence of certain weeds, year after year, in consequence of ploughing operations, would indicate some relation between the life of the plant and the greater depth of soil through which the roots could penetrate; ploughing, for instance, would probably increase the number of weeds with a deep-rooted system. One result of the constant ploughing to which arable land is naturally subjected is, that many of the weeds are annuals ; the weeds of meadows and pastures, undisturbed by the plough, are, as has been stated, perennials.

The result of leaving ground fallow for a year and its effect on the next crop may be observed. Experiments at Rothamsted on Wheat plots showed that the produce of Wheat after fallow is considerably higher when it is grown continuously, partly owing to the fact that there are fewer weeds.

The effect of a wet or dry season is best realised by keeping a weather chart, which should show the temperature and the hours of sunshine. These can usually be checked from the records of the meteorologist of the district. The rainfall and degrees of frost should be also entered. The date of cutting the hay, of the ripening of Wheat or Oats should be recorded. If these charts are kept and compared from year to year, the effect of climatic changes, which are perhaps the most important factor in the cultivation of Wheat and other cereals, can be estimated. It is quite possible, in agricultural districts, to have charts of this kind kept by even the lower classes in a school. The date of the flowering of the different weeds found in fields may also be observed; in this way children come to associate certain plants with the reaping of Corn. Even those who live near a town can observe a great deal in the market gardens, so common in the neighbourhood of towns.

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THE SCHOOL GARDEN

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Author of "The School Garden."

CHAPTER V

General

The School Garden is no new institution. Comenius, who lived in the seventeenth century, recommended that every school should possess its own garden, where the scholars could learn to love trees and flowers and herbs, and be taught something of their life-stories. A little later, Francke, who had an asylum at Halle for orphan children, laid out a school garden in which the children could employ their leisure time with pleasure and profit. Rousseau, Pestalozzi, and Froebel all did something to help forward the movement. Pestalozzi, who had established on his estate at Neuhof a home for orphans, laid down the principle that the farm was to be the central point of his educational work, and that his pupils were to be instructed at work and through work. While the idea that children should receive instruction by and through their environment was thus kept alive, it was not until about forty years ago that the particular method of instruction now under consideration began to spread widely. In the years 1869 and 1870 a law was passed by the Austrian Government requiring that where possible a garden and ground for agricultural demonstrations should be attached to every rural school, and that wherever natural history formed a part of a school curriculum the instruction should be based on material provided from a school garden specially arranged for the purpose. Since the date of passing of this law it is stated that more than 18,000 school gardens have been established in Austria-Hungary. Much valuable help has been given by the Styrian Horticultural Society, which has annually distributed to the schools, free of charge, large quantities of seeds and cuttings. Though not to the same extent as in Austria, the School Garden has firmly established its position as a valuable educational instrument in Germany, France, Belgium, Switzerland, Sweden, and Russia. In England, State aid is given to instruction in School Gardens whether attached to elementary schools or continuation schools, and the number of such gardens has increased greatly during the past ten years.

This general increase is mainly due to the recognition in present-day educational methods of the fact that the most valuable and lasting results are obtained from teaching gained by the pupil through his own observation and activity. For such teaching the School Garden offers the widest scope, because it brings the pupil into direct contact with a large variety of natural phenomena from the observation of which inferences may be drawn. Moreover, the School Garden affords an occupation for children which fosters in them a sense of the beauty of nature, makes them self-reliant, promotes neatness, and tends to make them healthier. These physical and moral results are equally as important as the educational ones (using the word "educational" in its narrower sense). The economic aspect, again, must not be overlooked. Dexterity in the use of garden tools and appliances, exact knowledge of the "how" and "when" in planting garden crops, and of the quantities of the various crops obtainable from a garden, are a valuable possession to any one, but more especially to those who live in a country district.

In this country, School Gardens fall roughly into three classes, namely, day-school gardens for boys, day-school gardens for girls, and evening-school gardens for adults or for boys who have left school. Instruction in day-school gardens, whether for boys or girls, will aim at the general intellectual development of the scholars. In the evening-school gardens the first place will be given to the acquirement of such methods of practical working as will result in the production of abundant crops of good quality. The arrangement of the instruction in the case of girls will naturally take account of the facts that they are physically not so strong as boys, and that when they are grown up it will be

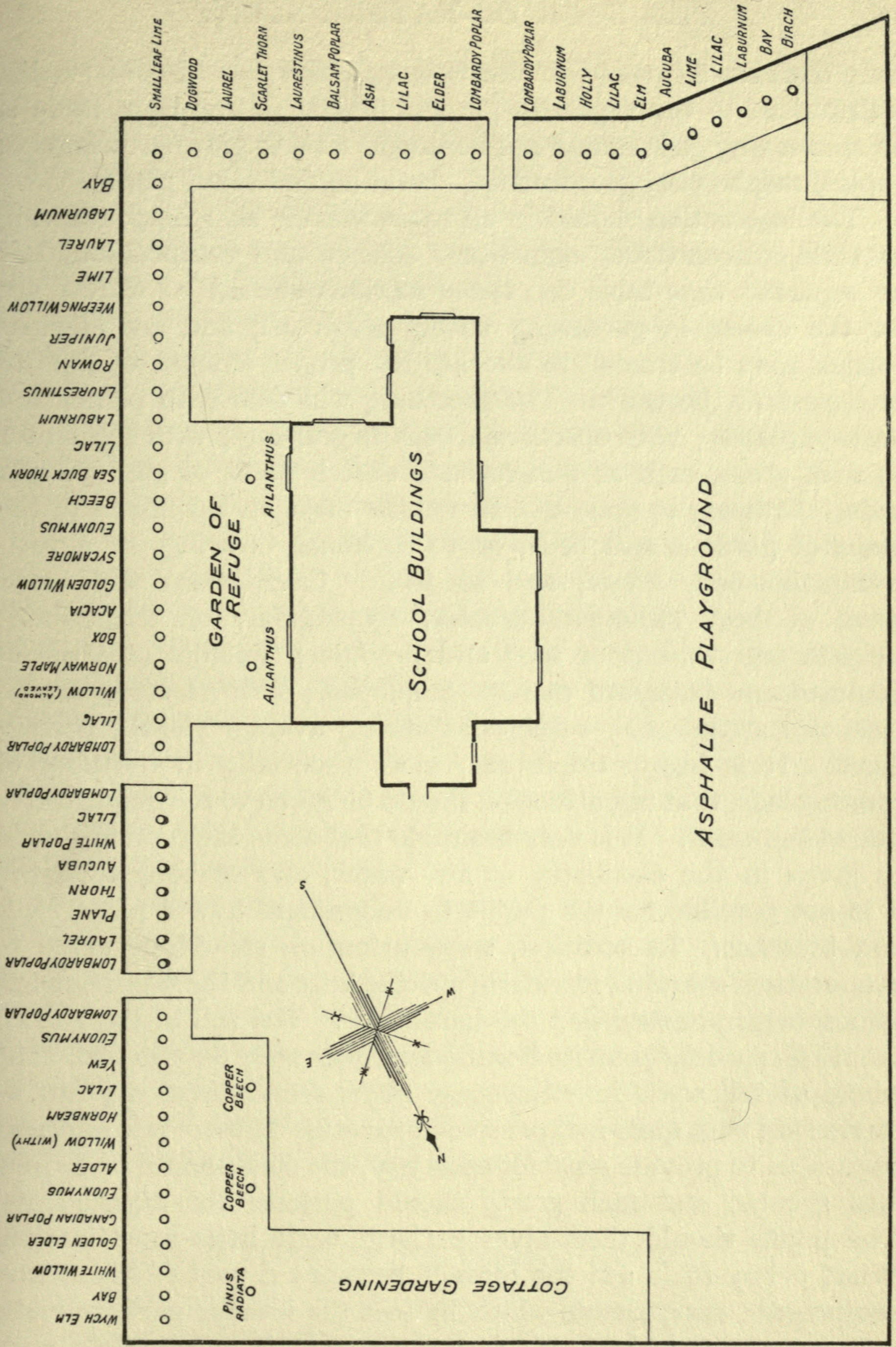

FIG. 42.—School garden attached to an Elementary Day School in a large town. Note the collection of British trees, and the Garden of Refuge which contains a collection of the rarer wild plants of the district.

their business to attend to the flower garden and window garden rather than to the vegetable garden. At the same time, there is no reason why girls should not be taught how to grow strawberries, apples, raspberries, gooseberries, currants, and salad plants.

The instruction should in all cases include sketching, drawing to scale, calculations, elementary science and composition, but no separate time-table for these sections should be drawn up, for the course in gardening covers them all, and an efficient teacher may be trusted to allocate the proper amount of time to each part of the work. The sketching will deal with plants and parts of plants ; with operations, such as grafting ; with appliances or with areas, such as dimensioned sketch plans of gardens and beds. Drawing to scale will be for the most part confined to the plans of gardens and beds, or to sectional drawings of a tool-house, hot-bed, frame, and so forth. Calculations will cover areas of beds (whether circular, rectangular, or triangular) ; weights and volume of seed and produce ; weights of artificial manures and farmyard manure employed ; cost of seed, labour, rent, and appliances ; value of produce ; average yields ; percentages. It is highly important, more especially in the case of country lads, that full attention should be given to the quantitative side of the work. It is very desirable that some instruction should be given in the chemistry of air, water, and carbon, otherwise it is not possible for the pupils to understand how a plant feeds and breathes. In addition, some attention should be given to evaporation, solution, filtration, specific heat and the thermometer, atmospheric pressure and the barometer. The soil of the garden should be air dried, and its texture approximately determined. The whole of this work in elementary physics and chemistry can be carried out with quite inexpensive apparatus. If there is insufficient apparatus to provide a set for each boy, the class should be formed into groups, and each group should perform the experiments. The pupils should themselves perform each little investigation. What a boy finds out for himself becomes a part of his mental equipment ; experiments which he sees the teacher perform make but a comparatively feeble impression on his mind, while mere lecturing by the teacher is frequently not only a waste of time but may be positively harmful.

The associated course of work thus briefly outlined is intended for pupils beginning work in the School Garden at about the age of twelve. It will extend over two years, and elementary science will be taken in the second year. So far as children under twelve are concerned, the associated work need not extend beyond sketching, brushwork, nature knowledge based on the objects of the garden, and simple composition.

It may be useful at this point to give an example of the method for combining sketching, drawing to scale, and calculations with the garden work. Suppose the object about which the instruction is to be grouped is a hot-bed. Having made the hot-bed and placed the frame in position, each boy should make a sketch of the whole, showing all the essential features. With a measuring stick, notched so as to measure to a quarter foot, he will then take all the dimensions, that is to say, the length, breadth, and depth, at front and back of the frame. These dimensions as they are taken off will be entered on the sketch. The boys will then go into the classroom and draw a plan and elevation of the whole. In this particular case not many calculations of practical value can be based on the work, but the boys might be asked to determine (*a*) the area of the base of the manure heap, (*b*) the area of the base of the frame, (*c*) the number of cubic feet of air contained inside the frame.

For day-school gardens it is desirable for a number of reasons that the teacher should be a member of the ordinary school staff, for he will maintain better discipline, he will be in touch more nearly with the pupils, and he will more efficiently carry out the associated instruction than would a visiting teacher. Besides, it is an excellent thing, more especially in a rural school, for one member of the staff at least to be thus brought into close contact with one aspect of rural life and work.

Sections of the School Garden

The best methods of growing all the common vegetables must of necessity be the first consideration, because physical well-being is a preliminary to all work and thought. A nursery for young plants must also be provided. The great increase in recent years in fruit consumption in this country, the profitableness of fruit growing, and the large importations of fruit from the Colonies and the United States, all point to the advisability of establishing a fruit plot. In rural schools it is an excellent plan to set aside one portion of the garden for specimens of agricultural plants, manurial demonstration plots, and for a set of plots illustrating a rotation of agricultural crops. All persons who have had experience of rural education will recognise the importance of giving boys adequate practice in the identification of species and varieties of agricultural plants and seeds. So far

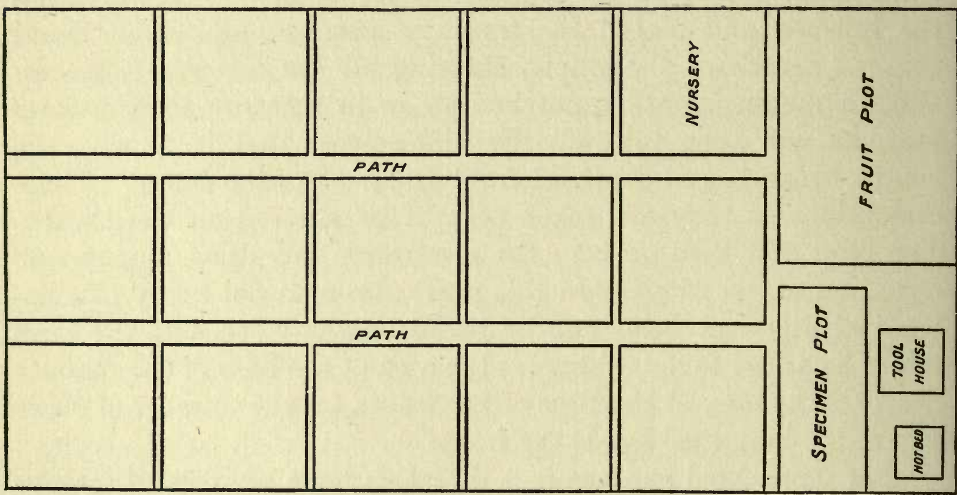

FIG. 43.—Arrangement of a school garden suitable for boys of eleven to fourteen years of age. Individual plots.

as the specimen plots are concerned, it will be sufficient if just a clump of each be sewn, the area covered by each specimen being about one square foot, with a space of six inches between each clump.[1]

It may be here mentioned that in German school gardens a small collection of injurious and poisonous plants is regarded as an important feature, while in a few school gardens in this country the teachers have succeeded in establishing a complete collection of British trees. Last but not least, flowers should be grown, and a special border set apart for that purpose. A collection

[1] A better way, perhaps, especially for clovers and grasses is to sow in drills, each drill being about three feet in length.

of perennials can be gradually acquired, by gift as often by purchase, and such a collection will be a constant source of interest to the teaching staff and to visitors, as well as to the scholars. It may perhaps be said that to suggest the provision of school gardens containing the six sections specified above is a counsel of perfection. This may be a sound contention so far as town gardens are concerned, because of the high price of urban land and the frequently inconvenient distribution of the small quantity available. In country places, however, provided that the school staff and the local managers are in earnest, there should be no difficulty in hiring the half acre or so of ground necessary for obtaining the fullest possible value from a well planned course of work. The garden should be a place in which not only the boys and girls, but also their teachers, parents, and friends, can find pleasure, interest, and profit.

CHAPTER VI

Selection of Site and Preliminary Operations

For convenience in carrying out the practical work and the associated indoor work it is important that the garden should be near the school building, and, provided that it can be securely fenced in, it is desirable that it should be open to the view of those passing by in the road: the interest and sympathy of people

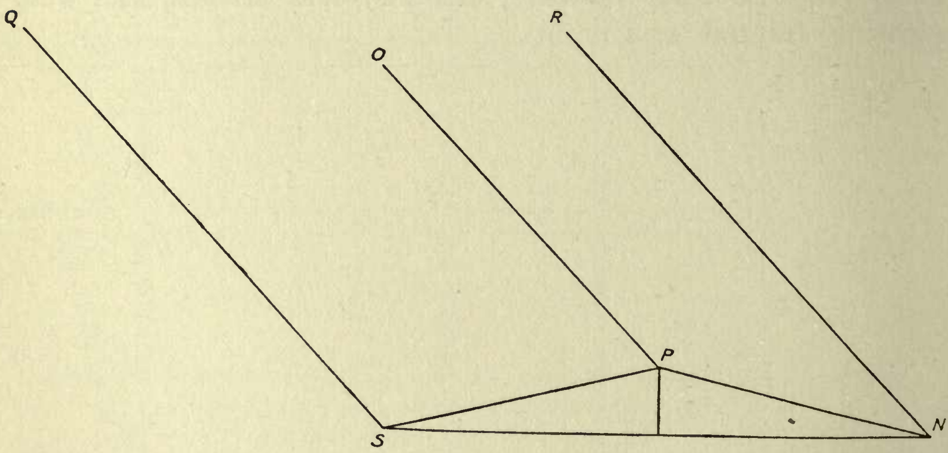

Fig. 44 —Diagram showing how the direction of slope of the surface of the soil affects the quantity of heat and light received from the sun.

living in the neighbourhood is thus stimulated. The garden must also be near a satisfactory water supply, as the necessity for fetching water from a distance takes up valuable time and tends to disorganise the work. The best soil available should be secured, as, although there are some advantages in watching the gradual amelioration of a piece of unfertile ground, these advantages are more than counterbalanced by the discouraging slowness of the process in the case of very light or very heavy soils. The garden ground should be either horizontal or should have a gentle slope south-east, south-west, or west. A slope towards the north,

ROYAL HORTICULTURAL SOCIETY'S GARDENS, WISLEY
The Rose Pergola: Students at Work

ROYAL HORTICULTURAL SOCIETY'S GARDENS, WISLEY
A Class in the Laboratory

is a great disadvantage. The reason for this will be obvious from a consideration of the accompanying sketch (Fig. 44).

It will be seen that if SPN represents a piece of ground one half of which slopes from the ridge P in the southerly direction PS, and the other half slopes in the northerly direction PN, while the area of the ground on the two slopes is the same, the total amount of sunlight and heat which falls on the ground and is represented by RNSQ, is not equally divided between the two slopes—more than half (represented by OPSQ) falling on the southern slope, and a correspondingly diminished quantity (represented by OPNR) falling on the northern half. The angle of incidence of the sun's rays is increased where the ground has a southern slope, and this is in fact equivalent to a change in latitude. If the garden ground is horizontal it must not be in an exposed situation, for it is impossible to obtain satisfactory results when plants are open to cold sweeping winds from the north or east. If such a situation is unavoidable, steps should be taken at the outset to provide shelter in those directions either by planting a thickset hedge of quickly growing plants or by making a plantation of trees to form a wind-break. For the purpose of increasing the educational value of the garden the latter is the better plan, because a variety of trees may be employed which will afford useful material for nature-study lessons. A very good arrangement would be to plant one row of British trees on the outside, and on the inner side of these, alternating with them, a row of plum trees, which are, for the most part, very hardy and cold resisting. While on the subject of trees, it may be useful to point out that large trees like the oak, elm, ash, and beech cover a very considerable area both above and below ground; their dense foliage intercepts a great deal of the rainfall which evaporates from the surfaces of the leaves instead of

FIG. 45.—An Error in Planting. Showing the mistake, or result of planting too near to large trees or shrubs, as the roots of the latter rob the plants of food. A, herbaceous plants; B, tree roots.

reaching the ground, while their roots, which extend sometimes to a distance horizontally of twenty or thirty feet, abstract large quantities of water and plant food from the area embraced by them. The garden should therefore be so situated that it is not nearer than the distance mentioned to forest trees of considerable size.

The best soil for a garden is a medium loam, that is to say, a soil containing about 50 per cent. of soil particles intermediate in size between the large grains (sand) and the very fine ones (clay), which possess a diameter of only from one-hundredth to one-thousandth of a millimetre. A sandy soil is characterised by its warmth, porosity, feeble power of holding capillary water, inability to "bind," and deficiency of mineral salts. While, therefore, on the one hand it is easy to work and produces early crops, it tends on the other hand to become parched, and soluble plant food is readily washed through it into the subsoil. A clay soil is cold, tenacious, and heavy in working; water passes through it only very slowly. Owing to the fineness of its constituent particles it is always moist, at any rate just below the surface. It absorbs and retains certain mineral matter from aqueous solutions. Roughly speaking, very light soils are satisfactory only in moist seasons, and very heavy soils only in fairly dry ones. To improve the water-holding capacity of a light soil, plenty of decayed vegetable matter should be worked into it, and the same substance only slightly decayed will, if worked into a heavy soil, tend to provide air spaces and thus make it more porous. Heavy soils are also as a rule improved by liming.

The same considerations as those mentioned apply to the underlying rock. Soils situated on sand, gravel, or chalk are warm and well drained, those resting on clay are cold and apt to become waterlogged. Hence where the underlying soil is composed of clay the garden must be drained. The main drain, at a depth of three and a half feet, should run down the centre of the garden and into a water course; the subsidiary drains should be at a depth of three feet. The accompanying sketch (Fig. 46) shows the arrangement. If the expense is considered too great a main drain at a depth of two and a half feet, with subsidiary drains at a depth of two feet may be laid, but this means bringing the drain pipes perilously near the spade when trenching operations are in progress, and should only be adopted when the soil is exceptionally heavy.

Whether a main drainage system is installed or not, it is essential on almost any soil except the very lightest that provi-

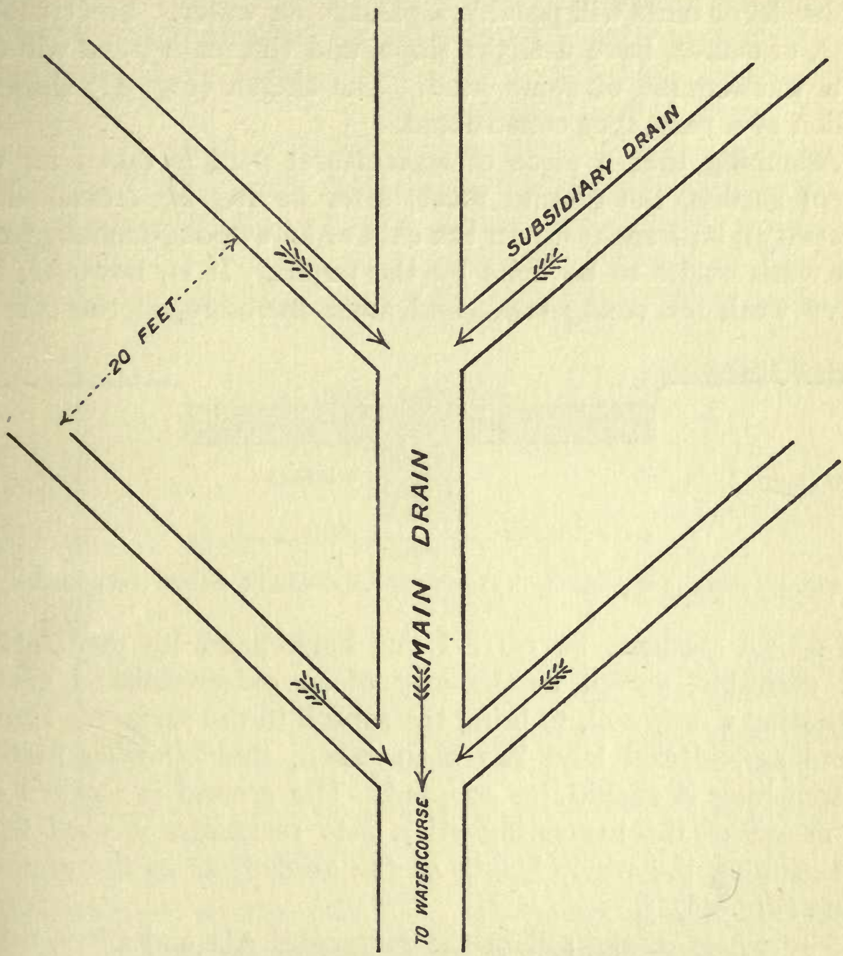

FIG. 46.—Drainage system for a stiff soil.

sion should be made for carrying off the surface water. As the cultivated ground will, in a year or two, be at a higher level than the paths, the surplus surface water will tend to run into the paths, and the surface drains are therefore most conveniently laid in the paths. These surface drains are very simply made, and there is no reason why the boys should not themselves construct them. After the paths have been taken out, and before they are gravelled, a trench should be taken out in the middle of each path, eight inches wide and six inches deep. The trench is then filled in with good sized pieces of broken brick and flints. When covered in with gravel the interstices between the bricks or flints will provide a passage for water. The trenches must, of course, have a slight slope, and the main trend will run to a watercourse of some kind. The sketch (Fig. 47) shows a section of a path thus constructed.

Assuming that a piece of agricultural land is taken for the school garden, the ground must, after having been drained (if necessary), be trenched. In the case of an evening-school garden this work ought to be done by the pupils. It is, however, too heavy work for young boys, and must therefore, in the case of

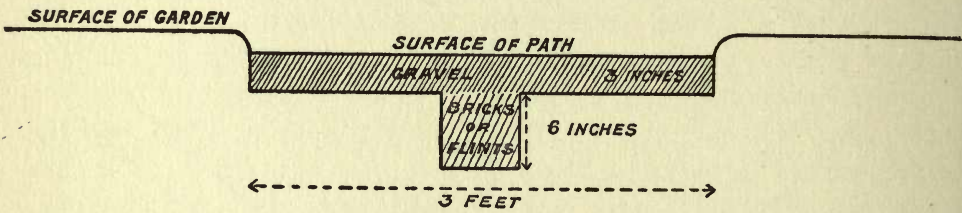

FIG. 47.—Section of garden path showing how it should be drained and gravelled.

day-school gardens, be carried out beforehand by men. It is not desirable, except in the case of an old-established garden possessing a deep soil, to bring the subsoil to the surface. Hence, where agricultural land has been taken, the following method of trenching it should be adopted. The ground is marked out by means of the measuring stick into rectangles a yard wide, and running the whole length of the garden, as in the annexed figure (Fig. 48).

The whole of the soil in the rectangles AD and CF is taken out to one spade's depth, and wheeled to the other end beyond JK. Similarly, a second spade's depth of soil is taken out of rectangle AD and wheeled to the other end. As this is not to be brought to the surface of the soil, it must be kept separate from the soil of the top spit already removed. The bottom of the trench AD is then dug over, and this rectangle has thus been dug to a depth of three spades. Next, the second spade's depth of soil is transferred from the rectangle CF to the rectangle AD, and finally the top spit of the rectangle EH is used to fill up the rectangle AD. This series of operations is then repeated in the rectangles CF and EH, and so on in successive rectangles until JK is reached, when there will be two rectangles at that end,—one deficient of soil to the extent of one spade's depth and the

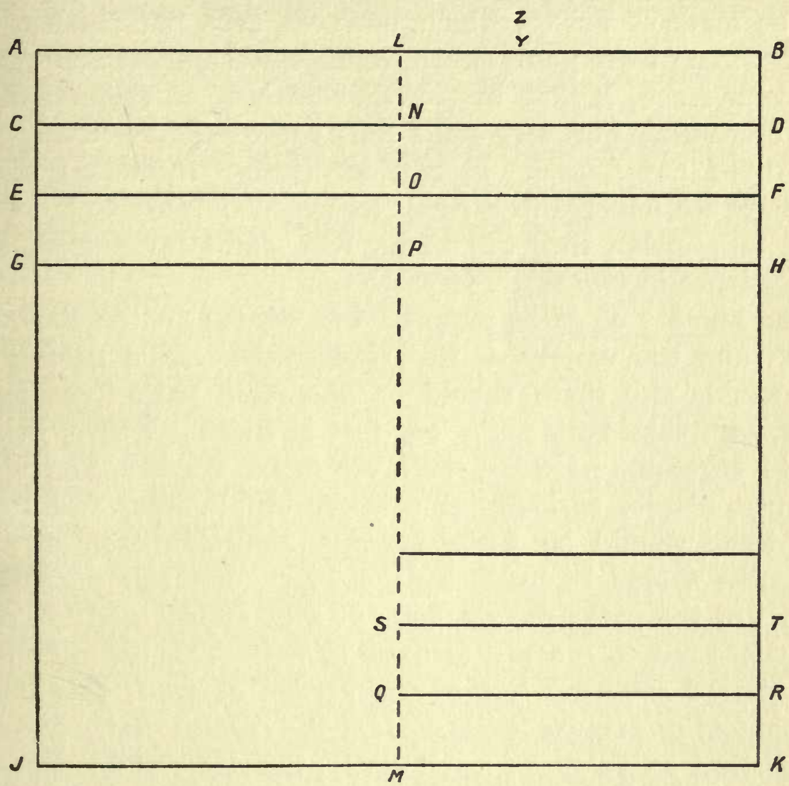

FIG. 48.—Arrangement of ground for full trenching.

other deficient to the extent of two spades' depth. These will be filled with the soil first removed from the other end.

Although boys will not, as a rule, carry out this operation of full trenching when the garden is being formed, they should, if possible, see it done, and should make a sketch and write a description of it. Later, when the garden is well established, every boy should, once in his course, take part in the operation. The preliminary trenching having been completed, we now have to consider fencing and path-making. This work is not beyond the strength of boys of twelve to fourteen. For fencing there is no better plant than the Whitethorn. This can be bought in quantities very cheaply. The plants should be set into the ground in a double row, the rows being six inches and the plants at half that distance apart. The planting should be done at the end of October. Of other plants used for fencing, mention may be made of Privet, which, however, does not make a sufficiently strong fence; and Beech, which while making a strong and handsome fence, is slow in growth, especially on soils other than sand or chalk. For very light soils the quickest growing plant is perhaps the Laurel. If cuttings (hedge trimmings will do) of Laurel are inserted in a small trench in October to a depth of about four inches they will readily root, and form a fairly satisfactory fence in two or three years time.

The number of paths required will depend on the size of the garden and the variety of its arrangement. In a garden of a considerable size there should be one main path three feet in width, with subsidiary paths two feet in width. Where, in addition to vegetable portions, there are flower borders, agricultural specimen plants, agricultural demonstration plots, and a fruit plot, there should be paths running alongside each of them. The paths should be made by the boys. For this purpose the outlines of the paths are marked out with stakes, and the soil is then taken out to a depth of three inches. This soil may either be scattered over the rest of the garden or used, as a bottom for compost or manure heaps. Next the surface drains are made as described on page 100; and lastly, the material for the paths is filled in and well trodden or rolled down. This material may be either gravel or preferably cinders or "brise" from the gas works, mixed with a little slaked lime to cement the whole. Well made paths add greatly to comfort in getting about the garden. It may be desirable to provide an edging to the main path. This is sometimes made with ornamental tiles, or with bricks stuck endwise into the ground; or box may be planted, but this is objectionable, because it affords a hiding-place for slugs. Probably the best edging is one made of boards seven inches wide by three-quarters of an inch in thickness. These, after being tarred, are let into the ground to a depth of three inches and secured in position by being nailed to short posts, two inches square and eighteen inches long, driven into the ground until flush with the upper edge of the planks. The cost of this edging is about sixpence per yard, or say, one pound for a single main path. It will save a great deal of trouble in keeping the path clean and the garden neat.

The equipment required for a school garden will vary with the age of the pupils, and with the variety of the work done in it. In elementary school gardens each boy should have a set of tools, consisting of a spade, fork, rake, Dutch hoe and trowel. Each tool of each set should have a number burnt or cut on it for purposes of identification. The cost of each set will be about twelve shillings. In addition, for general use there should be provided two or three draw hoes, a barrow, two watering cans, three garden lines, a thermometer, wooden labels, flower-pots, and bast, costing altogether about two pounds. If possible a spraying machine costing thirty shillings, and a budding knife, should also be provided. Some kind of storehouse must be provided for the tools and materials used in the garden, and for this purpose a wooden shed, ten feet long, five feet wide, and six feet to the eaves, is sufficient. A portable shed of this size can be bought for about two pounds. For more advanced work, however, it is a great convenience if a larger shed, to be used as a potting and store shed as well as a toolhouse, can be provided. A shed measuring sixteen feet by ten feet, and provided on one side with a bench two feet wide, and a shelf six inches wide, will cost about five pounds. If, as is strongly recommended, a hot-bed is used for raising seedlings and striking cuttings, a frame with one or two lights will be required, and this will cost from one to two pounds, according to size.

Besides the equipment above mentioned, certain materials will be required for carrying out a good course of work in gardening. Chief of these are manure (farmyard and artificial), sand, leaf-mould, leaves, and loam. The best farmyard manure is that of the horse. This should, if possible, be obtained in the green (that is unfermented) state, when it consists of undecomposed straw saturated with urine from the animals and mixed with their dung. In this state it can be used for making a hot-bed, and afterwards, when spent, can be spread over the beds. The cost of farmyard manure is from two shillings and sixpence to five shillings per tumbril load, weighing about one ton. Of artificial manures the only ones required are: (*a*) superphosphate of lime and steamed bone flour, which should as a rule be applied together, because the bone flour helps to dilute the acidity of the superphosphate; (*b*) nitrate of soda; (*c*) sulphate of potash; (*d*) sulphate of ammonia. Clean white sand will be required for making up potting mixtures, and also for bulb planting. Leaf mould can be obtained from the surface of the ground under trees. Dead leaves, which are required for the hot-bed, can always be gathered from the roadside in November. Another ingredient of the potting mixture, termed by the gardener "yellow loam," is obtained by cutting sods from the surface of an old pasture or from the grassy edges of the road and piling these in a heap where the grass is left to decay for three or four months.

Allocation of the Ground to the Students

As has already been stated, it is generally desirable in the case of girls that their work should be confined to the cultivation of flowers, salad plants, herbs, and fruit. For outdoor flowers various corners of the garden or playground may be assigned to individual pupils, but if the girls' class is a fairly large one an herbaceous border should be formed, four or five feet

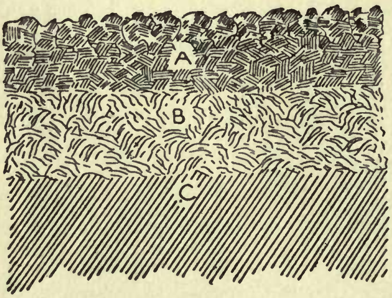

Fig. 49.—Preparing Ground for Borders. A, soil well broken up; B, soil generously manured; C, loosened sub-soil.

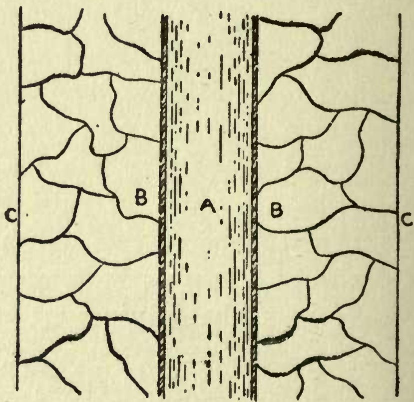

Fig. 50.—Herbaceous Borders. A, path; B, B, borders; C, C, boundary of borders.

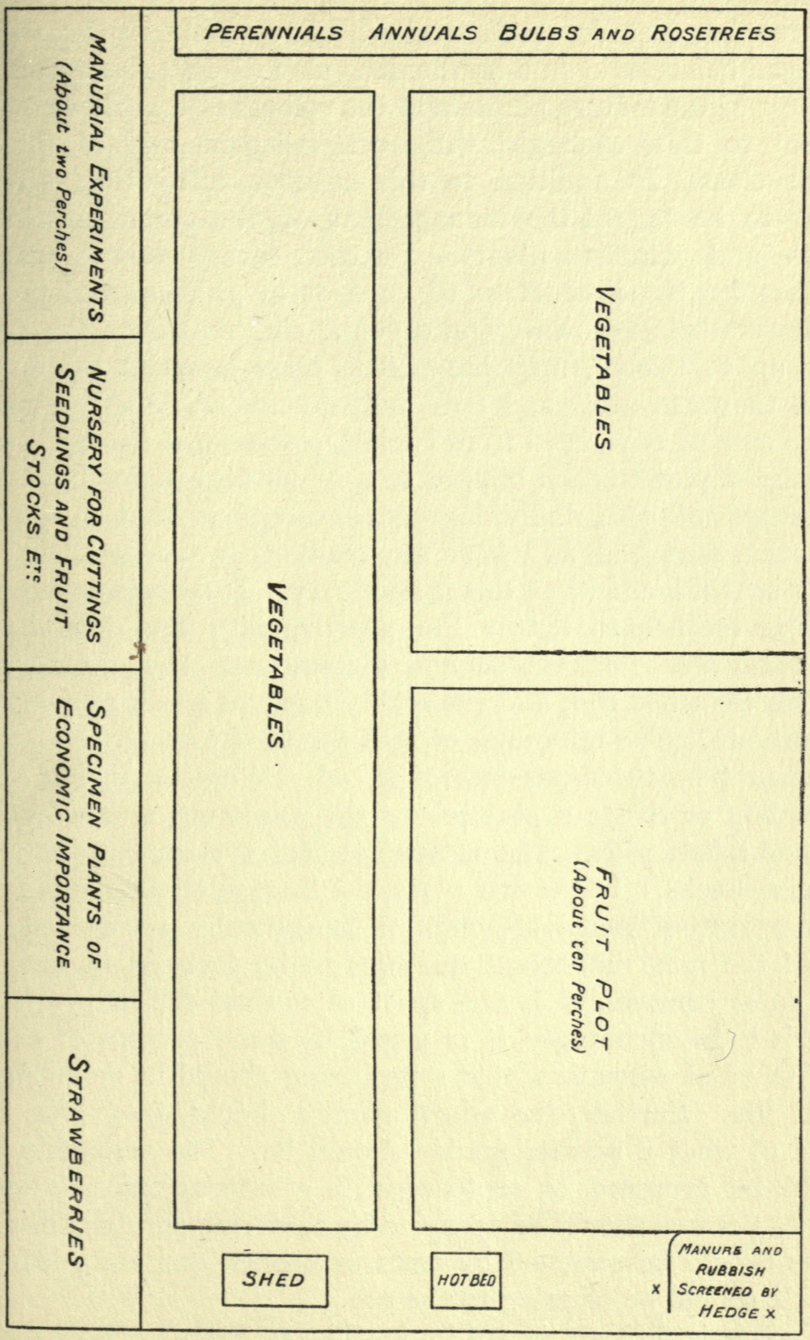

FIG. 51.—An industrial garden suitable for evening schools, cultivated co-operatively.

in width, and long enough to provide a length of not less than eight or ten feet for each worker. The whole border will be arranged beforehand on a harmonious plan which takes account of the sizes of the mature plants and the colours of their flowers, but, subject to this, each girl will work independently of the rest of the class. In addition to this outdoor cultivation, all girls ought to be taught the management of the commoner indoor plants and window plants. Further, every school garden, whether for the instruction of boys or of girls, should provide for flowers being grown. Quite young children, from the age of eight up to twelve, may have little plots assigned to them in which they can grow and tend bulb plants and hardy annuals. In the case of boys aged from twelve to sixteen it has been usual to assign a plot to each boy, or to a senior and junior boy. The advantage of this individual-plot system is that a spirit of emulation is roused, and boys are ready to work on their plots out of school hours when this is necessary. It is easier, moreover, for the teacher to detect the shortcomings and mistakes of individual workers. On such a system each boy should have not less than one rod, and preferably one and a half to two rods, to cultivate. The minimum of area assigned to each boy at this age should be three-quarters of a rod. Where a junior and a senior boy cultivate a plot jointly the minimum area should be one and a half rods. The individual plot system has, however, two drawbacks. In the first place, the English character is averse to co-operative work, although it is generally recognised that one of the most important qualities to be fostered in members of a rural community is the spirit of mutual self-help. If this spirit is to be encouraged it is urged, by some persons of experience in rural education, that a beginning should be made during school life. Further, the school garden should, *inter alia*, be a model of what a private garden should be. The vegetable beds should be arranged so as to provide a satisfactory rotation of crops. Corners should be occupied by flowering shrubs, unsightly spaces should be screened by trees or bushes, and the garden as a whole should be pleasing to the eye.

Now, it is difficult, if not impossible, to form a school garden arranged on the plot system which shall comply with this condition of being a model garden, and in too many instances the school garden is a spot devoid of interest and even positively ugly. Little rectangular beds of cabbages, onions, beet, potatoes, and so on, in monotonous succession, bounded by bare palings and walls, make a picture the reverse of educational. The weight of expert opinion seems to be on the side of individual work, so far as day-school gardens are concerned, but as a compromise the possibility is suggested of laying out the garden in single large beds, there being one bed of each crop, but assigning particular rows to particular boys. In this way, while the garden would present the appearance of an ordinary garden, each boy would still have his own sets of plants, for the management of which he would be entirely responsible.

If the co-operative method is not adopted in the case of day-school gardens, it is highly desirable that evening-school gardens should be cultivated in common. The teaching here will lean more to the utilitarian and commercial side. Grading, packing, and marketing of produce might be taught, and this can only be done satisfactorily when the garden is cultivated in common. The industrial-school garden affords a valuable instrument for the instruction of the younger members of the rural population in the essentials of co-operation, and should be a fitting introduction to the more complex co-operative methods which are generally recognised as necessary to ensure success in the management of small holdings.

Figs. 42, 43, and 51 show the arrangement of the beds adopted in three distinct types of schools.

CHAPTER VII

Tillage Operations and Manuring

In order that seeds may germinate the seed bed must supply to them warmth, moisture, and oxygen. Subject to this supply the seedling plant requires nothing else until it has exhausted the store of food material contained in the seed. When that point is reached the plant begins to draw upon the soil for mineral substances, in a soluble condition, containing nitrogen, phosphorus, sulphur, potassium, iron, magnesium, and calcium. Of these seven elementary substances, four, namely, sulphur, iron, magnesium, and calcium, are nearly always present in the soil in sufficient quantity, although not necessarily in a soluble condition. On the other hand, nitrogenous, phosphatic, and potassic compounds tend to become deficient in the soil, and must therefore be supplied either by means of farmyard manure or by such artificial manures as nitrate of soda, sulphate of ammonia (nitrogenous), superphosphate of lime, steamed bone flour, basic slag (phosphatic), sulphate of potash, and kainit (potassic). Nitrogenous manures appear to encourage vegetative growth and the production of foliage. The chief nitrogenous artificial manure is nitrate of soda, and as this substance is readily soluble in water it should be applied to the soil in spring, when it will be absorbed quickly by the roots of the growing plants, and there will not be the same risk of loss. Experience shows that about three pounds per rod may be applied with advantage in most cases. Basic slag and steamed bone flour become soluble only slowly, and may therefore be applied in the autumn at the rate of four pounds per rod. Sulphate of potash is the most suitable potassic manure for the garden. Like nitrate of soda, it is soluble in water, and should therefore be applied in the spring, at the rate of two pounds per rod. It frequently gives good results with potatoes and strawberries. Whether the garden soil would be benefited by the application of these artificial manures is a question which should be determined by experiment, and for this purpose one or two rows of each crop should be separately treated.

Lime, in the form of marl, ground limestone, or freshly slaked lime, may generally be applied with advantage at intervals of about four years. Lime tends to be washed by rain from the upper soil into the subsoil. In soil which has been heavily manured with farmyard manure or decayed vegetation for some years there is generally an accumulation of organic acids, especially humic acid, which may seriously affect the healthy action of the roots and arrest the work of the soil bacteria. In such a case the application of lime will neutralise the free acid of the soil and render the soil sweet.

Of almost greater importance than the chemical character of the soil is its physical condition, and this is capable of almost indefinite improvement by tillage properly carried out at the proper time, and by the application of decaying vegetable matter and lime. Digging, hoeing, raking, and pressing are the four chief methods employed in gardening for the improvement of the physical condition of the soil, and these will now be considered in some detail.

The object of digging is to provide a moderately firm soil in which the roots of the plants can spread freely, and to admit air, moisture, and carbonic acid, which act chemically upon the insoluble reserve mineral matter of the soil, rendering it available for absorption by the roots. Boys should be instructed how to hold the spade properly, how to use their strength to the best advantage in driving the spade into the ground and in lifting the soil, and how to place the soil so as to have a fairly level surface. The method of full trenching has been already described. Bastard trenching, or double digging, consists of cultivating the soil to a depth equal to that of twice the spade's depth. As in full trenching, the ground to be double dug is marked off into rectangles one yard wide (see Fig. 52).

The whole of the top spit in the rectangle ACDB is dug out, placed in a wheelbarrow, and transferred to the other end of the plot beyond GH. The second spit of ACDB is then dug over. Next, the top spit of the rectangle CEFD, is dug out and transferred to rectangle ACDB, the second spit of CEFD is then dug over. This series of operations is repeated on successive rectangles until GH is reached, when the top spit of ACDE is used to fill up the rectangle GHLK. The effect of the operation thus is that the soil has been thoroughly stirred to two spades' depth, but no subsoil has been brought to the surface. The reason for not bringing the subsoil to the surface is that it is frequently incompletely aerated, and not suitable for a seed bed. Where, however, a garden has been established some years it will be an advantage to deepen the soil, as distinct from the subsoil, by bringing the second spade's depth to the surface.

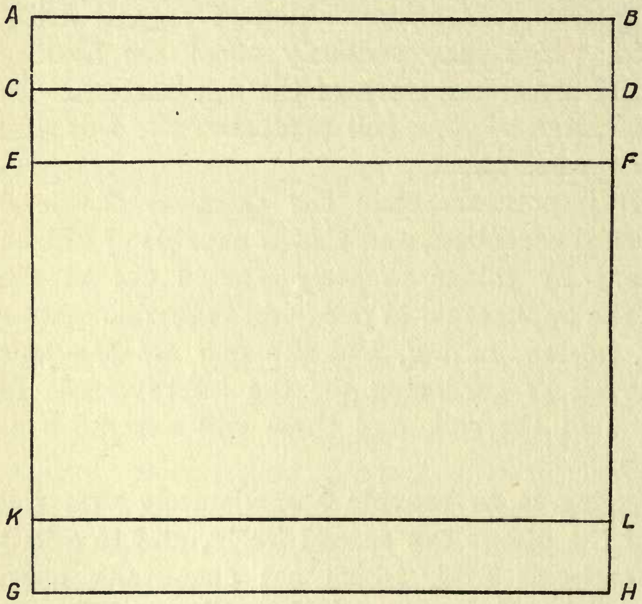

FIG. 52.—Arrangement of ground for bastard trenching.

In the process of digging the soil is loosened so as to permit the plant roots to forage freely throughout the soil which is within their reach. This is specially important in the early stages of growth when any circumstance which tends to check the growth of the plant has a particularly harmful effect. When the plant is thoroughly established in the soil it is able, and in fact does, send down its roots far below the level reached by spade cultivation. In the process of digging, moreover, atmospheric oxygen is introduced into the soil spaces, and provision is thus made for the supply of oxygen to the roots, without which they would die. Oxygen is required too for the bacteria in the soil, which in a number of ways are necessary for fertility. Any substances not fully oxidised, as, for example, sulphides and lower oxides of iron, are converted by oxygen into harmless sulphates and higher oxides. In a soil which has been loosened by digging, water percolates more freely. The exposure of fresh surfaces to the action of atmospheric oxygen, carbonic acid, and water results in bringing into solution small quantities of mineral salts necessary to plant life, and this is assisted by the mechanical effect of alternations of heat and cold on the soil particles. This mechanical effect is especially marked in the case of frost action, and for this reason autumn digging is of great importance. Water expands about one-twelfth of its volume on freezing, and the result is that any compound particle of soil containing interstitial water is, on exposure to a temperature at or below the freezing-point of water, subjected to a powerful disintegrating force far exceeding any that can be directly exercised by an implement of tillage. The results of this disintegration are most marked on strongly cohesive clay particles, which after exposure, first to frost and subsequently to a higher temperature, break down and form a tilth exceedingly suitable for a seed bed. It is important that, when such a surface has been produced, there should be no subsequent tillage which will destroy the tilth. The surface should be touched only with the rake or hoe. It is desirable in autumn tillage to expose as large a surface of the soil as possible to the action of frost, and hence ground dug at this period of the year with the intention of leaving it until the spring should be as rough as possible. The more lumpy it is the greater will be the area exposed to frost action. For rather heavy soils the process of ridging in the autumn may be adopted. This operation is carried out by means of the spade, and consists in digging out a series of parallel rectangles equal in width to twice that of the spade, and laying the soil thus dug out in a series of parallel ridges occupying the centre line of each rectangle. Only a moderate depth of soil should be thus dealt with, otherwise the ridges will be too large to be raked down in the spring. Apart from the mechanical result obtained by ridging, the exposure of a large volume of surface soil to a low temperature will result in the destruction of many grubs of hurtful insects.

In considering the mechanical effect of change of temperature on soil, it must be borne in mind that the soil does not consist of particles of a uniform size, that the particles are coated with films of water, and that the particles are cemented together with a small quantity of a colloidal substance. When, therefore, a mass of soil is exposed to alternations of cold and heat, there are different pressures in different directions, which cause the mass to split, not into its ultimate particles, but into compound particles, and it is the production of these compound particles which constitutes one of the principal objects promoted by tillage.

Next to the spade, the hoe is probably the most generally important garden tool. There are two main kinds of hoes, the draw hoe, which, as the name indicates, is used by pulling it towards the worker, and the Dutch hoe, in which a pushing motion is adopted. The latter is probably the more generally useful for schoolboys. The most obvious use of the hoe is for severing the roots of weeds. The draw hoe is also used in ridging up rows of plants, and sometimes for making drills for seeds. In a dry season, whether in spring or summer, the production with the hoe of a surface mulch of loose soil is of great benefit in preventing evaporation by sun and wind of water from the soil. The shallow coating rapidly becomes dry, but it protects the under undisturbed surface from evaporation, and thus preserves the store of moisture in the soil.

It may be useful at this point to notice the effect on soil moisture of treading the soil down. This effect is twofold. In the first place, the firmer and more even surface has less tendency than a loose surface to become dried by sun and wind; in the second place, the consolidation of the soil by treading promotes the passage of water upwards, the drier soil being brought into closer contact with the moister subsoil. Thus the result is a better supply of moisture just below the surface, which supply is necessary for the germination of shallow drilled seeds. The effect of treading is only temporary, and a firmly pressed soil, in the long run, loses more water by evaporation than a looser soil, but this does not matter so long as the object of an immediate supply of moisture to the seed and the tender seedling is secured.

Drawn by Lilian Stannard

A ROCK GARDEN

CHAPTER VIII

Multiplication of Plants

Seeds.—The commonest method, whether in nature or in the field and garden, for increasing the number of plants is by seeding, and on this account, and also because seeds lend themselves to a variety of simple but instructive experimental work, it is desirable that the boys or girls should make some preliminary observations of the conditions of germination, and on the germinative capacity of various species of seeds. For this purpose it is best as a rule to select large seeds, such as those of the Broad Bean, Pea, or Scarlet Runner. For the study of the structure of a seed, peas may be soaked in water for a few hours in order to soften them, and then dissected, so as to show the seed coat, the seed leaves, the plumule, and the radicle. Drawings should be made. To show the changes resulting from germination, other seeds should be placed between pieces of moist blotting paper or flannel, and kept in a fairly warm room. If some of the seeds are just covered with sand in a flower pot, and kept moist and warm, the way in which the seedling roots itself in the soil can be studied. To show the effect of temperature, one set of seeds may be placed in a cold room and the other in a warm room; the conditions being otherwise the same, the growth in the latter case will be much more rapid. It is a little more difficult to demonstrate the necessity for oxygen, but if a supply of carbon dioxide is available this may be done by moistening the seeds, placing them at the bottom of a flask, and passing the washed gas through the flask for a quarter of an hour. The flask is then quickly corked, and should be kept in a warm place.

It is easy and instructive to determine the germinative capacity of various samples and species of seeds. To do this, we take an exact and convenient number of seeds (fifty or one hundred), place them between two pieces of flannel or blotting paper on a tile which lies in a dinner plate containing a little water. The whole is left in a warm place (60° to 65° Fahr.) for not less than ten days, care being taken that the water in the plate is replenished if necessary, and that the flannel or blotting paper is maintained in a moist condition without being soaked. At the end of the period the number of germinated seeds is counted and expressed as a percentage. The experiments will be more instructive if a variety of seeds are dealt with. For example, three pupils might work with Carrot seed (these are really fruits), three with Parsnip seed (also really fruits), three with Cabbage seed, three with Peas, and so on. By arranging for at least three samples of one kind of seed to be tested the accuracy of the work is ensured, while the natural differences in germinative capacity of the various seeds will also be brought out. Thus it will probably be found, in the case of samples of average excellence, that the percentage of germinated Cabbage seed will be about three times that of the Parsnip seed, and that Carrot seed comes somewhere about midway between these. If a sufficiently large number of species are observed an interesting table of results can be constructed.

For practice in identifying seeds the teacher should keep as many different sorts of seeds as he can procure, in small pill boxes, to be distributed occasionally to the class. The supply will require to be replenished every second year as a rule, because old seeds lose their brightness and plumpness if kept longer than that time.[1]

[1] The writer finds that Messrs. Sutton & Sons, of Reading, supply seeds of the following species and varieties in small glass tubes with metal caps at three shillings per dozen tubes. Small bags of seeds for refilling the tubes are supplied by them at one shilling and sixpence per dozen bags.

Achillea Millefolium
Agrostis stolonifera
Alopecurus pratensis
Anthoxanthum odoratum
Avena elatior
„ flavescens
Bromus inermis
„ Schraederi
Cynosurus cristatus
Dactylis glomerata
Festuca duriuscula
Festuca elatior
„ heterophylla
„ ovina
„ ovina tenuifolia
„ pratensis
„ rubra
Lolium italicum
„ perenne
„ annuum
Phleum pratense
Poa aquatica

The soil of a seed bed must be composed of fairly fine particles, neither too loose nor too compact; it must be moderately moist, and must be at a temperature (which varies with different species of seeds) suitable for germination. If excess of water be present it is clear that the interspaces of the soil will be occupied by water to the exclusion of air, which is essential both for germination and for root growth. If the soil is not sufficiently fine the seed may find its way too deeply into the soil, and also the roots of the seedling plant may fail to come into sufficiently close contact with the soil particles to obtain from them the full necessary supply of mineral food.

Definite rules respecting the depth at which various seeds should be sown cannot be given, but, speaking generally, the smaller the seed the more shallow should it be planted. Very fine seeds should be just covered with soil, while peas and beans may be covered to a depth of one and a half to two inches.

Poa nemoralis
,, pratensis
,, trivialis
,, serotina
Elymus arenarius
Ammophila arundinacea
Trifolium pratense
,, ,, perenne
,, repens perenne
,, hybridum
Medicago lupulina
Trifolium minus
,, incarnatum
,, ,, var. album
Vicia sativa
Cichorium Intybus
Faba vulgaris
Pisum sativum arvense
Carum Carui
Ervum Lens
Melilotus alba
Medicago sativa
Lotus corniculatus
Lotus major
Beta vulgaris
Brassica campestris
Brassica Rapa
,, oleracea capitata
,, ,, var. caulo-rapa
,, campestris, var. Napus
Daucus Carota
Pastinaca sativa
Sinapis nigra
Spergula arvensis
Ornithopus sativus
Trigonella Fœnum-græcum
Onobrychis sativa
Cytisus scoparius
Ulex europæus
Anthyllis Vulneraria
Lupinus luteus
,, hirsutus
Linum usitatissimum
Poterium Sanguisorba
Plantago lanceolata
Polygonum Fagopyrum
Zea Mays
Petroselinum sativum
Cannabis sativa
Sorghum saccharatum
,, vulgare

Messrs. Toogood, of Southampton, are also prepared to supply schools with tubes of seeds at a cheap rate.

The multiplication of plants by means of seeds is a sexual method of reproduction,—that is to say, it involves the union of two cells produced, so far as flowering plants are concerned, in the stamen, or male portion of a flower, and the carpel, or female portion of the flower, respectively. The other method of multiplication of plants is by vegetative reproduction, which involves the separation from the parent plant of a portion of its leaf-stem or root, such portion developing roots and thus becoming a new plant. The act of separation may be the result of the natural growth of the plant, or it may be effected artificially.

THE CORM.—This is really a short underground thickened stem coated with membranous scales. To understand the method of reproduction, dig up Crocuses (*Crocus verni*) in the spring, after the flowers have died down, and note: (*a*) at the base, the adventitious roots, with possibly the remnants of the corm of the preceding year; (*b*) above these, the corm of the year, which is now shrivelled, owing to its reserve substances having been partly used up in producing the leaves and flowers which have just withered; (*c*) the new corm, which will be mature by the end of the summer, and which is being stored with food material for the growth of the leaves and flowers of the succeeding season. With the corm of the Garden Crocus compare the corm of the Gladiolus.

THE TUBER.—This is also a stem, usually underground, and possessing small membranous scale-leaves from whose axils buds arise. Dig up a young potato plant in the early summer, and note that the tubers are swollen portions of underground stems. Select a very small tuber, and with the aid of a magnifying glass make out the scale-leaves near the "eyes" of the tuber.

THE BULB.—A bulb consists of a relatively short stem which is enveloped by a number of fleshy scale-leaves. The essential difference between a bulb and a corm is that the reserve material is in the former stored in the scale-leaves, and in the latter in the stem. Dig up a growing Onion, Hyacinth, or Tulip, and cut a vertical section of the whole plant, noting the roots, short stem, scale-leaves, and foliage-leaves.

THE RUNNER.—Good examples of these are found in the Strawberry and Creeping Crowsfoot. The runner is a creeping stem with long internodes. At the nodes are produced a tuft of shoots and adventitious roots. These roots attach themselves to the soil, and the internode ultimately decays.

The above are the principal ways in which a plant reproduces itself vegetatively. The chief artificial methods of vegetative reproduction are effected by means of division, layers, cuttings, grafting, and budding.

Nearly all woody plants at some period or other in their growth give rise to branches from underground points in their stems. These branches grow in an oblique direction towards the surface, and when they reach it develop leaves above ground and adventitious roots underground. Such a growth is very appropriately termed a "sucker," since it frequently robs the parent of nourishment. Ultimately the portion of the stem which connects the sucker with the parent plant rots away, but this process is hastened by the gardener, who cuts through the sucker at a point below its roots. This method of increasing the number of plants is commonly employed in the case of perennial flowering plants. For purposes of study, note the suckers of Raspberry, Rose, and Plum trees. Dig out the soil around one of these, so as to see that the sucker arises from a subterranean portion of the stem, and to observe the adventitious roots.

If we cut off a portion of the stem of a plant, insert the cut portion in the soil, and keep it moist and warm, the cutting will in most cases "strike." That is to say, adventitious roots will be formed at the node immediately above the cut, provided this node is covered by the soil. A similar formation of roots can be induced in the severed leaves of Begonias and Gloxinias, and in the roots of Pelargoniums. Moreover, it is not necessary to separate the stem completely from the parent plant, for if the stem is bent downwards and one portion of it partly cut through and covered with soil, adventitious roots may be produced. Detailed examples will now be given of the ways in which these facts are utilised in gardening.

CUTTINGS.—Two distinct classes of cuttings must be distinguished, namely, cuttings of woody stemmed plants and cuttings of soft stemmed plants. Woody stems, as a rule, contain a larger store of reserve food material than do herbaceous stems. Moreover, in the case of the former less water is lost by transpiration from the stem. The propagation of woody plants by this method is therefore a rather simpler operation than in the case of plants with herbaceous stems. For illustrative purposes any of the following plants may be selected: Privet, Whitethorn, Lilac, Lavender, Barberry, Syringa (*Philadelphus*), or Laurel. Select a

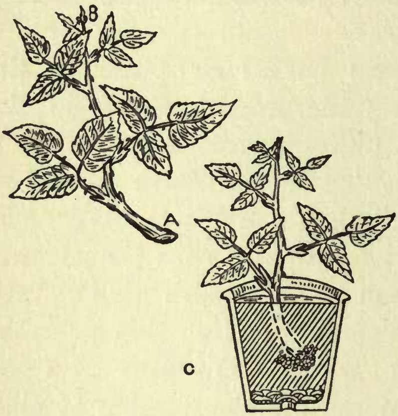

FIG. 53.—Propagating Roses from Spring Cuttings. A, cutting with a heel, severed beneath a joint; B, point of cutting retained; C, the cutting inserted.

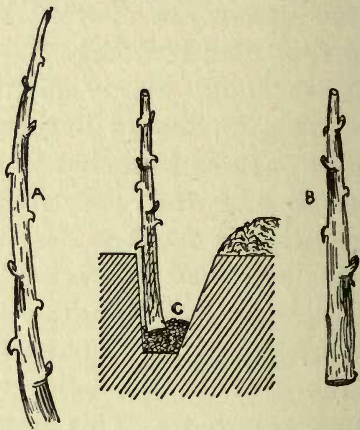

FIG. 54.—Propagating Roses from Autumn Cuttings. A, suitable shoot; B, cutting prepared for insertion; C, cutting inserted, with its base on a layer of sand.

portion of the garden where the soil is good and has been recently cropped. There should be no undecomposed farmyard manure in it. Mark off a rectangular portion four feet wide and twelve feet long. This will be sufficient for a hundred cuttings. Dig over the rectangle a week or a fortnight before the cuttings are to be inserted, so as to give the soil time to settle, and just before planting tread the soil all over so as to make it firm. With the aid of the garden line trace four lines on the bed at a distance of one foot apart, and along these lines make small trenches about four inches deep, and so that one side of each trench is strictly vertical. To provide for aeration and drainage in the case of a heavy soil, sprinkle a layer of sand along the bottom of the trench.

In taking the cuttings do not sever them from the parent plant by means of a knife, but break off side shoots close to the main shoot, so as to leave what gardeners call a "heel," *i.e.* an oval-shaped base. Trim the ragged edges of this base, and place the trimmed shoots upright in the trench, taking care that the base is pressed firmly against the sanded bottom. Having thus carefully placed all the cuttings in position, at a distance from each other of six inches, shovel the earth into the trench, with the foot treading it firmly against the cuttings, and then rake lightly between the rows. This operation is carried out in the early autumn. In the following spring one or two cuttings may be dug up for examination, and after shaking off the soil from the base the adventitious roots should be noted, and a drawing made. Note also the protective callus, partly covering the cut surface and produced by the cambium. By the following spring —that is to say, about twenty months from the date of planting —a good mass of roots will have been produced, and the plants will be ready for placing in their permanent quarters. In removing them the ball of earth enclosed by the roots should be disturbed as little as possible. The rooted cuttings of Thorn and Privet may, if necessary, be used for making a hedge, and for this purpose should be planted in a double row at a distance of three inches between the plants and six inches between the rows. The Syringa, Laurel, or Lilac plants may be planted in corners of the garden. The Lavender plants may either be distributed among the students' plots or used to make a Lavender bed, in which case they are planted in rows, giving them a space of fifteen inches each way. It will, of course, be understood that it is not essential when planting the cuttings to set apart a separate bed for the purpose, as, if thought fit, each pupil may plant half a dozen on his or her own individual plot.

As indicated above, the propagation of herbaceous perennials by cuttings requires rather more skill and attention. The soil must be fertile and well drained, and we shall require the assistance of the hot-bed to promote adequate root formation before the winter comes on. The operation should be effected rather earlier than in the case of woody perennials, and not later than the middle of September. Six-inch flower pots may be conveniently employed, and these are half filled with pieces of broken pot to ensure free access of air, and over this is spread a thin layer of decayed leaves. Into the pots is firmly pressed a potting mixture composed of two parts of "loam," two parts of leaf-mould, and one part of sharp white sand. With a sharp knife take the cuttings from strong side shoots just below a node, and trim off the lower leaves from the cutting. Five or six such cuttings may be planted in a six-inch pot. In planting them, the essential point to observe is to make sure that the soil is pressed firmly against the base of the cutting. With a small dibble as many holes are made, equidistant from each other and from the circumference of the pot, as there are cuttings. In the case of small cuttings, such as those of Lobelia, these holes should be only about one to one and a half inches in depth. Insert the cuttings one by one, and as each is placed in the hole insert the dibble in the soil a little on one side, so as to press the soil firmly against the length and base of the cutting.

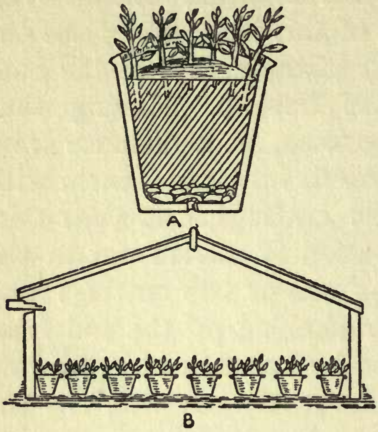

FIG. 55.—Propagation by Cuttings. A, Cuttings in a pot; B, pots of cuttings in a frame.

Herbaceous cuttings have little reserve food material in their stems and leaves, and tend also to lose relatively considerable quantities of water by transpiration from the leaves and stem. If too much water is thus lost before the cutting produces roots it will wilt and die. Subsequent treatment aims accordingly at reducing transpiration and at inducing rapid formation of roots. The three conditions which favour root formation in these circumstances are warmth, moisture, and oxygen at the cut surface. When the cuttings have been planted we water them well, and transfer to a hot-bed. The hot-bed must have been prepared some days beforehand. At least two loads of good horse manure is required even for a small frame. A rectangular area one foot longer and one foot wider than the frame is marked on the ground, and covered with a layer of manure. This is well trodden down, and a thin layer of dead leaves is then sprinkled over it. The alternate layers of manure and leaves are repeated until all the manure has been utilised. It is important that the heap should be trodden down as firmly as possible. The object of this, and also of the leaves, is to reduce the rate of fermentation, and thus to maintain a moderate temperature for a considerable period. The rise in temperature is in effect an oxidation of the substance of the manure heap through the agency of various species of bacteria. By treading the heap down we reduce the amount of air in the heap, and so reduce the speed of oxidation. The action of the leaves is mainly one of dilution. On the heap thus prepared the frame is placed, and inside is spread a layer of ashes to a depth of three inches, in which we can plunge the pots to a suitable depth for a steady supply of warmth to the cuttings. During the first two or three days there will be a considerable rise in temperature, as observed by means of a thermometer placed inside the frame, and most of the oxygen in the heap will be used up. When this stage is reached the fermentation processes depend mainly on the infiltration of air from the outside, the processes therefore slacken in intensity, and the temperature falls a little. At the end of about five days from the time of making, the temperature is steady, and the pots containing the cuttings may be plunged in the ashes. To reduce transpiration, the atmosphere of the frame must be maintained moderately moist by watering, and for the same reason direct sunlight must be excluded. For the first fortnight the frame is opened an inch for half an hour daily to admit air. The plants are then gradually hardened off by partly opening the frame during the warm part of the day, and finally are transferred to the greenhouse or room where the temperature throughout the winter is not allowed to fall below 40° Fahr.

If a hot-bed is not available, cuttings may also be taken in the spring, although in that case the time available for the plant to establish itself before flowering is shorter. Pinks, such as the Clove Pink and "Mrs. Sinkins" Pink, may be treated in this way. The method of taking and of potting the cuttings is the same. Indeed, cuttings of Pinks may be planted out at once on the border, provided this is well shaded from the sun.

The cuttings are taken in March, planted at a distance of one foot from each other, and well watered.

Propagation by Division.—This is a very simple operation. Experience shows that the smaller perennial herbaceous and woody flowering plants are at their best during the first three or four years after planting. At the end of that time the plant usually deteriorates from a horticultural point of view. It will have become straggling and "leggy," and the proportion of flowers to the size of the plant will have decreased. Part of this effect is due to the natural growth of the plant, and part to exhaustion of the available mineral matter in the soil. In these circumstances it is desirable to transfer the plant to another position, and at the same time to divide it up into several portions, each of which may be separately planted. The original plant is dug up with a fork, and it will then be found that adventitious roots will have been produced on the underground portions of most of the shoots. These may be torn apart with one's hands, the coarser shoots being discarded and the younger ones trimmed and replanted, care being of course taken that each shoot selected for replanting bears some roots. Propagation by division should be carried out in October, when the plant is entering upon its resting stage.

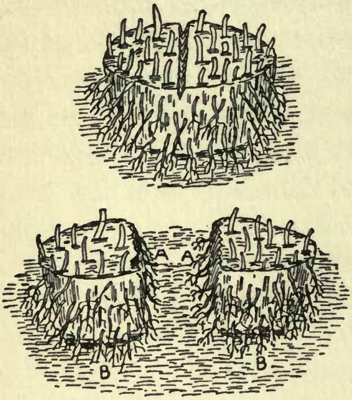

Fig. 56.—Lifting and Dividing Clumps. Roots A, A are not broken when a fork is used; B, B, outside fibrous roots preserved.

Layering.—This is an operation intermediate between propagation by cuttings and propagation by division. In the former case adventitious roots are developed after the cutting is taken; in the latter case, before the separation from the parent plant. In layering we induce the formation of adventitious roots in a shoot by partially severing the shoot from the parent. The essence of the method consists in cutting partly through a shoot, just below a node, and then bending the shoot down, fastening it to the ground by means of a peg of some kind, and then covering the cut portion with moist soil. Roots are produced at the node, and when well developed the shoot may be completely cut through and planted out. A very large number of species of plants may be propagated in this way, and the students should be encouraged to experiment on a variety of herbaceous plants, shrubs, and bushes, not necessarily confining themselves to plants of the garden. They should notice that the farm labourer, when making or renovating a thorn hedge, makes use of the two methods of propagation, by cuttings and by layers. The period which should be allowed to elapse between layering and separating the rooted shoot is different for different sorts of plants. Generally speaking, herbaceous plants may be layered in July, and the shoots taken off in September. Woody shrubs should be layered in autumn, and not severed until the following August or September. For detailed description we may select the propagation of Carnations, which is usually effected by layering at the end of July. We require for the purpose a really sharp knife, a small quantity of potting soil, and small wooden pegs such as may be easily cut from any hedge. A vigorous side shoot should be chosen, and after trimming off the leaves from the lower portion of it a node convenient for pegging down should be selected. An oblique cut is then made in the shoot commencing a little distance below the node and extending through the middle of the stem up to, but not through, the node. The shoot is next bent down so that the cut portion rests firmly on a small pressed-down heap of the potting soil, and is there pegged. It is then covered with some more of the potting soil, also firmly pressed down, and the mass of soil thoroughly moistened. The parent plant is also well watered, and the

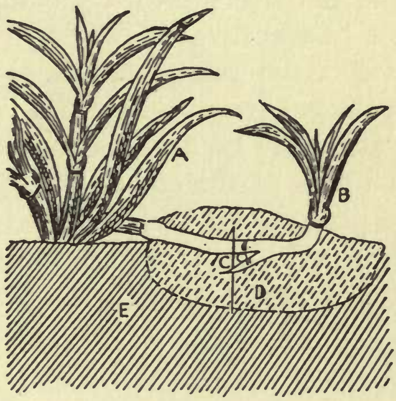

FIG. 57.—Layering Carnations.—A, old plant; B, young layer; C, shows the cut made with a sharp knife, lip of stem kept open with small pebble; D, special compost; E, border soil.

watering must be repeated every few days if the weather is dry. Under these conditions adventitious roots are produced at the node within a month, and in two months' time from the date of layering these roots will be sufficiently well developed to permit of the separation of the shoot from the parent. The rooted shoot is then potted in good potting soil, and placed in a cold frame or on a window-sill. Care must be taken during the first few days after potting that the plant is not exposed to conditions which favour much transpiration, otherwise the plant will lose more water than can be supplied by the roots, and will wilt. The potting mixture should not be dry, and the plant should not be watered for the first four days after potting. During the winter the plants are kept preferably in the cold frame and protected from frost. If a cold frame is not available the young plants may be kept indoors during the winter, and planted out in the beds at the end of March; or again, the layered cuttings may be planted out in a sheltered bed out of doors in the autumn, but they will then require to be protected with matting during severe winter frosts.

CHAPTER IX

Vegetable Culture

An abundant supply of good fresh vegetables throughout the year is essential for health, and therefore, whatever other departments of horticultural work are undertaken in the school garden, vegetable culture ought, except in the case of a school in the centre of a large urban area, to take the first place.

Continuity of supply is important, and the young student should therefore be so instructed that he may have exact information as to the time of planting and the length of the period during which the ground is occupied by the various crops commonly grown in the vegetable garden. He should thus be able to say at once what crops may be expected to be occupying the garden at any time of the year. It is only when the worker has clear and exact knowledge under these heads that he is able to utilise the ground at his disposal to full advantage, and to provide a satisfactory supply.

It is of some importance to arrange for a rotation of crops, though, provided the garden soil is good, this is not so necessary as in the case of farm crops. In a good rotation of crops a shallow rooted plant is succeeded by one which roots deeply; and further, plants of closely allied species should not succeed each other, for the reason that closely related plants frequently make similar demands on the mineral constituents of the soil, and also harbour the same fungoid and insect enemies.

The pupils may with advantage receive some instruction on the food values of the various vegetables cultivated by them, and if the school possesses some equipment for chemistry they may be taught how to isolate and examine some of the most important common constituents. Microscopic sections of vegetable tissue may be examined for cellulose, starch, protoplasm, and oil drops. The most abundant constituent of most vegetables is water. To determine this amount very roughly, a very thin slice of potato, apple, radish, etc. may be weighed on the ordinary balance used in schools for elementary chemical and physical determinations. The slice is then strung on a knitting needle and placed in an air oven maintained at a temperature of about 110° for some hours. A very great decrease in weight owing to loss of water will be observed. The results may be compared with those obtained similarly in the case of slices of Brazil nuts or chestnuts. The results, though rough, will sufficiently indicate the difference in water contents. Nuts and seeds contain from 1 to 10 per cent. of water, while juicy fruits and vegetables contain from 50 up to over 90 per cent.

Of the carbohydrates, starch is present to the extent of 10 to 14 per cent. in Potatoes, while sugars are present to about the same amount in ripe Apples, Pears, Grapes, Strawberries, and Raspberries. Parsnips and Carrots contain 6 to 10 per cent. of sugar, and Sugar Beet contains 15 per cent. To show the presence of starch, peel a potato, and then grate it on a nutmeg grater, allowing the grated portion to fall on a piece of fine muslin stretched over a glass jar or jug. By washing the grated mass with water the starch grains are carried through into the glass vessel, while the cellulose remains on the muslin as a soft whitish mass. If the starch is allowed to settle and the liquid decanted the finely granular character of starch can be easily made out. Starch grains from various vegetables may be examined under the microscope and their appearance compared.

Sugars can, of course, be detected in ripe fruit by the taste, and their presence demonstrated chemically by warming a little of the filtered expressed juice with Fehling's solution. Crystals of sugar may also be obtained by boiling Carrots, Parsnips, or Sugar Beet in water, crushing the boiled mass, filtering, and evaporating the filtrate to small bulk.

The presence of oil in nuts is best shown by means of thin sections mounted in water and examined under the microscope. Or we may imitate the process of manufacture of agricultural "oilcake," by crushing seeds of rape or of flax, which contain 30 to 40 per cent. of oil. Many of the proteid substances of plants are soluble in water, and like white of eggs are coagulable by heat.

To demonstrate the presence of proteid, we may therefore crush succulent vegetable tissue, filter the expressed liquid into a test tube and warm, when a whitish precipitate will be produced. The mineral substance of plants is contained in their ashes, part of which is soluble in water and part (carbonate of lime, etc.) insoluble.

To grow heavy crops of vegetables of good quality the conditions of moisture, temperature, aeration, presence of mineral food in an available form, and absence of injurious substances from the soil, must be met. The ground must therefore be trenched, unless this has been done in the previous year, and well manured. The best manure is farmyard manure, this being a general manure; that is to say, it contains, either in an immediately available form or in a form which will gradually become available within a few months, those three chemical elements which are essential to plant life and are shown by experience to be easily removable from the soil. These three elements are nitrogen, phosphorus, and potassium. The four remaining elements (sulphur, iron, calcium, and magnesium) are in practically all cases present in sufficient quantity. Apart from the fact of its being a general manure, farmyard manure keeps a heavy soil open, and thus ensures the presence of air and the passage of water. When partly decomposed under the action of soil bacteria, it gives rise to a dark, powdery substance termed humus, which possesses the property of retaining moisture, and consequently farmyard manure is equally valuable from its physical effect on light sandy soil. Stable manure is drier and more easily fermentable than manure from the cowshed or pigstye. The former is therefore the most suitable for very heavy soils, and the two latter for sandy soils. For intermediate types of soils the difference in the behaviour is so slight as to be negligible. A soil which has not previously been used as a garden ground, or, having been so used, is in poor condition, should receive a heavy dressing of farmyard manure. For farm purposes, twenty tons per acre is an average dressing. For a garden, the soil of which is poor, this amount may be doubled. The ordinary two-wheeled farm-cart will hold about a ton of farmyard manure, and this, therefore, is the quantity which may be applied to every four rods of the garden. This will be in no way an exceedingly heavy dressing. If the soil is heavy and is to be trenched in the autumn, the manure may with advantage be mixed with the bottom layer of each trench. It will keep the soil open to a good depth below the surface. Light sandy soils are very porous to heavy rains, and there is risk on such soils of valuable soluble matter being washed into the subsoil in the winter and ultimately removed in the drainage waters. On light soils, therefore, the farmyard manure is best applied in the spring, just before the principal crops are put in. There is obviously no necessity to take special precautions to keep sandy soils open, and the manure, after being spread on the surface, should in these cases be simply dug under. It will then be within reach of the roots of the young plants. Old garden ground is generally very rich in humus, owing to the decay of many generations of plant roots. If, as is generally the case, the humus contains much humic acid, the soil is distinctly acid, and unfavourable to root and bacterial activity. Humic acid is best neutralised by a dressing of lime. The lime may be in the form of very finely ground limestone, or better, quicklime may be put in small heaps on the garden, and just sufficient water added to slake it, when the lumps of quicklime (thus converted into calcium hydrate) will break into a fine powder, which should be immediately spread over the surface of the soil and raked, or gently forked in. About one bushel of lime per rod may be applied. There is not much danger of an over-accumulation of humic acid in most soils with sandy or gravelly subsoils, for such soils are sufficiently aerated to permit the roots and bacteria to flourish. Light soils are, however, often benefited by a dressing of marl or other calcareous clay, and this dressing may profitably be applied every six or eight years.

Farmyard manure may in many cases be usefully supplemented by artificial mineral manures, namely, nitrate of soda, sulphate of ammonia, or nitrate of lime (nitrogenous), superphosphate of lime, or bone flour (phosphatic), and sulphate of potash or kainit[1] (potassic). The experimental data respecting

[1] Kainit is mined from deposits occurring at Stassfurt and elsewhere in Germany, and is composed of sulphates of potassium and magnesium together with chlorides of potassium, magnesium, and sodium.

Boys and Girls aged eleven to thirteen at work on herbaceous and rose borders, June

the quantity to be applied and the crops to which they may be applied, as well as respecting the kinds of soils in which they will benefit particular sorts of plants, are not at present sufficiently complete for any full and detailed rules to be laid down as to the use of artificial manures on garden crops. Generally speaking, nitrates favour the production of foliage, potash the production of carbohydrates, while phosphates appear to improve the quality of the crop. Nitrate of soda certainly tends to produce heavier crops of cabbages, and sulphate of potash in most soils and seasons gives an increased crop of potatoes. Kainit is not so good for garden crops, since the considerable amount of magnesium which it contains (and possibly the chlorine also) appears to exert a harmful effect. Kainit may, however, be applied in autumn on rather heavy soils which contain grubs, for it acts as an insecticide as well as a manure.

There is a considerable field for simple experimental work in school gardens on the effect of various artificial manures, and teachers are recommended to arrange trial plots or trial rows with this object in view. The quantity of artificial manures to be applied may vary between two and five pounds per rod. Most of them are fairly soluble in water (nitrate of soda is readily soluble), and they are in consequence best applied as a top dressing to the young growing crop.

Of other manures used in the vegetable garden we may mention liquid farmyard manure, which is a valuable form for application to cabbage plants. Soot is sometimes used as a top dressing, partly for the nitrogen which it always contains, and partly to prevent attacks from slugs. If a bag of soot is suspended in a tub of water, a weak nitrogenous solution is obtained, which may be used for watering young tender plants. Guano (nitrogenous and phosphatic) is frequently applied as a top dressing to flowers, but is seldom used for manuring vegetables.

Arrangement of the Vegetable Beds.

As a rule the rows of vegetables should run north and south, because in this way only shall we secure that each individual plant receives its fair share of sunlight. For purposes of change of ground, the garden or (on the individual-plot system) the plot may be regarded as divided into three approximately equal portions. On the first we should grow leguminous plants, such as Broad Beans, Dwarf Beans, Scarlet Runners, and Peas; on the second, Parsnips, Carrots, and Beet; and on the third portion, Onions, Cabbages, Potatoes, and Turnips. In the following year the positions of these three portions would be interchanged. A small portion of ground must be reserved for salad plants, such as Mustard and Cress, Radishes and Lettuces, while a few flowers may be planted along the border. A small common nursery bed will be required for Cabbages or other crops requiring transplanting. It is highly important, if strong healthy plants are desired, that seeds should always be thinly sown, whether in drills or in beds, and for the same reason thinning must be carried out at an early stage, and transplanting, where required, should be done as soon as the plants are big enough to handle, that is to say, when they are, roughly speaking, a couple of inches high.

The Cabbage and its Varieties

The Cabbage, Savoy, Brussels Sprout, Borecole, Brocoli, and Cauliflower are all derived from a common parent, the Wild Cabbage (*Brassica oleracea*), which may be found growing in the south of England, in Denmark, and elsewhere in North-West Europe. The wild form most closely resembles the cultivated variety, Kohlrabi. The differences in form between the various varieties above mentioned depend upon differences in the development, either of the stem, the inflorescence, or the axillary buds. In the case of White and Red Cabbage and of the Savoy Cabbage, the internodes of the stem are short, and the terminal bud becomes greatly enlarged, giving rise to a closely packed head of large leaves. The Savoy differs from the White Cabbage only in the fact of the leaves being wrinkled. The internodes of the stem of the Brussels Sprout are well developed, and the axillary buds remain small and compact, like miniature Cabbages. In Borecole, these buds branch into elongated leaves. Brocoli and Cauliflowers differ only in the fact of the latter being rather less hardy. In both the "head" is an inflorescence, produced in the first year instead of the second, and with much thickened branches. Cabbages, Savoys, Brussels Sprouts, and Borecole contain a very high percentage of water (about 90 per cent.), and their value as food depends mainly upon the fact that they furnish an abundant winter supply of green food-stuff. They are all sown on a seed bed, from which they are transplanted as soon as the young plants are big enough to be handled. The seed should be sown quite thinly on a fine seed bed previously watered if at all dry. Thick sowing gives rise to weak, leggy plants. The permanent bed must be deeply dug and well manured, as all members of the Cabbage tribe are heavy feeders. Brocoli may be sown in almost any month; Brussels Sprouts are usually sown in March, April, and May; Cauliflowers are unable to withstand frost. Subject to these remarks, we may say that there are two principal periods during which the varieties of *Brassica oleracea* may be sown, namely, in March for a winter supply, and in June for a spring supply. In planting out, the rows are marked with the garden line, and the young plants dibbled in, care being taken, as with the transplanting of all small young plants, that the young plant reaches the bottom of the hole. The distance between the rows should be two feet, and this also should be the distance between the plants in the rows, except that in the case of the spring Cabbages the distance in the row may be reduced to fifteen or eighteen inches. Brocoli, though much hardier than Cauliflowers, suffer also to some extent when exposed to lengthy periods of frost succeeded by a rapid thaw. Hence it is usual to "heel" Brocoli,—that is, to bend them over towards the north on the approach of bad weather, the object being to prevent a too speedy thawing by the sun. Cabbages require to be well watered, and they are also benefited by doses of liquid manure (farmyard) applied close to the roots. To preserve the soil moisture from evaporation a good surface mulch should be maintained by means of the Dutch hoe. In the following list are given the names of the best kinds.

Brocoli—Winter White, for spring sowing.
,, King of the Brocoli, for May sowing.
Cauliflower—Walcheren, Sutton's Purity.
Brussels Sprouts—Aigburth.

Cabbage Sprouts—Ellams Early, Enfield Market, Daniel's Defiance.

Savoy Sprouts—Drumhead, Perfection.

The Potato (*Solanum tuberosum*)

This vegetable is indigenous in Chili, where it grows in the wild state at considerable heights above the sea level. For this reason, probably, the cultivated Potato is found to thrive on the uplands in this country. The Spaniards introduced it into North America from Chili, and Sir Walter Raleigh brought it to England late in the sixteenth century. The Potato plant possesses a green herbaceous aerial stem, and a short rhizome with closely clustered tuberous branches which constitute the edible part. On the tubers are depressions arranged spirally, called the "eyes," and in the "eyes" are a number of buds. As in the case of an aerial stem, the "eyes" are more numerous at the apex of the tuber. The tubers if exposed to light develop chlorophyll and turn green. The tubers are classified by the growers into three divisions, namely: the round, the oval, and the kidney shape. The tubers contain from 18 to 20 per cent. of starch, and it is on the proportion of this substance that their value for food depends. Other things being equal, the best Potatoes are those containing abundance of starch grains packed in large cells with thin cell walls.

The fruit of the Potato plant is a berry containing numerous seeds. New varieties are obtained by sowing the seeds produced by cross fertilisation and propagating the tubers for four years, when they are large enough for their value for food purposes to be determined. The tubers of the first year are only about as large as peas. Potatoes are grown in immense quantities in Ayrshire and in Lincolnshire. The total annual production in the United Kingdom is about eight million tons.

The Potato is propagated by means of the tubers. Now, the tuber is a part of the stem, and hence, since the life of a plant is limited, it follows that propagation by this method cannot be continued for an indefinite period. It follows from this that any given variety must after a time die out, and as a matter of fact all the varieties in cultivation thirty years ago have disappeared. Twenty-five to thirty years is therefore the maximum duration of a variety. Owing to the special methods of rapid propagation now adopted when good varieties have been raised, the duration of life has been considerably shortened, and about ten to fifteen years is the average duration of life of the varieties now in use. The best "seed" Potatoes are found to be medium sized tubers (what gardeners call the "big-little" ones) with shallow "eyes" and smooth skins. Sometimes larger tubers are cut into two or three pieces (each piece, of course, with an "eye") for planting; but these do not give such good results, probably because of the loss by evaporation of water across the cut surface, which naturally hinders the growth of the shoot. Numerous experiments in various parts of England have demonstrated the fact that the largest yields are obtained from seed procured either from Scotland or from Ireland. The experiments conducted by the Lancashire County Council showed an increase of from one to four tons per acre in the case of seed obtained from Scotland, as compared with seed obtained from the south of England. The seed Potatoes should be procured early in the spring, and should be at once "boxed." That is to say, they are placed in shallow boxes, each box containing one layer of tubers, and kept in a shed or stable, where an even temperature high enough to cause the tubers to sprout is maintained. The sprouting must proceed in the light, so as to produce short internodes, and must be so managed that short internodes are developed at the time for planting. Stems with long internodes have fewer points from which tuber-producing stems can arise. All but the two strongest shoots should be rubbed off just before planting. In the Lancashire experiments above referred to, sprouted tubers gave an increased yield of nearly two tons per acre over the unsprouted tubers. The best soil for Potatoes is a deep, light loam, well drained, possessing a rich store of well decayed organic matter. It is important that the soil should be open enough to allow full expansion of the tubers. Cold undrained clay and peat soils are the most unsuitable of all. Potatoes of the best quality are not produced when the soil contains much undecomposed farmyard manure, and hence the best procedure is to manure the preceding crop rather heavily with farmyard manure, and to apply to the Potato crop only artificial manure. If farmyard manure is applied to the Potato ground, the application should be made in the preceding autumn, and the manure dug in at that time. If farmyard manure only is applied, the quantity should be about one cartload (*i.e.* one ton) per eight rods ; but if, as is best, a dressing of artificial manure is also given, this quantity should be sufficient for sixteen rods. The artificial manures should be complete,—that is to say, they should supply nitrogen, potash, and phosphoric acid, and this is secured by a dressing at the rate per rod of 1 lb. of sulphate of ammonia, 3 lb. of superphosphate of lime, and 1 lb. of muriate of potash. On many garden soils rich in nitrogen the amount of sulphate of ammonia may be reduced by one-half. The three artificial manures here recommended should be mixed together immediately before planting, and sown broadcast across the Potato drills.

For a succession of crops, early, mid-season, and late plantings are made. For early Potatoes (which are consumed in an immature state) the best varieties at the present time are Sharpe's Victor, Sutton's Ringleader, Sir John Llewellyn, and Ashleaf. These should be planted in the middle of March. Main crop varieties for planting from the middle of April to the early part of May are : Main Crop, Windsor Castle, Up-to-Date, Snowdrop, Flour-ball, Factor, Abundance, British Queen, and Sutton's Triumph.

Heavy soil should be ridged up in the autumn, and the ridges may then be raked down level in spring, and lightly dug over just before planting. Light soils should be double dug in spring. The ground having been dug and levelled with the rake, shallow trenches, about seven inches deep and two feet apart, are made with the spade and garden line, and the artificial manures are then sown. Next, the tubers are carefully planted with the sprouts pointing upwards, the distance between the tubers being twelve to fifteen inches. The soil is then raked into the trenches. In about a month the tops of the stems will show above the surface, and so soon as the rows can be clearly seen we should hoe between them so as to preserve the soil moisture at what is usually a dry period of the year. A little later, when the stems are four inches above ground, the rows should be earthed up with the draw hoe. The object of the earthing up is to keep the rhizomes in the dark. Rhizomes exposed to light become ordinary green stems and do not produce tubers. The earthing up must be repeated about a month later. The chief qualities required in a good variety of Potato are shallow "eyes," power of resisting disease, good flavour and appearance when cooked, and good keeping properties. The main crop Potatoes are ready to be dug up when the aerial stems have begun to die down. They are dug up with the fork, separated into three portions, according to size, namely, for cooking, for seed, and for pig feeding. If any disease has appeared the stems should be dried and burnt.

To store Potatoes, they are piled in any convenient spot on a bed of straw, and are also covered with straw. A trench is then dug out all round the pile, and the earth taken from it is used for the purpose of covering the straw. The thickness of this covering depends on the locality, the point being that, as frost destroys the Potato for cooking purposes, the Potatoes must be adequately protected from frost. The thickness of the soil covering must therefore not be less than three inches. It may be more.

The cultivation of the Potato lends itself to a variety of simple, interesting, and important experimental work. It is therefore recommended that every year in the school garden comparative tests should be made: (*a*) of new varieties, or (*b*) of various kinds and amounts of manures, or (*c*) of sprouted as against unsprouted seed, or (*d*) of differences in distances and depths of planting, or (*e*) different sizes of "seed" and cut tubers as compared with uncut tubers.

The Carrot (*Daucus Carota*)

The Carrot, together with the Parsnip, Celery, and Parsley, belongs to the natural order Umbelliferæ. The Wild Carrot is a roadside plant found in most parts of the country. Generally it is an annual, but occasionally it is a biennial, storing up reserve material in the form of starch in the first year, and utilising this store for the production of the fruit in the second year. By taking advantage of this occasional habit, and by sowing the seed of late flowering plants in the autumn, Vilmorin succeeded in producing a biennial strain resembling the cultivated varieties. The fruit of the Carrot is a schizocarp, the ripe carpels of which split into mericarps, each containing one seed. It is the mericarps which are sown by the gardener. The edible portion of the Carrot is the large conical taproot, made up of the hypocotyl and the primary root. At its lower end this taproot thins out into a long cordlike portion, which extends to a very considerable distance into the soil. A cross section of the taproot shows a red rind and a yellow core. The rind is the bast and cortex; the core is the wood. The cells of the tissues of the core are neither lignified nor fibrous during the first year, except in the case of plants which have reverted to the ancestral habit by "running to seed." The reserve material of the cultivated plant is not starch but sugar, and this is stored to the extent of 4 to 8 per cent. in the tissues of the rind. It is the endeavour of seedsmen to produce strains with a maximum of rind, since the proportion of sugar is dependent on the proportion of rind.

The most suitable soil for the growth of Carrots is a rather light, well drained loam. The presence of undecomposed farmyard manure tends to the production of forked roots, and consequently, as in the case of the Potato, it is the preceding crops which should be well manured. Since it is the mericarps which are sown, germination is slower than in the case of true seeds. It is therefore best to damp the mericarps a few days before sowing so as to soften their walls. It is also usual to mix the "seed" with sand, so as to ensure a thin distribution. A soil which has been well worked for the preceding crop and is on the light side will require only to be dug over in March. From the end of that month, and successionally if desired, in April and May, the seed may be sown. The ground having been first trodden, not too heavily, and then raked over, shallow drills are made with the draw hoe one inch deep and one foot apart; after sowing thinly the soil is lightly raked over the drills. When the young plants are two inches high they should be thinned out. This thinning may be so conducted that at first the plants are four inches apart. When big enough to be used for soups and stews, every other plant may be drawn, thus leaving eight inches between those plants which will constitute the autumn main crop. Keep the Dutch hoe going between the rows during the hot dry weather, and water if necessary. The main crop is gathered in the latter half of October, the fork being used for loosening them in the ground, so as to avoid snapping the roots in the region of thicker growth. They should be stored in a dry place in ashes or sand. For this purpose a layer of sand is placed on the ground in a corner of a shed, and on this a layer of roots is placed, over this layer is spread another layer of sand an inch thick, and so on. Among the best varieties are, James' Scarlet Intermediate, Early Nantes, Early Horn, and Veitch's Model.

For experimental work, the pupils should examine the flower, schizocarp, and mericarp. They should compare the times of germination of dry and damped mericarps. They should grow seedlings, and should also dig up young plants about two months old and observe the root system. They should also examine the taproot of a second year plant (or of a plant which has " bolted "), comparing it with that of a one-year-old unbolted plant.

The Parsnip (*Pastinaca sativa*)

Much of what has been said about the Carrot applies also to the Parsnip. Its ancestor is a common roadside annual or biennial plant possessing a small taproot. Professor Buckman, of the Cirencester Royal Agricultural College, was able by cultivation and selection of the wild variety, extending over a few generations, to increase the size of the taproot and to fix the biennial character, so as to produce the " Student," a variety quite suitable for garden cultivation. The edible portion is a taproot formed of the hypocotyl and main root. The taproot may be conical, or short and bulbous. It contains about 80 per cent. of water, 4 per cent. of sugar, and 3 per cent. of starch. The percentage of sugar increases slightly through the growing period at the expense of the starch. These two carbohydrates, of course, constitute reserve stores on which the plant draws during its second year of growth for the increase in the stem and the production of flower and fruit. The fruit is a schizocarp, the mericarps of which constitute the "seed." Each mericarp contains a seed. The essential oil contained in canals in the fresh mericarps give the seed a characteristic smell which is absent from two-year-old seed. Parsnips will do well on heavier soil than is suitable for Carrots. The bed should be manured and double dug in autumn, and left rough. Early in March it should be raked down and the seed sown thinly in dry weather in drills made with the draw hoe, at a distance of fifteen inches apart, so as to give sufficient room for the leaves. The seed is then covered in by means of the rake. When the young plants are two inches high they should be thinned out so as to stand nine inches apart. Parsnips are best not stored, but dug up as required for household use in late autumn and winter. The varieties are not numerous, and of these the best for home consumption are The Student and Tender and True.

The Beet (*Beta maritima*)

The ancestor of this vegetable is the wild perennial Beet, which is found abundantly on our sea-coasts. It belongs to the natural order Chenopodiaceæ. Under cultivation it is a biennial. The edible portion is the conical or napiform hypocotyl and main root. The cell sap is rich in sugar. The "seeds" are really fruits, each containing one true seed. The plant being a halophyte, it is benefited by a thin manuring with common salt, or with seaweed. In cookery it may be used either as a vegetable, a salad, or a pickle. Like the Carrot, it tends to fork if the soil contains undecomposed farmyard manure. The bed should be double dug in the previous autumn, raked down at the end of March, and the seed sown from April to June if a succession is desired, but the main sowing should be made at the beginning of April. Drills are made with the draw hoe one inch deep, and at a distance apart of one foot. When about two inches high the plants should be thinned out to a distance of eight inches, and as the Beet is injuriously affected by dryness the thinning should be effected in showery weather. For the same reason the surface soil should be kept in a powdery condition, and in very dry weather water or liquid manure should be supplied. Salt may be given as a thin top dressing during showery weather in June or July. The roots may be pulled and stored at the end of Ocotber, and special care should be taken not to injure the main root, which "bleeds" freely. Special attention must be devoted to storage in a cool place, where the roots will not be exposed to evaporation. The method followed is the same as that recommended for Carrots, except that the stored roots must be protected from frost by a good covering of straw or litter. The best varieties are Dell's Crimson, Crimson Ball, Sutton's Globe, and Cheltenham Green Top.

The Turnip (*Brassica Rapa*)

The White Turnip of the garden differs from the agricultural Swede Turnip in the colour of its flesh. The Garden Turnip also has no "neck," and its leaves are grass green in colour as compared with the glaucous green leaves of the Swede. The Turnip is a biennial, and the part consumed is the "bulb," which is composed of the primary root and the hypocotyl. All but the outer portion, one-eighth of an inch in thickness, of the bulb, consists of wood, composed of non-lignified, thin-walled parenchyma. The bulb contains approximately 90 per cent. of water, 5 per cent. of sugar, 0·5 per cent. of proteid, 0·5 per cent. of fibre, and 0·3 per cent. of fat. The maximum proportion of sugar and of proteid, and the minimum proportion of water, occur when the bulb has reached maturity. After germination the cotyledons of the seedling plants come above ground, and, like ordinary foliage-leaves, carry on the work of assimilation. It is important at this stage to hasten the development of the hairy first foliage-leaves, since the smooth seed-leaves are particularly susceptible to attack by the Turnip beetle. This acceleration of growth is best secured by dressing the bed at the time of sowing with a thin coat of superphosphate of lime.

During the second year of growth the very short stem bearing the rosette of first year leaves elongates considerably and produces the inflorescence. The flowers of the White Turnip are bright yellow. Those of the Swede are pale yellow. The fruit is a siliqua. When ripe the two carpels dehisce upwards, exposing the seeds which are borne on the placenta and replum.

The Turnip thrives best in a light loamy soil and in a moist season. Drought is fatal, and hence watering must be carefully attended to.

For a succession of crops the seeds may be sown from the beginning of March to the end of July. Manure may be put on before sowing, and the seed bed must be well worked. By means of the draw hoe and garden line shallow drills are made, not more than two inches deep, and at a distance apart of one foot. In a moist season germination and growth are rapid, and in three weeks from sowing the rows will be ready for thinning, which in the case of small beds may be done by hand picking, or in larger quantities by means of the hoe. For home consumption, medium sized bulbs are better than large ones, and hence it will be sufficient to leave a space of eight inches between the plants.

"Cardinal" is a good early variety, while "All the Year Round" is satisfactory for main crop sowings. Roots maturing in November should be stored in sand or ashes for winter consumption.

The Radish (*Raphanus sativus*)

Cultivation of this crop is very simple. The principal thing is to ensure rapid growth so as to avoid the development of woody fibre in the xylem tissue, which constitutes the edible portion. Hence a deep mellow, rich, well worked seed bed is necessary. Sowings may be made broadcast, commencing in a sheltered position in February, and continuing through the summer at intervals. Thinning can be effected in the process of pulling the most forward roots for consumption, *i.e.* provided the seed was thinly sown.

In town schools where garden ground is not available the seeds may be sown in boxes, provided that good soil can be procured for the boxes, and that the soil is kept fairly moist.

The Onion (*Allium Cepa*)

A vertical section of an Onion plant shows a very short stem wrapped over with thickened scale-leaves. It is therefore a bulb. Usually the plant is a biennial, but occasionally individual plants live for more than two years. The reserve food material stored during the first year in the scale-leaves is utilised in the second year for the production of the inflorescence. The pungent smell of the Onion is due to the presence of a volatile sulphur-containing oil.

The plant requires for its full development a rich, moist, fine seed bed. The bed is preferably manured and ridged up in the preceding autumn. The ridges are levelled down in March, and the ground is then trodden firm. After the surface has been raked fine the seed is sown thinly in drills, one foot apart and one inch deep. Give a dusting of soot, if this can be readily procured, and then rake over lightly. The rows must be thinned until the young plants stand singly at a distance of six or eight inches apart. The thinnings may be consumed as salad. If the ground is very dry during the summer it should be watered. It should also be kept as free from weeds as possible. Towards the end of the summer the leaves begin to turn yellow, and they should then be trodden over carefully, so that they lie horizontally. This operation assists in the production of larger bulbs, and at the same time gives full play to the ripening effect of the sun's rays. In September the bulbs will be ready to be taken up. They should be laid out to dry and harden in the sun, and when this is accomplished they may be tied together in bunches and hung up in a cool dry place and kept free from frost. Giant Rocca, James' Long Keeping, and Bedfordshire Champion are good varieties. Ailsa Craig produces exceptionally large bulbs, and is therefore very common at horticultural shows. Its quality is, however, not nearly so good as the varieties recommended.

A rather different culture is required in the case of Tripoli Onions. These are sown in drills in August, and are transplanted in March for spring Onions.

The Leek (*Allium porrum*) and The Shallott (*Allium ascalonicum*)

are closely allied to the Onion. Leek seed may be sown broadcast and very thinly on a nursery bed in March. When the young plants are about four inches high they must be transplanted to V-shaped trenches, eight inches deep and two feet apart. The plants should be one foot apart. They should be lightly watered from time to time, and when firmly rooted and grown sufficiently to appear well above the surface of the ground, the trenches should be carefully filled in. As the plants continue to grow in height the earth should be ridged round them. The object of this treatment is obviously similar to that adopted in the case of Celery, and aims at the production of well blanched tender bulbs. Musselburgh is the best variety.

The Shallot is a perennial. Some of the lateral buds produce shoots which form small buds, and a bed of Shallots therefore shows a series of groups of bulbs arranged circularly round the main bulb. It is these smaller bulbs called "cloves" which are usually employed for "seed," though the Shallot may also, of course, be propagated from true seed. The "cloves" are planted in drills in March, the drills being one foot apart and the cloves at six inches in the drills. Gather and dry in September as in the case of Onions.

Celery (*Apium graveolens*)

In order that the stems of this plant may be fit for consumption it is essential that they should be as free as possible from woody fibre and be well blanched. This object is secured by planting in trenches and subsequently earthing up at intervals as the plants develop. A soil rich in farmyard manure is essential. The seeds are sown in March in rich soil and transplanted to the trenches in July, at a distance apart of nine to twelve inches. The trenches are prepared by taking out the soil to a depth of fifteen inches by fifteen inches in width. A heavy dressing of well rotted manure is then dug into the bottom of the trench and thoroughly mixed with the soil. On the top of this is spread some of the soil removed from the trench to a depth of about three inches, and in this soil the young plants are carefully set. As the plants grow in height they are earthed up from time to time, and particular attention must be given to watering at the roots; neither water nor soil should be allowed to get between the stems. They are dug up as required during the winter. A good variety is Incomparable White.

Parsley (*Carum petroselinum*)

This plant belongs to the same order as Celery. The seed, which takes some weeks to germinate, may be sown thinly at any time from April to July in drills one foot apart. The plants are thinned to a distance of six inches apart. A small proportion of the shoots will produce flowers and seed in the following year, but the plant may be regarded for practical purposes as a perennial, and unless the climate is rigorous may be allowed to stand for at least two seasons. Parsley grows satisfactorily in almost any moderately good garden soil.

Spinach (*Spinacia oleracea*)

This plant, belonging to the Goosefoot order, is cultivated for its leaves. The most useful variety is the winter or prickly Spinach, since this comes into use at a time of the year when there is some shortage in the supply of a variety of green vegetables. Cultivation is very simple. A moist, well drained, rich soil is required, and in this the seed should be sown very thinly in August, in rows fifteen inches apart. The plants are thinned to a distance of six inches apart, and if the weather is subsequently dry, water or liquid manure should be given at the roots from time to time. The crop will be ready for gathering from the beginning of November.

The Lettuce (*Lactuca sativa*)

Small patches of this valuable salad plant may be sown from March till the end of August on a warm moist bed. If sown very thinly and in very small patches it is not necessary to transplant. It will be sufficient merely to pull out and consume the largest plants as required. Cultivation on a larger scale involves transplanting into rows one foot apart with a distance of nine inches between the plants. If desired we may, instead of sowing in patches, sow thinly in drills, thinning out to the proper distance. The treatment for Cos and Cabbage Lettuces is the same, with the exception that the plants of the former variety must, when large enough, be tied round with string or bast, so as to prevent bolting, and to blanch the inner leaves.

Cress (*Lepidium sativum*)

This is best grown in boxes, and is therefore equally as suitable for cultivation in town as in country schools. Any small wooden box may be used. The box should be filled with a mixture of good garden soil and leaf-mould pressed firmly down, and so that its surface is about one inch from the top of the box. The seed is sown thickly on the surface, a little soil is sprinkled thinly over them and gently pressed down. The box is then covered over with paper until the seedlings begin to appear. The Cress will be ready for cutting in ten days or a fortnight from the time of sowing. In the early part of the spring the Cress boxes should be kept in the schoolroom. Later they may stand out of doors.

Beans and Peas

These plants belong to the natural order Leguminosæ and the sub-order Papilionaceæ. They all possess the power of assimilating free nitrogen from the mixture of gases present in the soil spaces. This they do through the agency of the *Bacterium radicicola* with which they have a symbiotic relationship. If one of these plants is carefully dug up by the roots and well washed until free from soil particles there will be seen on the roots numerous small round pink or white bodies varying in size from a pin's head to a small pea. These are the nodules. A cross section of a nodule when mounted or viewed under the microscope shows a central mass of parenchymatous cells packed with rod-shaped and Y-shaped bacteria. When the plant gets old the nodules become disintegrated, and the bacteria become free in the soil. When new plants are grown in the soil the bacteria make their way through the root epidermis and again give rise to the nodular excrescences. Thus in a soil rich in this species of bacterium, leguminous plants are independent of the nitrates present in the soil; and further, owing to the accumulation of nitrogenous compounds in the roots, such plants may leave a

HALE CONTINUATION SCHOOL GARDENS, FARNHAM

Cultivated in the Evenings by boys who have left the Day School

soil richer in nitrogen after the crop is gathered than before it was planted. It is for this reason that wheat, which requires an abundant supply of nitrogen, does best as a rule when it follows a clover crop. During the past few years numerous experiments have been made in seeding with *Bacterium radicicola* soils which were poor in nitrogen and poor in this particular micro-organism. Various preparations of soil containing the bacteria in abundance have been put on the market under the name of Nitragin, Nitro-bacterine, etc. In a number of cases in this country and in America it is stated that increased crops have resulted from the dressing. The careful experiments on Peas carried out by Chittenden at the Royal Horticultural Society's Experimental Gardens at Wisley seem to show, however, that the inoculation of leguminous crops with Nitrobacterine in ordinary garden soil is not likely to prove beneficial.[1]

Beans and Peas, regarded from the point of view of food, are remarkable for their high nitrogenous contents. They contain 14 per cent. only of water, 50 per cent. of carbohydrates (starch and sugar), and over 20 per cent. of proteid. They also contain considerable quantities of salts of potassium and calcium. Peas and Beans thus contain a bigger proportion of food material than any other vegetable, and for persons of robust digestive powers approach meat in their value as suppliers of nitrogen.

The Dwarf French or Kidney Bean (*Phaseolus vulgaris*)

This, like the Scarlet Runner, is much less hardy than the Broad Bean or Pea, and it is therefore not safe to sow the seeds earlier than the last week in April. Even at that date the bed should be in a sheltered and sunny position. The soil, which must be good, should have been manured in the preceding autumn, as this plant does not thrive in soil containing undecomposed farmyard manure. For sowing the seeds, make a shallow drill with the draw hoe one and a half inch deep, drop two or three seeds at intervals of six inches, and leave one and a half foot between the rows. If, when the young plants show above ground,

[1] See "Contributions from the Wisley Laboratory, No. IV. The Inoculation of Leguminous Crops," *Journ. of the Roy. Hort. Soc.* 1908.

the weather is very dry, they will be benefited by a good watering. It is important that throughout growth the soil should be kept moist, and this can best be secured by maintaining a good surface mulch of loose soil with the hoe.

The Scarlet Runner (*Phaseolus multiflorus*)

The time and method of planting are much the same as in the case of the Dwarf Bean, except that the seeds are sown in a double row in a drill ten to twelve inches wide. The plants will grow to a height of six or seven feet. When the plants are three inches above ground they must be staked with stout poles seven feet high. Like the Dwarf Bean, the plants require an abundance of moisture, and they should therefore be mulched with manure or by hoeing.

The Broad Bean (*Vicia Faba*)

This is a very hardy plant, which will succeed on almost any soil, though it is most productive on a stiffish clay. It is better to plant in rows rather than, as is usually done, in plots. The seeds are sown, at the end of February or the beginning of March, in drills ten inches wide and three inches deep made with the draw hoe. A double row is sown on either side of the drill, the distance between each seed being about six or eight inches. As soon as the flowers drop off and the pods begin to form the tip of each plant is pinched off. This procedure is found to result in the production of better filled pods.

The Pea (*Pisum sativum*)

The Pea thrives best in a deep rich soil, and requires abundance of light and air. Hence the soil should be trenched and well manured before planting, and the rows should run north and south, and should not be close together or overshadowed with other tall-growing crops. Peas are hardy like the Broad Bean, and the main crop sowing may be made at the beginning of March. Successional sowings may be made in April and May. A shallow trench eight inches wide and two inches deep is made with the draw hoe, and over this the seeds are sprinkled thinly at the rate of one pint of Peas to every ten yards of the drill. Peas suffer very much from the depredations of mice and birds, and to protect them from these it is well to moisten the seeds with water and then to dust them with red lead just before sowing. After the soil has been raked over the drills, black thread, to which white feathers have been tied, should be stretched over the drills with the object of scaring the birds. Or, instead, pieces of fine wire netting fourteen inches wide and three feet long may be bent into the form of an arch and laid over the drills. As soon as the young plants are two to three inches high, the rows should be earthed up on either side. Dwarf varieties, such as American Wonder, will not require further treatment, but the tall maincrop kinds, such as Telephone, Telegraph, Marrowfat, Autocrat, and Early Giant, will require to be carefully staked with trimmed branches of larch or fir, four to five feet high.

CHAPTER X

Fruit Culture

Botanists define a fruit as consisting of the ovary and whatever other parts of the flower persist at the time the seed is ripe. A number of plants, however, such, for example as the Tomato, Cucumber, Vegetable Marrow, Peas, and Beans, are classed by horticulturists as vegetables, although the edible portion complies with this definition. Horticulturally, only those fruits which are juicy and contain considerable quantities of sugars and organic acids (malic, citric, and tartaric) are regarded as coming under this category. The common hardy fruits of the British Isles include Apples, Pears, Plums, Damsons, Cherries, Medlars, Gooseberries, Currants, Raspberries, Strawberries, Blackberries, Loganberries; and it is noteworthy that, excepting Medlars, Gooseberries, and Currants, all these fruits are members of the great natural order, Rosaceæ, characterised by the regular perigynous flower, the gamosepalous five-sepalled calyx, the polypetalous five-petalled corolla, the many stamened andrœcium, and the apocarpous gynœcium. Among the less hardy fruits which nevertheless in some parts of the country may be satisfactorily grown out of doors in sheltered positions, are the Fig, Grape, Nectarine, Peach, and Apricot.

Of the fruits above mentioned the following only are generally suitable for cultivation in a school garden :—

The Apple (*Pyrus Malus*), the Pear (*Pyrus communis*), the Plum (*Prunus domestica*), the Cherry (*Prunus Cerasus*), the Gooseberry (*Ribes Grossularia*) the Currant (*Ribes rubrum* and *Ribes nigrum*), and the Strawberry (*Fragaria vesca*). It is suggested, however, that in school gardens, where there are facilities for the training of Blackberries along wire fences, some experimental work might be carried on in the direction of the domestication and improvement of this fruit. It would appear that there is considerable scope for cultivation of the Blackberry, and it would be interesting work to study the effect of cultivation, pruning, and manuring on some of the thirty-four species or sub-species of *Rubus fruticosus* described in the British Flora. (Consult Bentham and Hooker, *British Flora.*)

It is to be hoped that in course of time a portion of every school garden will be devoted to fruit culture. The fact that the hardy British fruits can be profitably grown in perfection in this country with ordinary attention and skill, considered in connection with the further fact that between four and five million of bushels of apples alone are yearly imported into this country, point to the desirability of the further increase in the area devoted to fruit culture. According to the returns of the Board of Agriculture, the total area of land under cultivation in Great Britain is about fifty-six million acres, of which about a quarter of a million acres are orchards and one hundred thousand acres are under small fruit (Currants, Gooseberries, and Strawberries). The greatest amount of orchard ground is found in the counties of Worcester, Hereford, Gloucester, Somerset, Devon, and Kent, but it must be remembered that all but the last named are mainly cider-producing counties. In small fruit Kent easily heads the list with some twenty-two thousand acres. Next come Worcestershire, Herefordshire, Hants, Cambridge, Norfolk, Essex, Middlesex, and Surrey. There can be no doubt that while the soil of some of these counties, such as Hereford, Worcester, Somerset, Devon, and Gloucester, are especially suitable for Apple culture, there is no county in which the area under fruit culture could not be profitably increased.[1] There appears to be a considerable need for soil surveys in each county for the purpose of ascertaining what soils and formations are specially suitable for the cultivation of various fruits.

In deciding what varieties to plant of a particular fruit, it is desirable to ascertain from other growers in the neighbourhood and from local nurserymen what kinds have been found to succeed best in the locality. As in the case of the numerous varieties of potatoes, differences of soil, situation, and climate have a

[1] Consult the *Journal of the Roy. Hort. Soc.*, vol. xxx., 1906; also, "The Report of the Departmental Committee upon the Fruit Industry of Great Britain." (Cd. 2589).

remarkable effect on the quality and even appearance of the fruit. Subject to this, the following lists supply information respecting the best varieties of fruits possessing the essential characteristics of quality, fertility, good growth, and hardiness. The varieties are arranged in the order in which they become ready for use.

Apples for Cooking

Early White Transparent	August
Lord Grosvenor	September
Pott's Seedling	September
Stirling Castle	October
New Hawthornden	November
Warner's King	October to December
Beauty of Kent	November to January
Bismarck	December and January
Bramley's Seedling	December to March
Prince Albert	January and February
Newton Wonder	February and March

Dessert Apples

Mr. Gladstone	August
Irish Peach	August
Devonshire Quarrenden	September
Worcester Pearmain	September
James Grieve	October
Cox's Orange Pippin	November to January
Lord Hindlip	January to April

All the above Apples may be grown as bushes on the Paradise stock, or as half-standards on the Crab stock.

Pears for Cooking

Pitmaston Duchess	October and November
Catillac	January and February

Dessert Pears

William's Bon Chrétien	September
Louise Bonne de Jersey	October
Doyenne du Comice (in sheltered positions)	October and November
Emile d'Heyst	November

Plums for Cooking

The Czar	August
Victoria	August and September
Pond's Seedling	September

Dessert Plums

Early Transparent Gage	September
Count Althann's Gage	September
Bryanston Gage	September
Coe's Golden Drop (in sheltered positions)	September

Cherries for Cooking

The Kentish — The Morello

Dessert Cherries

Early Rivers — May Duke — Black Eagle

Raspberries

Superlative — Hornet — Baumforth's Seedling

Currants

White Dutch (white)	
Raby Castle (red)	
Lee's Prolific (black)	On light soils
Boskoop Giant (black)	Stated by some Growers to be less subject to attack by the Black Currant mite

Gooseberries for Cooking

Crown Bob — Keepsake — Whinham's Industry

Gooseberries for Dessert

Yellow Champagne — Red Champagne
Warrington — Whitesmith

Strawberries

Royal Sovereign	Early
President	Midseason
Black Prince	Midseason. Small but best for flavour.
Givon's Late Prolific	Late
Sir Joseph Paxton	Midseason. The chief market variety, but not so good in flavour

The following general notes on planting apply for the most part to all the bush and tree fruits mentioned above. They indicate the present practice as followed by the most experienced growers. Readers should, however, consult the reports issued from the Woburn Experimental Fruit Station under the supervision of the Duke of Bedford and Mr. Spencer Pickering. Their results are not in harmony with the common practice as regards planting, and go to show that a method of planting which seriously checks the tree's root system may give a better result as regards fruit production. Further experiments in methods of planting in a variety of soils and climates are required, and such experiments are very suitable for inclusion in a course of evening school gardening.

Notes on Planting

(i) Bushes and trees should be planted when in the resting stage, and preferably in October and November.

(ii) Do not expose the roots to evaporation in the air.

(iii) Cut off with a clean cut all torn roots, and also cut off all large roots which tend to grow vertically downwards.

(iv) In preparing the hole in which the tree is to be planted see that it has a diameter at least one foot longer than the diameter of the mass of roots.

(v) Dig out the hole to a depth varying with the kind of tree or bush to be planted, but such that, when covered in the tree, will be at the same depth in the soil as when it was taken up by the nurseryman. This will generally mean a depth of about one foot. Having removed the soil to this depth, dig over the under soil so as to provide a well broken substratum; over this spread a little of the top soil.

(vi) Place the tree in position, spread out the roots so that they may occupy their natural position, and carefully crumble over them some more soil, taking care that it is worked in between the roots and is in close contact with them. Shovel in a little more soil so as to cover them and tread it down lightly. Fill in the remainder of the soil and again tread it down, but not hard. There should be no farmyard manure or pieces of turf in contact with the roots of the newly planted tree. When all the soil has been filled in it should be two or three inches above the ground level, so as to avoid the formation of a pit as it subsides.

(vii) Water well, unless the soil is naturally well supplied with moisture.

(viii) Drive a stout stake firmly into the ground close to the tree, and tie the tree to it with tarred string. This will support the tree against the autumn and winter gales. The string should be examined from time to time to make sure that it is not chafing the bark.

(ix) If there are any rabbits within reach they are almost certain to nibble the bark of the tree in hard weather. It is therefore important in such a case to protect the tree with wire netting. This can only be done effectively by surrounding the tree or the plantation with narrow meshed wire netting four feet high, sunk into the ground to a depth of six inches, and having another six inches underground bent at right angles to the plane of the main piece and pointing away from the tree. If this precaution is not taken the rabbits may burrow an entrance under the netting.

(x) Keep down all weeds round the young trees, and maintain a surface mulch with the hoe, so as to prevent evaporation of moisture.

The Apple

The Apple is an improved form of the Wild Crab which is found growing in hedgerows in all parts of Great Britain. On account of its productivity and high content (12 to 15 per cent.) of sugar, starch, and organic acids it is the most valuable of the British fruits. Although it may be profitably grown on almost any soil, except a very shallow topsoil resting on gravel or chalk, it thrives on a somewhat heavy loam, and there is reason, moreover, to suppose that such a soil, containing a relatively high percentage of ferric oxide, is, *ceteris paribus*, the best of all.

New varieties of Apples are obtained by cross fertilisation of existing varieties and subsequent sowing of the pips of the resulting fruits. Owing to the effects of reversion, however, not more than one in a thousand of the seedlings will produce fruit even passably good in flavour and quality. Multiplication of trees may be effected by grafting,—that is to say, by the insertion on the stem of a portion of a shoot possessing a number of buds. The stem is called the stock, and the inserted shoot the scion. When the operation is properly carried out scion and stock become organically connected through the union and subsequent development of the cambial tissues. The stock, through which water and mineral substances are supplied to the scion, to that extent exercises an influence on the latter, so that we speak of strong and weak stocks; very rarely the scion assumes some of the morphological characters of the stock, but generally speaking stock and scion retain their individual characteristics. Three kinds of stocks are available for use, namely, the Crab, the Paradise, and the "Free stock." The Crab is a strong, somewhat deeply rooting, hardy tree, and is used if standard trees are required,—that is to say, tall trees with a clean stem up to a height of five feet. Standard apple trees on the Crab stock come into bearing some ten years from the time of grafting, and remain productive for from forty to seventy years. The Paradise stock is believed to be an Asiatic variety of the wild apple. It is dwarf in habit, has a short tap root and numerous fibrous surface feeding rootlets. Apple trees on this stock are dwarf (10 feet high), come into bearing four years from the time of grafting, and remain productive for from twenty to twenty-five years. For these reasons orchards of trees on the Paradise are now much more frequently planted than those on the Crab stock. Free stocks result from sowing the pips of varieties of cultivated apples. They are sown in drills in the autumn; when two years old the seedling trees are transplanted into good soil at a distance apart of two feet all round. They may be grafted in the succeeding year. Trees on such stocks, while possessing fibrous surface feeding roots, are intermediate as regards size, vigour, and longevity between the Paradise and the Crab. One or two such seedling trees should be grown in the school garden. There are various slightly differing methods of grafting, namely, whip and tongue grafting, saddle grafting, and crown grafting. The principle, is however, the same in all, and depends upon the close juxtaposition of the cambial layers of stock and scion with protection from the atmosphere. The most suitable method for school gardens is that of whip and tongue, and the procedure is as follows.

For the stock we may select either the Crab, the Paradise, or the Free stock. Crabs may be found in the hedges. Paradise stocks may be bought from nurserymen at about thirty shillings per thousand, or ninepence the dozen. Free stocks may be raised from seed as described above. The young stocks should be planted in autumn at such a distance apart (say two feet) as will permit the grafting operations to be conveniently carried out. The scions are obtained by cutting off from the cultivated trees of the varieties which it is desired to propagate unbranched shoots eighteen inches in length. These are taken off in November or December, tied in bunches, and the cut ends buried in the soil to a depth of three or four inches. About the end of March[1] the stocks will show by the swelling of the buds that the spring awakening is at hand, and that the time for grafting is ripe. The scions are taken up, and with a sharp knife a clean oblique cut is made across each one, exposing an elliptical surface two inches in its longer diameter. A surface corresponding in size is similarly exposed by cutting the stock at a height from the ground of about six inches. Next, two vertical slits are made on the stock and on the scion respectively in such a way that one tongue on each fits into the slit in the other. The scion is then dovetailed on to the stock, the whole carefully bound round with bast, and the bast covered with grafting wax to exclude air and moisture (see Fig. 59). If the operation has been successful the buds of the scion will open and produce shoots in the normal way, and the bast may then be removed. The young grafted trees may be transplanted into their permanent quarters in the November next but one following. Before actually trying their hand at grafting an apple tree (and the same applies to budding), beginners should practise the operation on small pieces of green twigs of any kind.

Crown grafting (see Fig. 58) is a variety of grafting practised where the diameter of the stock is considerably greater than that

[1] It is probable that grafting might with advantage be deferred till rather later. Some men of great practical experience hold that if the operation is carried out towards the end of April there are fewer failures, and more vigorous trees are obtained.

of the scion. It is a method specially applicable in the renovation of old standard trees of poor varieties. Two or three stout branches (say two inches in diameter) of the stock are severed with a slightly oblique cut. On each of the stumps longitudinal incisions two inches in length are made in the bark. The bark is then opened by means of the handle of the budding knife along one side only of the incision. This will serve to grip the scion and hold it in position. The other side is left untouched, and the scion must be so shaped that one portion of its bark and cambial layer fits as closely as possible against the perpendicular undisturbed edge of the incision. The scions having been inserted, the whole is bound round with bast and covered with grafting wax.

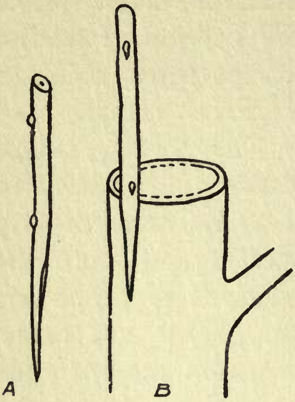

FIG. 58.—Crown Grafting.

Where considerable numbers of young trees of a particular variety are required there may be a difficulty in obtaining the requisite number of scions for grafting. In such cases it is more economical and just as effective to bud the trees instead of grafting them. Apples, Pears, Cherries, Plums, and Roses may be propagated readily by this method. The operation is carried out at the end of July. A T-shaped incision (see Fig. 60) is made in the bark of the stock and the bark slightly opened with the handle of the budding knife to admit the bud. The bud, which must be a vegetative one, is taken from about the middle of a shoot of the current year. To cut out this bud, an oval incision is made in the bark which surrounds it, and then by means of a scooping cut the bud, bark, and a small portion of the underlying wood are cut out. The whole length

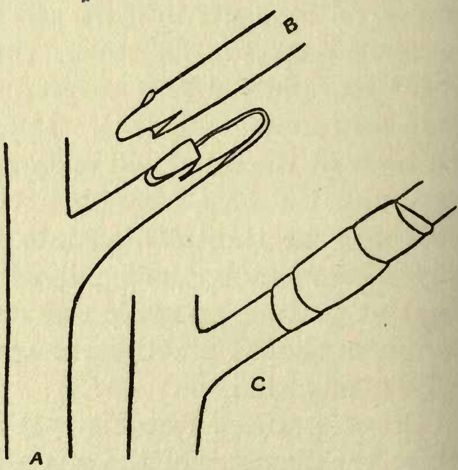

FIG. 59.—Whip and Tongue Grafting.

of the excised portion should not exceed one inch. The small piece of adhering wood is then carefully picked out without disturbing the bud itself, and the bud is inserted under the bark at the T-shaped cut, and bound round with bast. If the operation has been successful, union of the tissues takes place rapidly, and the bast may be removed at the end of three weeks' time.

General rules for the planting of apple trees have already been given. Where a number of trees are to be planted it is important to give sufficient space for the admission of light and air, taking care at the same time that there is no waste of ground. The trees should be planted in rows running north and south. Standard trees must be at a distance of twenty feet apart, dwarf trees at a distance of eight feet. As the standard trees will not come into bearing for some years, the ground between them may be occupied by Currant and Gooseberry bushes. It is best that the orchard ground should be kept quite free from grass and weeds. In this way only can the trees be fed with manure and a surface mulch maintained with the hoe. If, however, some of the ground must be under grass, at least a circular space eight feet in diameter must be kept bare round each tree. If grass is allowed to grow close to the stem of newly planted trees, the demands which it makes on the moisture and mineral matter of the soil will cause serious permanent injury to the trees. In cultivating the ground around fruit trees it should be borne in mind that the tree is largely fed from the soil through its fibrous surface roots, and that any operation which injures these will affect the fruitfulness of the tree. Hence the cultivation must be shallow. On light open soils the Dutch hoe may be used for keeping the surface free from weeds and in a loose condition. On heavier soils the fork or spade must be used, but the soil should not be disturbed to a greater depth than two to three inches.

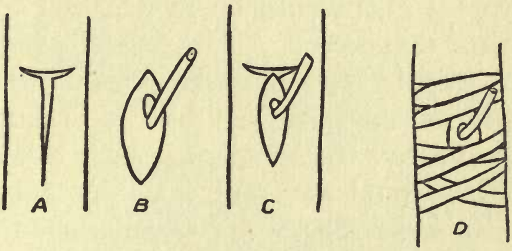

FIG. 60.—Budding. A, Incision; B, bud; C, bud inserted; D, Bud fastened in and bound with bast.

Very little experimental work has been carried out on the effect of the manuring of fruit trees. It appears probable, however, that any excess of soluble plant food in the soil may result in an increased vegetative activity of the trees, accompanied by a diminution in the amount of fruit produced. In fairly fertile soils it would seem that it is sufficient to apply in summer a moderate dressing of farmyard manure. This would supply food to the surface roots just at the time when the fruit is forming, and would also serve to keep the soil moist and cool. Very light soils containing relatively small quantities of available mineral food might be benefited by a spring top dressing of superphosphate of lime and sulphate of potash, at the rate of one pound of each forked into the soil over one rod of ground round each tree. This would be in addition to the summer mulch of farmyard manure.

Apple trees must be pruned. It is only by pruning that the proper shape of the tree is maintained, that the branches are prevented from crossing each other, that the tree is kept open to sun and air, and that the maximum of fruit production is attained. There are two main seasons for pruning, namely, in December, January, or February, and at the beginning of August. If we examine an apple tree in the winter we can readily make out the following points. First, we find long slender shoots bearing numerous small vegetative buds. If we follow the shoot down from the tip we observe a group of rings which marks the position of the bud of the previous spring from which the twig sprang. The portion of the twig which lies between the rings represents, therefore, one year's growth. Below the first group of rings we shall find at a short distance a second group, lower still a third group, and so on; each portion between two groups of rings representing a year's growth. In this way we can determine the age of any particular portion of a branch. Besides the long slender twigs we shall observe also relatively stout branches only from one to four inches in length, each terminated by a large greyish bud. These are the fruit spurs, and the large buds are bloom buds which will develop fruit. Some of these spurs are natural spurs, others are induced artificially by the pruning. If two shoots are too close together or are growing across each others' paths, one of them should be severed at a point just above the rings. Strong shoots must be shortened by cutting off about one-fourth of their length, medium shoots must be similarly shortened to one-half their length, while very weak shoots must be cut back to a point two buds removed from the rings. In all cases the shoot is cut through just above a vegetative bud, and the particular bud selected must be so situated that the twig resulting from it will grow in such a direction that it will keep the tree open and will not interfere with the growth of other twigs and branches. As a rule this direction should be centrifugal.

Summer pruning consists in pinching out those shoots of the current season's growth which are not required for the growth of the tree. The shoots are shortened so as to leave only about four buds.

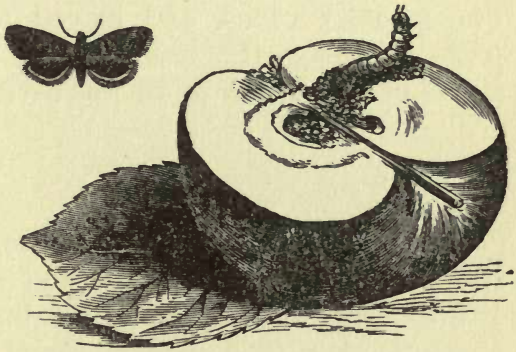

FIG. 61.—The codling moth and caterpillar.

Trees which send down deeply into the soil one or more large roots generally exhibit exuberant vegetative growth, accompanied by greatly diminished fruit-producing power. To remedy this condition of affairs the tree should be root pruned; that is to say, we must endeavour to encourage the production of more fibrous roots by severing the above-mentioned thick roots. The operation is effected in November. A circle of about three feet radius is described round the tree as centre, and a trench is taken out all round to a depth of three "spits." The earth from the top spit is put in one heap, that from the second in another, and that from the lowest in a third. In taking out the third spit the spade is worked obliquely inwards so as to remove the earth under the centre of the tree and expose all large roots. These are cut through with the spade, care being taken not to disturb more than can be helped the large mass of soil which is adhering to the finer roots. The earth is then replaced in the reverse order to that in which it was taken from the trench. At the end of the operation it may be found that the mass of earth round the roots is rather deeper in the ground than before. To avoid this we may, in the case of smallish trees, before removing the soil from under the centre, lay a stout pole across the circle and fasten the tree to it with a rope. This will prevent sinking.

The Pear

The Pear is propagated by grafting scions on Quince stocks in the same manner as in the case of the Apple. The Quince, as regards depth of rooting, is intermediate between the Paradise and the Crab stocks. Hence the Pear, for this reason, requires a somewhat deeper soil than is required for dwarf apple trees. For school gardens, and indeed for all small gardens, cordon pears are the most suitable. They may be trained either against a wall or to a stake, or on wires stretched between fence posts.

Plums and Cherries

The fruit is a drupe, consisting of a hard endocarp enclosing the seed, a juicy mesocarp, and a thin epicarp. Both Plums and Cherries thrive best on a rather light soil well stocked with available plant food and containing lime. Propagation is effected by budding or by grafting. The stock for Plums is either the Mussel Plum or the St. Julien Plum. For Cherries, two species of the Wild Cherry (*Prunus Cerasus*), are used, namely: *Prunus Cerasus* for the Morello and Duke type, and *Prunus Avium* (the Gean) for the Heart and Bigarreau varieties.

The Raspberry

This fruit is indigenous to the British Isles, and may often be found growing luxuriantly and fruiting abundantly in low-lying moist plantations. The brownish stems (the "canes") arise from buds on an underground root-stock; they mature in the first year, produce the leafy fruiting shoots in the second year, and then die in the autumn. Hence at that season all dead canes should be cut out. The fruit is a collection of small one-seeded

Drawn by Anna Lea-Merritt

AN OLD GARDEN

drupes. The Raspberry requires a moist rich soil, and succeeds well in a slightly shaded position. The canes should be planted in the autumn in rows, leaving a distance of four feet all round between the plants. They are best trained to wires; failing these they must be loosely tied up to stakes. The first spring after being planted the canes must be cut down to a height of one foot. The ground should be mulched with manure in winter, and kept well stirred with the Dutch hoe in summer. The roots are very near the surface, and hence the ground must not be either dug or forked. Propagation is effected either by means of seeds or by taking rooted suckers from the root-stock.

A valuable hybrid, the Loganberry, has been obtained by crossing the Raspberry with the Blackberry. In habit of growth the Loganberry resembles the Blackberry, while its rather acid fruit is like a very large red Raspberry, and is produced in great abundance.

The Gooseberry

All the cultivated varieties are derived from the wild *Ribes Grossularia*, which is an indigenous bush in the north of England, bearing small yellow, hairy, succulent berries.

To obtain new varieties of Gooseberries the plants must of course be grown from seed. The ordinary method of propagation is by cuttings. To obtain these, strong shoots of the year, about fifteen inches in length, are cut off close to the parent stem. All except the top five buds are removed, and we thus obtain a bush on a good, clean stem about one foot in height. The cuttings are planted in a shallow vertical walled trench about eighteen inches apart, preferably in a light sandy soil, and if such a soil is not available sand should be thickly sprinkled along the bottom of the trench. When all the cuttings have been placed in the trench, in a vertical position the soil is shovelled into the trench and trodden firmly, so that it is pressed close to the bases of the cuttings. In the winter next but one following, the four shoots which will have sprung from the cutting must be shortened to one half their length, and in the summer following the lateral shoots from these must be pinched back. In the autumn when the cutting is two years old the young bushes are transplanted to their permanent quarters, where they should have a space all round them of six feet from bush to bush. In the winter following transplantation the lateral shoots, which were pinched back in the summer, must be shortened to one inch. The object of this treatment is to produce an open bush with numerous vigorous fruiting spurs, and to allow subsequent increase in size by annual extension of new wood without choking the bush. The fruit is borne mainly on the spurs, but also partly on the new wood. A fairly cool climate suits the Gooseberry best, and hence it is seen to perfection only in Scotland and the north and midlands of England.

The plantation should be mulched with farmyard manure in the autumn. In cultivating the ground round the bushes care should be taken to avoid injury to the fibrous roots, which, as in the case of the Raspberry, lie very close to the surface. The hoe is the best implement to use.

For school gardens, where space is a consideration, Gooseberries may be better sown perhaps on cordons. The preparation of these is too difficult a matter for youthful gardeners, and the Cordons should therefore be bought from a nurseryman. They are trained to bamboo poles fastened to a wire trellis. Four shoots only should be maintained for bearing and extension. All other shoots should be summer pinched and cut back to one inch in length in winter.

The Currant

Of these there are three kinds—the White, the Red, and the Black Currant. The ancestral plant is the (probably) indigenous Wild Currant (*Ribes rubrum*), which occurs frequently in Scotland and the north of England. As in the case of the Gooseberry, while new varieties are raised from seed, propagation of existing varieties is effected by cuttings taken in the autumn. Strong side shoots are taken nine to fifteen inches in length. About an inch of the upper part of the shoot is removed, and also all but three top buds. The method of planting the cuttings is the same as that recommended in the case of Gooseberry cuttings. The form of bush to be aimed at is one standing on a clean stem four to six inches high bearing six main branches. To secure this the three shoots arising from the three buds left on the cutting are shortened back to four inches in the next winter but one from the time of planting the cutting, and in the following spring all but two of the buds on each of these three shoots are removed. The bushes may be transplanted to their permanent quarters in the autumn when two, or preferably, three years old, a distance of five feet being allowed between each pair of bushes.

The subsequent winter pruning of Black Currants differs from that required by White and Red Currants owing to the fact that the fruit of the Black Currant is borne mostly on the young wood, while that of *Ribes rubrum* is borne on wood two to four years old. Currants thrive best on a fairly moist rich loam, and they will produce an abundant crop of fruit even in a north aspect, although for the production of the maximum of sugar in the berries plenty of sunlight is required. The ground is manured and cultivated in the same way as that occupied by Gooseberries. On light soils Currants are benefited by occasional watering with soapy water.

The Strawberry (*Fragaria vesca*)

This occurs in the wild state in woods and on hedge banks throughout Europe, Northern Asia, and North America. The Hautboy (*Fragaria elatior*), a wild British variety, is distinguished from the common Wild Strawberry by its large fruit, its greater height, and the smaller number of its flowers and runners. Two other varieties are known, namely, the North American *Fragaria virginiana* and the South American *Fragaria chiloensis*. The Strawberry is a perennial plant possessing a short tufted stock, from which thin stolons are produced, which root and form new plants at each node. The very numerous modern varieties now in cultivation are derived from crosses between the varieties above mentioned. A vertical section of the pseudo-fruit shows that it is composed of small carpels inserted on a much enlarged juicy conical receptacle.

The propagation of the Strawberry is easily effected by means of rooted runners. The usual method adopted is as follows. The ground round the plants is loosened with a fork so as to provide a suitable rooting medium. It is then watered, and pieces of brick, tile, or stones are laid on the runners to assist the roots in attaching themselves to the soil. To obtain vigorous young plants it is necessary that all the nourishment passing along the stolon from each parent plant should be devoted to the support of one offspring only, and consequently we encourage the stolon to root at the first node, and as soon as rooting has taken place cut off the loose end. In dry weather frequent watering of the rooted plants will be necessary. They will be ready for separation from the parent towards the end of August, and they should be planted out in their permanent quarters at, or very shortly after, that date. In taking them up a trowel is used, and care should be taken not to break the ball of soil in which the roots are embedded. If, for any reason, the bed cannot be got ready in time, the plants may be planted in trenches, allowing two to three inches between the plants and one foot between the trenches. They are then transplanted in March.

The best kind of soil for Strawberries is a rich loam inclining to sandy. Strawberries do not thrive on a heavy clay. They are rather exacting in their main requirements, which are sunlight, moisture, and an abundance of plant food in the soil. The strawberry bed must have been trenched or heavily manured with farmyard manure. With a garden line and measuring stick the young plants are accurately set in rows at a distance of eighteen inches between the plants and two feet between the rows. The depth of planting is such that the ball of earth on the roots is just covered. As soon as the planting of the bed is completed the soil should be well watered. The bed will require no more attention until the spring, when it should be hoed. As soon as the flowers have dropped off, a dressing of soot or lime should be carefully applied to the soil all round the plants, so as to prevent attacks by slugs, and immediately after a mulching of long strawy stable manure should be applied. The summer rains will soon wash this clean, and the plant will thus be fed at the time when the fruit is forming. The strawy coating will also serve to preserve the soil moisture. Water must be given from time to time if the weather is very dry, and it is also desirable a few weeks before the fruit is ripe very lightly to fork over the soil between the rows. There is a very considerable difference in the date of ripening in different parts of the British Isles. For example, in the great strawberry district lying to the north-east of Southampton, the season is two to three weeks in advance of the Cambridgeshire and Bedfordshire season, and the former consequently monopolises the markets of the important northern industrial centres of consumption, such as Glasgow, Belfast, and Manchester.

The Strawberry plant produces abundantly only in its second and third year of growth. Beginning with the fourth year there is a diminution of productiveness, and this diminution becomes more and more marked in each succeeding year. It is so easy to obtain new plants from the old ones, as described above, that there is no excuse for the retention of the old plants beyond their fourth season, and at the end of that period at latest a new bed in a different part of the garden should be formed.

CHAPTER XI

FLOWERS

IN every school garden should be grown vegetables, fruit, and flowers. The first two are of such economic and industrial importance that they must have the lion's share of space, thought, and work; but, on the other hand, flowers have an æsthetic, moral, and educational value so great that equally they should be regarded as an essential in the school garden. Small children eight to twelve years of age should have each a small plot of about a square yard in area. Some of such plots would be side by side, either in the vegetable garden or so as to form little borders under the school walls. Others would occupy various corners of the school premises. In girls' schools every effort should be made to establish a herbaceous border, not less than four and not more than ten feet in width. A length of about six feet of such a border might be allocated to each girl. One would also like to see a herbaceous border in every boys' school garden, whether belonging to a day school or to an evening school. Hitherto it appears that the exigencies of time, space, and money have been regarded as obstacles. They are, nevertheless, not insuperable or even serious obstacles. It is sometimes urged that local education authorities and school authorities have insufficient funds to permit of indulgence in what is regarded

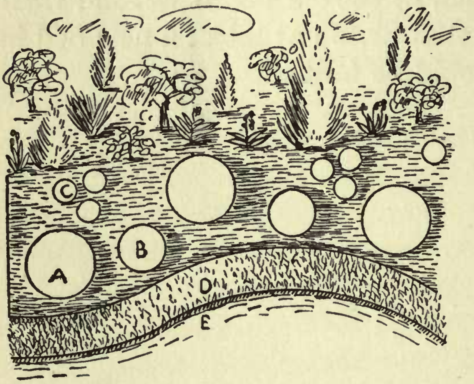

FIG. 62.—Annuals. Sowing seeds in borders. A, shows how to prepare the ground for large clumps of Annuals; B, shows how to arrange smaller clumps; C, shows how to arrange clumps of tall annuals near the back of the border; D, grass verge; E, path.

as the luxury of flower culture. But this is not a particularly valid objection, since penny packets of seeds both of annual and perennial flowers can now be bought, and each packet frequently contains enough seed to supply the requirements of four workers. Further, the scholars themselves could, in many cases, bring roots of perennials, and where there are large gardens in the neighbourhood, their owners would probably be pleased to make, out of their superfluity, donations of bits of plants to the school garden. Failing a herbaceous border, a narrow strip of each vegetable or fruit plot bordering on a path should be utilised for flower culture, and corners of the garden might be occupied with a few of the easily grown ornamental and flowering shrubs, such as Bamboos, Ceanothus, *Choisya ternata,* Butcher's Broom, Periwinkle, Almond, Golden English Yew, *Buddlea globosa,* Broom, Lilac or Syringa, Flowering Currant, Shrubby Spireas, and so on.

It is not possible to give detailed cultural directions for all the exceedingly numerous varieties of flowers and shrubs which might quite well be grown in a school garden. We must be contented for the most part with some general observations and directions, and refer the reader to the books mentioned in the Bibliography for more complete information.

Hardy Annuals

An annual is a plant whose life is limited to a single season. The seed is sown in the autumn or spring, leaves, flowers, fruit and seed are produced in the following summer, and in the autumn the plant dies. Hardy annuals are those the seedlings of which can be grown in the open air. Half-hardy annuals are raised in pans or boxes in the greenhouse or on the hotbed, and are planted out of doors in June, when all fear of prolonged low temperature during the night is at an end. If early blooms of hardy annuals are required many of them may, like their half-hardy brethren, be raised in gentle heat. For outdoor sowing the end of March is the best time. The seed bed should be as fine as possible, because the seeds as a rule are very small, and in rough ground would either not be in sufficiently close contact with the soil particles, or would sink too deeply into the soil. They are best sown in circular patches about a foot

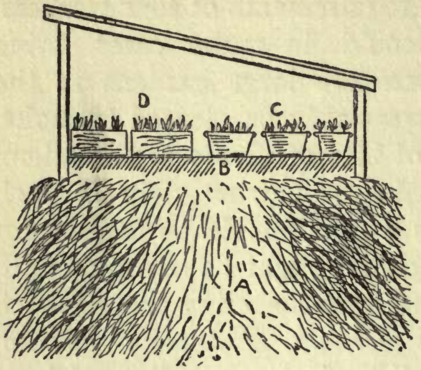

FIG. 63.—How to raise tender annuals. A, a hotbed; B, cocoa-nut fibre, ashes, or soil; C, seedlings in pots and pans; D, seedlings in boxes.

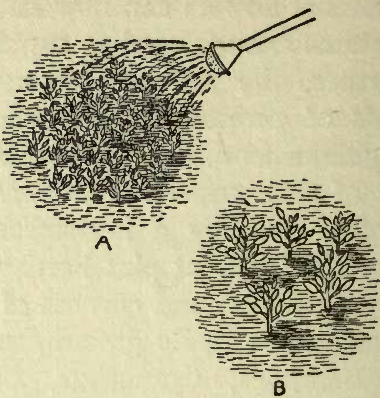

FIG. 64.—Annuals. Thinning-out seedlings. A, watering clump of seedlings before thinning is done; B, the result of thinning-out. Plants growing sturdily.

and a half in diameter, or in rows. The ground, having been dug a few weeks previously, is lightly scratched with a kind of circular motion of the rake, and over this the seeds are scattered evenly and very thinly, fine soil is then sifted or sprinkled over the seeds and lightly pressed down on them. Roughly speaking, the seeds should be covered with soil to a depth equal to their own diameter. Very small seeds may be mixed with a little fine dry sand to ensure even and thin distribution. If sown thickly the seedlings compete for air, moisture, and food, and suffer in the struggle. If, in spite of all precautions, the seedlings are too thick, they must be carefully thinned about a fortnight after they appear above the surface, and in any case they must be thoroughly thinned when about an inch high. When thinning is completely the plants left

FIG. 65.—Annuals. Staking. A, shows how to stake weakly-growing annuals in clumps; B, shows how to stake tall-growing annuals; C, shows how to prepare the tall stakes, which should be painted dark green.

standing should be dotted about the circle at a distance from each other of six inches more or less, according to the height and diameter of the full-grown plant. If the plants are not thus ruthlessly thinned we shall get weak, straggling, unsightly specimens, producing few blooms.

The following is a list of suitable hardy annuals, classified according to the approximate height of the mature plants.

Six inches

Sweet Alyssum	Silene pendula	Aubrietia
Dwarf Nasturtium	Virginian Stock	

Twelve inches

Bartonia aurea	Godetia	Phlox Drummondii
Candytuft	Larkspur	Iceland Poppy
Collinsia bicolor	Love-in-a-mist	Saponaria
Eschscholtzia	Lupin	Sweet Scabious
Linum	Mignonette	Sweet Sultan
Gaillardia picta	Nemophila	

Eighteen inches

Clarkia	Coreopsis Drummondi	Tagetes

Twenty-four inches and more

Lupins	Sunflower	Convolvulus
Shirley Poppy	Sweet Peas	

BIENNIALS

A biennial plant lives for two years. Leaves and stems are produced in the first year, and flowers in the second year. The seeds are sown in a nursery bed in May. As soon as they can be handled they are transplanted to a second bed in rows, allowing 6 inches all round each plant. In the September of the same year they are again transplanted, this time to their permanent quarters. The most suitable biennials for growth in the school garden are Wallflowers (18 in.), Sweet Williams (18 in.), Foxgloves (36 in.), Canterbury Bells (36 in.), and Cornflowers (24 in.).

Hardy Perennial Herbaceous Plants

Many of these may be easily raised from seed sown in the early summer, and it is suggested that half a dozen species should thus be raised in the school garden each year. Boxes or pans are filled with a mixture of equal parts of leaf-mould and sand loam, previously moistened. The seeds should be sown very thinly, and just covered with the fine sifted mixture which is lightly pressed down over them. The pans or boxes are placed in a sheltered position, and care must be taken that the soil is kept moist, but not wet. If the thinning has been thorough the young plants may be left in the pans until ready for planting out in permanent quarters in the following spring. Or, as in the case of biennials, they may be planted out from the pans into good soil in a well-sheltered position in September, being again transplanted in the spring. Of perennials, which may be grown from seed without much difficulty, the following are the best:—Campanulas, Delphiniums, Geum, perennial varieties of Coreopsis, Flax, Lobelia and Gypsophylla, Jacob's Ladder, Lychnis chalcedonica, Malva moschata, and Salvias.

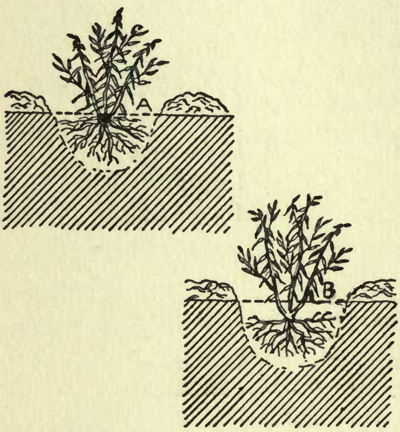

FIG. 66.—Planting. A, right depth to plant; B, too deep.

It would be a difficult matter to name all the hardy perennials which might be grown in a school garden, and since, as has been more than once hinted in these pages, the school garden may have to depend for a supply on gifts from kind sympathisers, a list is hardly necessary. It may be useful, however, to some readers if we transcribe here a list of fifty best hardy perennials which was given in the *Times* of 18th April 1908. These are beautiful plants, suitable for a border, quite hardy, easily grown, and perennial for some years.

A Selection of Fifty of the Best Hardy Perennials.

Delphinium Belladonna
Madonna Lily
Lilium testaceum
Paeony (the Bride)
Aquilegia cœrulea
Anchusa italica (Dropmore variety)
Campanula persicifolia, var. Grandiflora
Platycodon grandiflorum, var. Mariesii
Oenothera macrocarpa
Centaurea montana
Nepeta mussimi
Armeria cephalotes rubra
Polemonium reptans
Erigeron speciosus
Oriental Poppy (Goliath)
Gypsophylla paniculata
Thalictrum aquilegifolium
Geranium ibericum platypetallum
Potentilla nepalensis
Coreopsis lanceolata
Galega officinalis
Tradescantia virginica
Trollius asiaticus
Statice latifolia
Pentstemon barbata, var. Torreyi
Hollyhocks
Anemone japonica
Iris pallida Dalmatica (Princess Beatrice)
Viola (Florizel)
Pink (albino)
Phlox (Coquelicot)
Michaelmas Daisy (Aster acris)
Funkia Sieboldii
Hæmerocallis Thunbergii
Kniphofia caulescens
Veronica amethystina
Linum perenne
Yucca filamentosa
Scabiosa caucasica
Spiræa Aruncus
Epilobium angustifolium
Sidalcea Listeri
Malva moschata alba
Hypericum moserianum
Erodium manescavi
Saxifraga lasiophylla
Tiarella cordifolia
Incarvillea Delavayi

After perennials have been established a few years they are generally benefited by being transplanted, and advantage should be taken of this at the time to obtain an increased number of plants by division of the roots or root-stock.

Bulbs

Except for window boxes, bulbs are not very suitable for the school garden, for the reason that, in the first place, they are, compared with seeds, rather expensive; and in the second place, if left in the soil through the summer, in order that the bulbs may mature for next year, the masses of decayed leaves give a rather untidy appearance to the garden. As a rule they should only be grown in a garden where a feature is made of the herbaceous border. For such use the Narcissus is at once the most beautiful and the easiest of culture. The bulbs should be planted in the autumn, in clumps about a foot in diameter. A circular hole is scooped out in the soil to a depth of about three inches. If the soil is heavy a layer of sand a quarter of an inch deep should be sprinkled over the bottom, and on this the bulbs should be placed at regular intervals in a circle, and then covered with soil. At the end of March the tips of the leaves will appear above the surface, and in the second half of April the flowers will be in full bloom. The period of blooming extends over two or three weeks. If the soil is heavy and rather poor, few new bulbs will be produced, and there is therefore no object in such a case in allowing the plants to stand in the soil. In better and lighter soils the maturation of the new bulbs proceeds until the height of summer, when the leaves will begin to die down. The bulbs should then be dug up, laid out in the sun to dry, and stored prior to replanting in October.

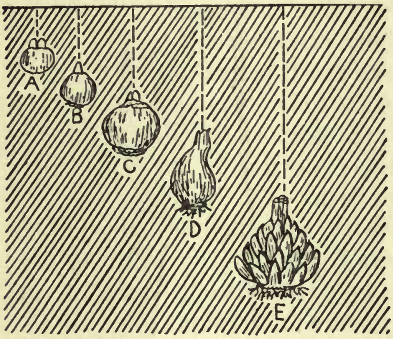

FIG. 67.—Depth at which to plant different Bulbs. A, Snowdrops, Crocuses, or Scillas; B, Jonquils, Tulips, etc.; C, Hyacinths; D, Narcissi, Gladioli, etc.; E, Liliums.

There are numerous kinds of Narcissus. The most suitable perhaps are: Barri Conspicuus, Emperor, Sir Watkin, and Poeticus Ornatus.

Roses

Two or three Roses should be grown in every school garden, if only for the sake of practice in the art of budding. The details of the manipulation have been given already under the head of the Apple, and it only remains here to deal with the question of the stock, and the subsequent treatment of the budded Rose. Two kinds of stocks are employed—the wild English Dog Rose and the Manetti stock. The Wild Rose is a suitable stock for almost any kind of Rose, the Manetti only for certain sorts. The scholars should obtain the stocks from the hedgerows in late October or November. Any clean-growing young briars with a good root system will do. A few of these should be brought into the garden and planted in rows, leaving a space of one to one and a half feet all round each stock. The operation of budding is carried out, as in the case of the Apple, at the beginning of August. For Dwarf Roses (and these are more suitable for practice than standards) the surface soil is scraped away from the base of the stock, in order that the bud may be inserted as low down as possible on the stem, thus diminishing the possibility of the production of suckers. The bud having been taken and inserted, nothing more remains to be done except to release, at the end of a month, the bast or worsted thread used to keep the bud in position. In March following the stock is cut off at a joint two or three inches above that from which the inserted bud is now growing. In the October following the bushes are transferred to their permanent quarters. A hole is dug one foot in diameter and one foot deep, and into the bottom of this is worked some well-decayed leaf-mould and dung. In this the Rose is placed at such a depth that the roots are within two inches of the surface.

Roses of one kind or another may be grown on almost any soil except a very raw heavy clay. That they will grow and bloom well on a thin sandy soil is evidenced by the fine display of Roses which may be seen in the summer in the gardens of the Royal Horticultural Society at Wisley. On such a soil, however, cow dung and loam must be well worked into the soil around the Rose bush, as Roses are "heavy feeders," and the bushes must be mulched each year with the same manure.

For bushes, plant Edith Gifford, Caroline Testout, Madame Pernet Ducher; for arches and walls, William Allan Richardson, Crimson Rambler, Dorothy Perkins.

Sweet Peas

In a school garden not provided with a greenhouse or frame, Sweet Peas may be sown during March, April, and May for a succession of blossoms. A deeply cultivated soil, well stocked with plant food, and fairly retentive of moisture, is required for the best results. The seeds may be sown either in circular clumps or rows. In either case the soil is taken out to a depth of about two inches, and the seeds are planted separately at a distance apart of from two to three inches. They are covered with soil to a depth of one inch. To protect them from attacks by birds, pieces of black thread to which white feathers are fastened at intervals should be stretched across the bed. Slugs are troublesome at the time the young plants show above ground, and a good

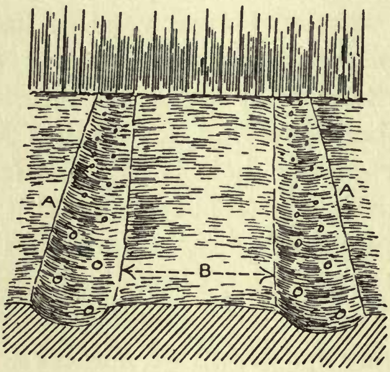

FIG. 68.—Sweet Peas. Sowing seeds in drills. A, A, drills 14 in. wide, 2 in. deep; B, space between drills, 6 ft. wide.

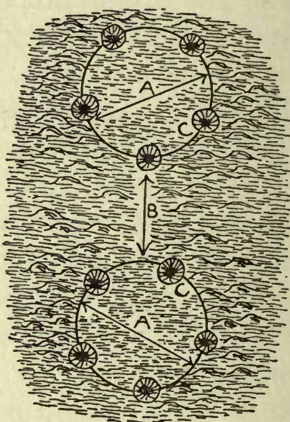

FIG. 69.—Sweet Peas. Sowing seeds in clumps. A, A, circles drawn 42 in. in diameter; B, circles 4 ft. apart; C, holes for seeds or plants.

dressing of soot should therefore be given. As soon as the plants are four inches high they must be supported with small twigs, and when six or eight inches high they must be staked with longer twigs (four feet or more in height). Drought is very injurious, and it is therefore important to maintain a good surface mulch with the hoe during the period of growth, and to give a top dressing of rotted manure at the time of flowering. There are numerous varieties. Among the best are: Dorothy Eckford (white); Black Knight (bronze); Navy Blue, Countess Cadogan and Lord Nelson (blue); Prima Donna, King Edward, Mars and Adonis (pinks or reds); Henry Eckford (orange).

Geraniums

It is not a very difficult matter to raise geraniums from seed. The seeds are sown in pans containing a mixture of equal parts of loam and sand. If a spent hotbed is available the seeds may be sown in March. If there is no hotbed the sowing must be done at the end of April and the pans kept indoors. Germination takes place quickly, and after thinning, the young plants, when two inches high, are transferred to separate pots in which they must be kept indoors through the following winter.

The ordinary method of propagation is by means of cuttings taken either in July or in March. For summer cuttings, good strong side shoots are taken off with a clean cut, trimmed, and firmly inserted in somewhat sandy soil in a sheltered position out of doors. Care must, as usual, be taken that the base of the cutting is in close contact with the soil. Root formation proceeds rapidly, and at the beginning of October the rooted cuttings will be ready to be taken up, potted, and stored for the winter, either in a frame or indoors.

In the case of spring cuttings, the slips are taken off old plants kept over from the previous summer. Gentle heat, however, is required for these spring cuttings, and consequently the method cannot be adopted unless the school garden possesses a heated greenhouse or a hotbed.

Window geraniums planted in pots may be kept through the winter (as is done by cottagers) in any room the temperature of which during the winter nights does not fall to a lower temperature than 40° F. Where it is desired to keep summer bedded Geraniums through the winter, they are best packed closely with the earth round their roots in boxes, which are then stored in some place free from frost.

The Herbaceous Border

The mainstay of the herbaceous border is a variety of soft-wooded hardy perennial plants. These are supplemented by such spring flowering bulbous plants as Snowdrops, Squills, Crocuses, Irises, and Narcissus, by annuals, and by a few small compact rooting bushes and shrubs, such as Lavender, Rosemary, and Dwarf Roses. The aim should be to supply a continuous variety of bloom and greenery from spring to autumn, to arrange contrast of colour and form, and yet to maintain a plan underlying the maze of plants. While, generally speaking, the smaller plants are placed towards the front of the border, and the taller ones towards the back, this should not be done with mathematical accuracy. The tallest plants should not be quite at the back, and some of the smaller plants should be placed between or even behind the line of the taller ones. The shrubby plants above mentioned should constitute the skeleton of the border, and should be planted in a regular slightly zigzag line, at intervals along its length. The clumps of bulbs should not be planted in isolated groups, but near some plant or shrub which will act as a background to them when they are in flower. The front part of the border may be occupied by Pinks, Sweet Alyssum, Aubrietia, Saxifrage, Pansies, Violas, Dwarf Larkspurs, arranged irregularly but at equal intervals. Behind these and between the shrubs would come the tall perennials. The clumps of annuals will be similarly arranged, approximately according to height, among the permanent occupants of the border.

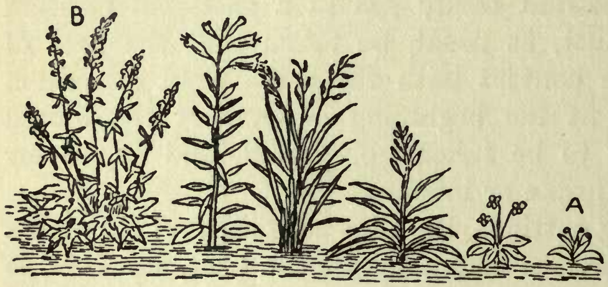

FIG. 70.—End view of plants in borders. A, front of border ; B, back of border.

Above all things, do not crowd the border, but let every plant, or group of plants, occupy a distinct space, with intervals between sufficient to cultivate with the Dutch hoe. Neatness is essential, and there can be no neatness when the plants are jostling each other.

Plants in Windows

For town schools, and for all girls' schools, whether in town or country, window gardening is an excellent means of developing an interest in flower culture. Window boxes may be constructed

HALE DAY SCHOOL GARDENS, FARNHAM, SURREY

Boys at work

very cheaply by the scholars. The dimensions of the window sill should be taken and a local timber merchant asked to supply half-inch deal boards, nine inches in width and of a length rather less than that of the sill. These can then be nailed together to form a box and painted. The best colour is green, though for trailing plants, such as Ivy Geranium, white looks very well, provided the box is freshly painted each year. Probably a brace and bit can be borrowed for the purpose of boring the drainage holes in the bottom of the box. In a box two feet long by nine inches wide, eight or ten such holes, half an inch in diameter, should be bored irregularly, so as not to produce a tendency to split. In the bottom of the box place a layer of broken flower pot, or failing these, any pieces of broken brick, or even stone. Over this layer sprinkle a thin coating of dead leaves, or of broken turf, so as to prevent the soil from getting down amongst the drainage pieces. The best soil available should then be filled in, to within an inch of the top, and gently pressed down. Good garden soil should be used, and this may with advantage be mixed with a little clean white sand, in the proportion of about three spadefuls of garden soil to one spadeful of sand—rather more sand for bulbs and less for other flowers. If well rotted turf can be had a little of this mixed with the soil will help. It is important to secure good open soil for the window box, because the sides of the window box are practically non-porous to air and water, and therefore if a heavy soil were used the roots would not be able to obtain their proper supply of air. For systematic window gardening we require at least two boxes for each sill, one for spring and the other for summer plants. The spring window box is prepared in the autumn, and for the purpose we rely mainly on bulbs. In it plant bulbs of Narcissus, such as *Narcissus poeticus* and *Barrii conspicuus.* These in clumps of three, the distance between the bulbs in a clump being about one inch, and the distance between the clumps about three inches. In the spaces between the clumps plant similarly other clumps of Snowdrops, Anemones, Scillas, and yellow, purple, and white Crocuses. These bulbs will give a succession of bloom through February, March, and April.

For the summer box there is a practically unlimited choice of plants. If a hotbed has been made in February we can raise early seedlings of most of the better hardy annuals, and these can be transplanted into the window box in March. They must not be exposed to the cold air all at once, but must be gradually hardened by taking them out-doors for a short time each day when it is sunny and warm. For the rest of the time the box must be kept inside in a light, moderately sunny, airy place. By the middle of April, unless the weather is cold and windy, the box may be placed permanently outside.

If we have no hotbed, the young plants must be raised in a sheltered warm part of the garden, the seeds being sown in March. Speaking generally, it is not desirable for school purposes to purchase plants raised elsewhere. It is much better for the pupils to be acquainted at first hand with the full history of the plants they are handling. Hardy perennial and biennial plants intended for the window box should, of course, be raised in seed beds in the preceding late spring or early summer, transplanted into fresh beds in autumn, and again transplanted in March into the window box.

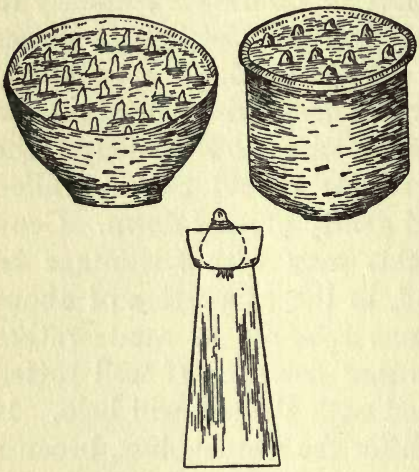

FIG. 71.—Bulb-growing in glasses, and in Moss fibre in vessels without drainage. Receptacles suitable for Narcissi, Tulips, and Snowdrops.

Instead of window boxes we may use large flowerpots, and almost everything which has been said above will apply also to this method of window gardening. Annual creepers may be made especially effective if sown thinly in large flower pots, and trained to climb up trellis work (or any home-made support) placed on either side of windows or doors. Some of these grow with extraordinary rapidity, and produce an abundance of flowers and foliage. For this purpose employ Canariensis, Hop, Convolvulus, and climbing Nasturtium. The seeds are sown in early March, in pots six to eight inches in diameter, containing good soil. As soon as the young plants are up they must be thinned, and the thinning should be repeated a week or two later, so as to leave not more than four plants situated at approximately equal distances from each other. A single plant would, in fact, be sufficient, but it is advisable to allow for contingencies.

Town Gardening

The principal difficulties which arise in gardening in towns are want of space, poverty of soil, and unsuitable atmospheric conditions. The first is insuperable, the second can be removed by tillage carried out at the proper time, and by the use of well rotted stable manure. Adverse atmospheric conditions are due in part to the fact that the air of large towns contains relatively large quantities of sulphuric acid and carbon, which when deposited choke the pores and injure the texture of the leaves of the plants. Further, the dust and soot-laden atmosphere hinders the passage of sunlight. These effects are most marked during the winter, when there is a greatly increased domestic consumption of coal and gas, coupled with a decrease in the amount of light and heat received from the sun. From this it follows that the plants which suffer most are those—the hardy perennials—which remain out of doors the whole year round.

Many annuals and bedding plants may be grown almost as successfully in town gardens as in country and semi-urban districts. The following have shown themselves best able to resist the adverse conditions attaching to a garden in a large town:—Coreopsis, Sunflower, Marigold, Nasturtium, Scabious, Clarkia, Nigella, Lupin, Sweet Pea, Mignonette, Virginia Stock, Sweet Alyssum, Larkspur, Hop, Canariensis, Convolvulus, Candytuft, Snowdrop, Crocus, Hyacinth, Narcissus, Iris, Pink, Auricula, Polyanthus, Wallflower, Aubrietia, Arabis, Hardy Ferns, Ivy, Virginia Creeper, Forsythia, Pyracanthus, Cotoneaster.

CHAPTER XII

Insect and Fungoid Enemies of Garden Crops

Probably every plant supplies either food or shelter or both to one or more insects or other animals and fungi, and where, as in the farm garden or orchard, plants are growing in greater numbers than is the case on land not cultivated, the abundance of the food or shelter thus provided encourages the multiplication of objectionable guests. In the United States of America, where fruit plantations frequently extend to hundreds of acres, it is a matter of life and death for the fruit grower to take all possible precautions against a fungus or insect obtaining a foothold on his plantations. In this country, generally speaking, crops are not cultivated on so large a scale, and the necessity for combating the spread of insect and fungoid enemies is not yet fully and generally recognised, although the losses yearly in one crop or another are sufficiently serious.

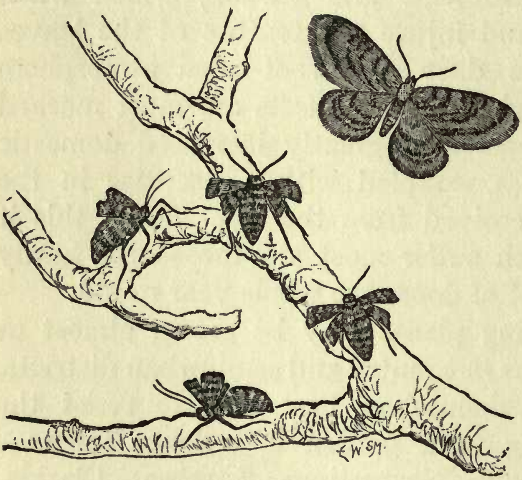

Fig. 72.—The Winter Moth.

In order to wage war successfully with plant pests it is essential to possess a complete knowledge of the life-history of the pest, so as to know where it is lurking at each stage of its existence, and at what stage it can best be attacked. The number of such pests is considerable; probably many have not yet been recorded, and in the case of many of those which have been recognised as causing injury to crops, we are not yet in possession of all the important facts as to their lives and habits. It is not beyond the powers of school children to study the life-histories of a few of the commoner noxious insects, and such a study, if carried out with thoroughness on some of those which are quite common, can be made highly instructive and interesting. An investigation can, for instance, be made of the life-history of the common winter moth; and this, if completely carried out, establishes a sort of type in the mind of the young observer. The life-histories of fungi involve the use of the microscope, and is not so suitable a subject for school study, although it is desirable to encourage the young students to look for blotches and discolorations on leaves and shoots. These are frequently attributed by gardeners and farmers to frost and cutting winds, when they are, in fact, the outcome of attacks by fungi or aphides.

Prevention is better than cure, and fortunately there are a

FIG. 73.—Common Vapourer Moth, with Caterpillar and wingless female Moth.

number of ways in which attacks may be forestalled. For example, if the soil is turned up in the autumn, any insect larvæ or pupæ, which may be buried in it, will be exposed to the weather and killed, or will be eaten by the birds. Insectivorous birds, such as the titmouse or the starling, should therefore be encouraged. Again, although fungi and insects can usually maintain themselves on more than one species of plant, the chances are that if ground occupied one summer with a given species of plant is occupied the following summer with a different species, or, better still, with a plant belonging to a different order, the insect or fungus which throve on the former will be starved out by the latter. Hence regular change of cropping is necessary. Crops, which owing to bad tillage, unfavourable weather, or poverty of soil, are not growing vigorously, are not in a position to resist the attack of fungi, and crops in the seedling stage are also very frequently the victims of attack.

When the pest has established itself in quantity the remedial operations include spraying, and in some cases handpicking or trapping.

Aphides, scale insects, and beetles feed during both the larval and adult stages; moths and sawflies, during the larval stage only. In combating insect attacks, the eggs and chrysalids may be destroyed in the winter, the larvæ in the summer. Moss, lichen, and dead bark afford shelter to the eggs during the winter, and consequently care should be taken to keep the trunks of fruit trees as clean as possible. Fungi frequently make wounds and cut surfaces their point of attack in the case of fruit trees, and such surfaces should therefore be cauterised with tar if fungus pests are prevalent.

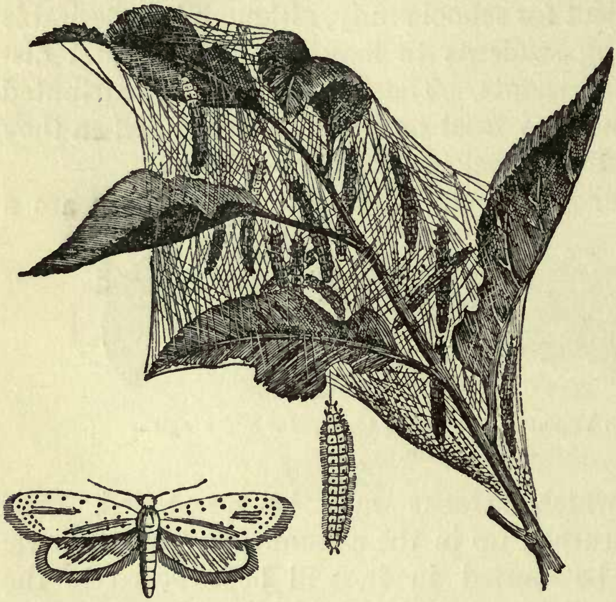

FIG. 74.—Small Ermine Moth and Caterpillar. Moth twice natural size; larvæ and web about natural size. (*By permission of the Board of Agriculture.*)

For spraying, on a small scale, a knapsack sprayer is required, costing about thirty shillings. Such a sprayer delivers the solution in a fine mist, which coats leaves, twigs, and stem, but is not in sufficient quantity to run off the plant and so be wasted or injure the roots. Spraying, if done at all, must be done with thoroughness, and the jet must therefore be directed to all sides of the stem, and also the under, as well as the upper, sides of the leaves.

WINTER WASH.—This may be applied to fruit trees every second or third year. It will remove moss and lichen, and kill a good many eggs and chrysalids. It should be applied in

February. The following recipe is recommended:—Soft soap, ½ lb.; paraffin, 5 pints; caustic soda, 2 lbs.; water, 9½ gallons.

Caustic soda in solution attacks the skin of the hands, and may cause serious wounds. In handling this solution, therefore, leather or rubber gloves should be worn. The mixture must be continually stirred, otherwise the soap and the paraffin will rise to the surface of the liquid.

A simple, but not so generally effective, winter wash for apple trees is made by employing a mixture containing 15 lbs. of quicklime, 2 lbs. of common salt in 8 gallons of water. The salt is dissolved in the water, the quicklime is slaked just before using by adding to it just so much water as will cause it to crumble into finely powdered slaked lime. It is then stirred into the salt solution, and the mixture painted on to trunk and branches with a large brush.

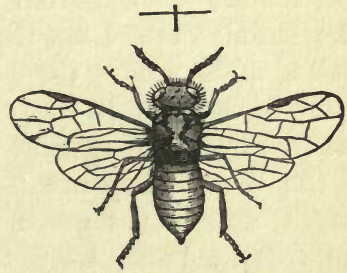

FIG. 75.—The Pear Sawfly—Erlocampa (enlarged).

FIG. 76.—Singworms (larvæ of the Pear Sawfly) upon a leaf.

SUMMER SPRAYING.—While winter washing should be regarded as a matter of routine in fruit plantations, summer treatment should, as a rule, only be done when a serious insect or fungus attack is imminent. Different pests are injured or destroyed by different substances, and in different ways. Lead arseniate probably poisons the insects, paraffin either poisons or corrodes them. Carbon bisulphide injected into the soil destroys the grubs, soft soap stops up the breathing pores. Fungi can be effectually removed only by treating them at regular intervals with a solution of either copper sulphate or sulphide of potassium, which destroys the spores. It is obviously beyond the scope of this book to go into this matter in greater detail. It will be sufficient, perhaps, to give here detailed accounts of the life-histories of a few pests, the preventive and remedial treatment of which is established on a sure foundation.

THE WINTER MOTH.—The essential fact on which the treatment of this insect pest depends is that the females have only rudimentary wings, and in consequence are unable to fly. Male and female emerge from the pupæ, at the earliest, in October. The females crawl up the stems of the Apple trees to join the males, after which they lay their eggs on twigs, branches, or trunk of the tree, in any convenient crevice. The caterpillars are hatched from the eggs in March, and begin to feed on the leaves of the tree. They are "loopers," measuring nearly an inch in length, and bright green in colour with pale lines. They leave the tree in June, bury themselves in the ground and pupate, emerging as moths in October or November. The remedy is to prevent the female from crawling up the trunk, and this is effected by grease banding, which consists in tying round the tree trunk a band of grease-proof paper six inches wide and coating this with cart grease. The band should be placed not far from the surface of the soil, since eggs may be laid quite low down on the trunk of the tree. When the females attempt to crawl over the grease band they stick on it and may be removed and destroyed. Since the moths begin to emerge from the pupæ in October it is plain that the grease bands must be put on in the last week of September.

THE GOOSEBERRY SAWFLY.—The sawfly emerges from the ground in April and May, and lays its eggs on the under surface of the leaves; the caterpillars hatched from these eggs begin to consume the leaves in May, and may defoliate the whole bush. The caterpillars when young are green with black spots; when fully grown some of the segments are orange coloured, and the caterpillar is then nearly an inch long. They then go into the ground and construct cocoons. From some of these sawflies are produced in about twenty days; others remain in the soil, pupate in spring, and produce the April and May sawflies. To destroy the pests rake gas lime into the soil round the tree in March. To destroy the caterpillars, spray the tree with an emulsion of paraffin oil

FARNHAM EAST STREET SCHOOL GARDENS

made up in the proportions of 6 lbs. of oil to 10 gallons of water.

THE CURRANT GALL MITE (*Big Bud*).—Attacks of this pest cannot be mistaken. The buds appear large and round instead of being pointed, and if opened and examined with a good magnifying glass will be found to contain large numbers of white mites. The mites begin hatching in March, and from May to June lay their eggs in the buds, from some of which mites are hatched the same summer, while others remain unhatched until the following spring. Some of the mites also remain in the buds through the winter, and others hide in the roots. There is no certain remedy other than picking off and burning infested buds, or in bad cases digging up and destroying the whole bush. In some cases, however, it is stated that the pest has been destroyed at the time of emerging from the previous year's buds in March, April, and May by dusting the bushes at fortnightly intervals with a mixture of powdered quick lime and flowers of sulphur, in the proportion by weight of one of the former to two of the latter.

THE POTATO DISEASE.—The commonest and most serious disease from which Potato plants suffer is that caused by a fungus called *Phytophthera infestans*. The disease appears every year, and apparently no variety is capable of resisting it, although it is stated that some varieties suffer less than others. The first symptoms of disease should be looked for between the last week of June and the first week of August, when the mycelium of the fungus may be found in white patches on the under surface of the leaves. The hyphæ penetrate into the tissues of the leaves, feeding on the nutritive material which should go to nourish the plant, and pass down through the stalks into the tubers. The leaves show brown blotches under the patches, and in severe cases the whole of the plant above ground becomes dark brown and gives out an offensive smell. Besides the branches which grow down into the stem of the plant, other branches grow out through the stomatic openings on the under side of the leaves. These produce conidia containing spores. When the conidia are ripe they drop off, are blown about by the wind, and ultimately burst, scattering the spores, which, if conditions of warmth, moisture, and presence of the host plant are favourable, germinate and give rise to fresh infection. Continuity of the life of the fungus is maintained by means of resting spores, which remain dormant during the winter and resume growth in the following summer.

To prevent the disease, care should be taken to burn all diseased leaves and stalks. Diseased tubers may be fed to pigs after being first thoroughly cooked by boiling.

Fortunately, the disease may be successfully combated in its early stages by spraying the plants with Bordeaux mixture, and as the disease is so common it is advisable to spray all Potato crops whether the presence of the fungus has been observed or not. Bordeaux mixture is made as follows. Dissolve 10 ounces of crystalline copper sulphate in half a gallon of water. Take half a pound of quicklime and slake it by adding water to it a little at a time until the lime becomes hot and crumbles to a powder. When cool add to it 12 to 15 gallons of water in a tub and stir once or twice. Allow to settle, and, when clear, measure out 8½ gallons of the lime water and mix it with the copper sulphate solution. Add sufficient water to make up to 10 gallons. Copper sulphate solution cannot be made in a metal vessel owing to the chemical action which would take place. A wooden tub should be employed. For spraying use a knapsack sprayer, and in applying the jet of liquid endeavour to get as much as possible on the under surfaces of the leaves. For this purpose one operator should direct the spray while a second turns up the leaves with a stick. The first spraying should be carried out at the beginning of July, and should be repeated once or twice at fortnightly intervals.

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THE WORK OF THE SOIL

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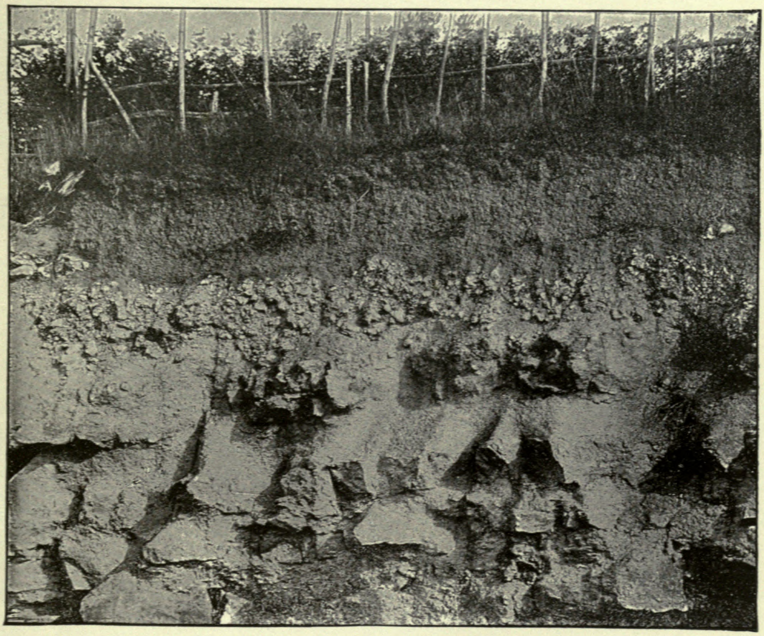
CHAPTER XIII

The Origin of Soils

In order to understand how the soil has come into being it is desirable to find some comparatively fresh excavation, like a stone quarry, preferably one situated a little way up the sloping side of a valley, so that the layer of soil covering the rock may not be too deep. The rock exposed in the quarry may be road stone, building stone, chalk, or even nothing more than hard clay or sand,—in any case, much the same sequence will be visible. At the bottom of the quarry will be seen the native rock, showing, except in such cases as basalt or granite, a distinct bedded structure of layer superimposed upon layer, often varying in colour or hardness from band to band. Nearer the surface the structure of the rock, whether massive or bedded, begins to fail; fractures become common until the layers consist of loose stones, though they are still lying in the positions they occupied before the breaking up took place. A little higher the stones become smaller and are separated by intervals filled with loose disintegrated rock, often a mere coarse sand; higher still, the loose material is greater in amount than the stones, which now lie scattered about in what fairly may be termed soil, since all the structure of the underlying rock has disappeared. Nearer the surface, again, the soil gains still more on the stones, which in some cases disappear entirely; finally, at the top, there is a darker layer, six inches to a foot or more in thickness, which constitutes the soil proper as distinct from the subsoil, this name being given to the fine material below.



A QUARRY IN THE HYTHE BEDS (*Lower Greensand*)

Showing the passage of hard calcareous rock into soil.
A sedentary soil (*p.* 188)

(From the author's book, *The Soil*, published by John Murray)

As a rule certain changes of colour accompany the passage from rock into soil that has just been described; not infrequently the rock possesses some shade of dark olive green or grey or black, and only begins to show yellow or brown stains and rusty marks along the fractures at a higher level; the fine broken-down rock, which gradually becomes the subsoil, is nearly always of an ochre colour—yellow, brown, or red—which becomes darker or duller as it passes into the soil. According to the nature and situation of the rock, the transition just described may extend over as much as twenty feet, or may be complete in two or three; indeed, on the high downs hard unbroken chalk may be found only a foot below the surface, and soil and subsoil together may not be more than six inches thick. The important feature is that the rock passes by insensible gradations into the soil, and that no sharp line of separation can be drawn at any point in the passage. Not infrequently, however, a different sequence may be observed: the rock surface ends abruptly without any of the breaking up described above; instead, it is overlaid by a bed of clay or sand or gravel of entirely different character, which in its turn passes by insensible degrees into the soil. Leaving such cases alone for the present, the quarry merits further examination to ascertain by what agencies the change from rock into subsoil and soil has been effected.

If the weather has not been dry for too long a period it will be seen that even the hardest and most uniform rock near the base of the quarry is still traversed by a number of up-and-down cracks, the "joints" of the stone, and that water works along these joints, as their discoloured edges demonstrate. Higher up the joint cracks become more numerous and a little wider, the edges are also somewhat rounded, as though the water oozing along them had softened and removed a little of the sides; moreover, down some of them fine roots of trees and other strong growing plants will be found to have wandered. As these roots are traced upwards they become thicker, and evidently exert a certain amount of pressure outwards, thus widening the crack and bursting the stone.

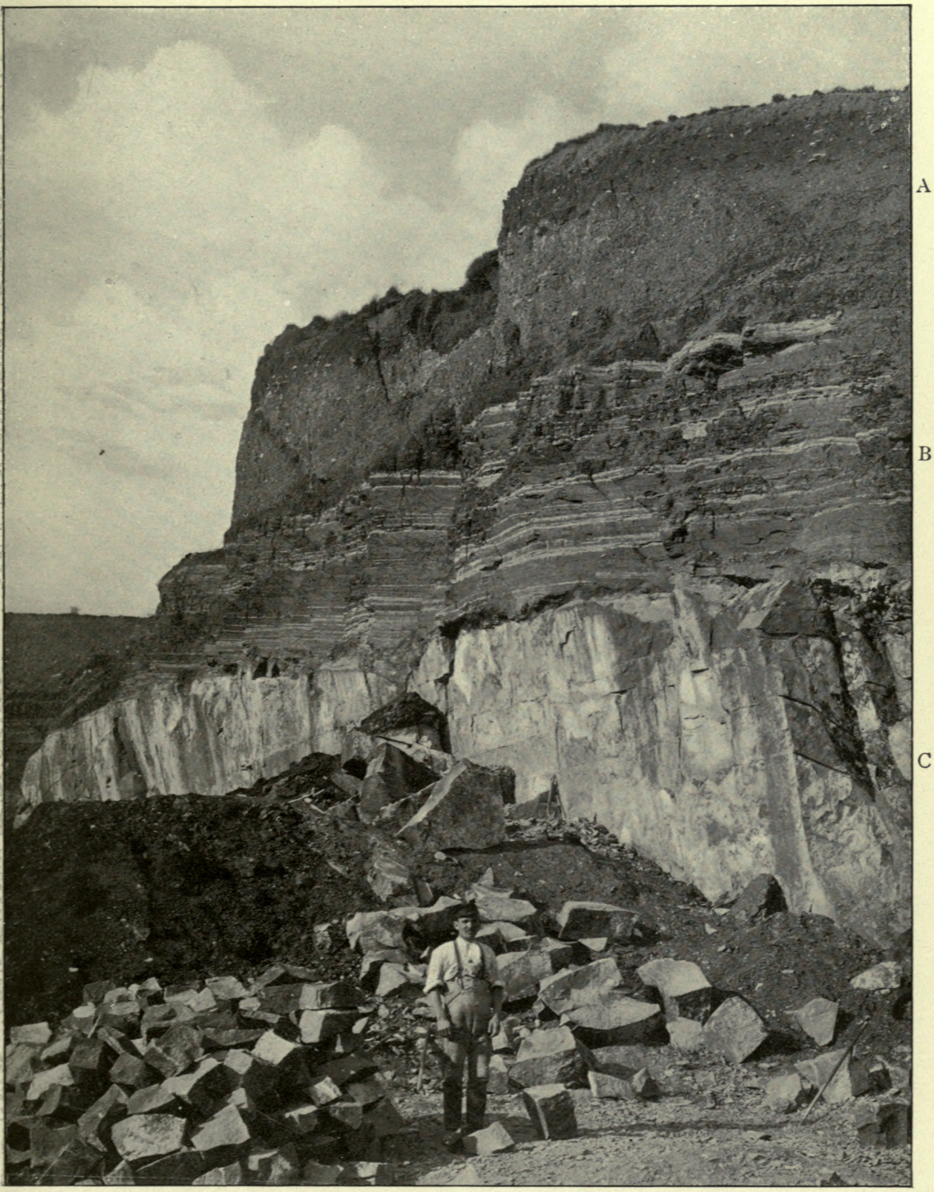
The mechanical effect of the roots is obvious enough, that of the water is rather more subtle; in some cases the water will appear to have dissolved away the cement which binds together the grains of sand making up the original sandstone rock. Other rocks, the basalts and granites, for example, under the influence of water, simply grow rotten, like an old exposed piece of iron covered with layer after layer of rust; they pass by insensible gradations into clay, whereas limestones keep a firm surface but seem to have largely melted away into thin layers of sticky clay.

Here, then, are two of the agents making soil out of rock —roots to burst, water to rot and dissolve; the work of a third great agent—frost—will be most in evidence if an old face of the quarry be examined just after a thaw. Failing that a visit may be paid to an old brick or stone wall, especially one backing against a bank that will keep plenty of moisture in the wall. After the frost has departed the ground at the foot of the quarry face or the wall will be covered with fragments of stone or brick which have obviously only just fallen away from the clean broken faces above. It is easy to show, by tightly tying in the cork of a bottle filled with water and exposing it in a frosty night, that water expands considerably in the act of turning into ice; and further, that it exerts a pressure on whatever resists this expansion such as very few materials can withstand. The stones or bricks of the wall, and even the stones a little below the surface of the ground, are generally saturated with water; they become rent open as the water expands on freezing and fall in pieces as it thaws again. Thus the expansion of water on freezing must be added to its dissolving and rotting powers as one of the agencies reducing rocks to soil, although, since frost in this country rarely penetrates the ground to a greater depth than a foot or eighteen inches, it is in the upper layers, the soil, that its disintegrating action is most felt. These agencies—roots, water, and ice—may at first sight appear too slow and trivial to have been capable of forming four or five feet of soil and perhaps ten or twelve feet of rotten stone, but it is only necessary to look at an old castle or unrestored church to realise how active the "tooth of time" can be. Five hundred years carves into the most fantastic shapes the face of even the hardest building stones, stones which have been kept comparatively dry by exposure instead of being buried in the wet ground, where also roots are at work. Yet many periods of five hundred years have elapsed since our present layer of soil began to be made, since the land surface upon which we now live either emerged from the sea or was left as naked rock on the melting of its last covering of glacial ice. As a matter of fact, the soil covering we see on the side of the hill is only a fraction of that which has been formed from the rock, because the soil is always creeping down the hill-side and being washed away by the river below. In time of heavy rain this is obvious enough, every little drainage gulley in the fields, each spring and streamlet well above the main river, are charged with turbid water; the river itself is not only heavily laden with sediment washed from the land, but is pushing along its bed sand and gravel and even stones of considerable size. The broad truth that rivers have carved out their own valleys, and that the material they remove is not rubbed off the solid rock, but is the soil into which the rock has first of all passed by the action of the weather, itself indicates that the soil-making process must have been a far greater one than can be measured by the amount of soil actually existing to-day.

Having thus seen that in times of heavy rain a great deal of the soil which had been previously formed gets washed into the rivers, it is instructive to collect some of this rapidly flowing turbid water and let it settle down in a clear glass in order to get an idea of the nature and amount of the sediment that is being transported. In most cases, when the water is drawn from a fair sized river in not too violent a state of flood, the material will take some days to settle down, and will then form a sticky deposit, which, however, is not wholly clay, because it feels a little gritty when rubbed between the fingers. It consists, in fact, of the finest particles of the soil; the stones, the gravel, and even the coarser sand have been left behind or are being pushed more slowly along the river bed. It will be dark coloured, because it has been chiefly washed off the surface layer of the soil containing vegetable matter, and if it is dried and heated in an open dish the presence of this vegetable matter will become evident by the charring smell.

As to the fate of this solid matter suspended in the fast running water, there can be but little doubt: much of it evidently finds its way down into the sea, and is there deposited as the mud flats, sand banks, and shoals which impede the mouth of many of our rivers. If the tides and currents off the mouth of the river are not such as will shift the deposit into deeper waters, the material gradually accumulates and forms new land, so that the river mouth is always moving seaward. Along the Channel and on the east coast of England, most noticeably in the Wash, the land is always steadily gaining on the sea by means of the detritus washed down by the rivers.

Some of the material, however, does not reach the sea, but accumulates along the river course; nearly all rivers, as soon as their early mountainous rush is over, will be found flowing quietly between broad level meadows, which are apt to be covered from time to time with flood water. On examining the soil beneath one of these meadows it will be found to be practically identical with the silt deposit which had previously settled out from the glassful of turbid river water. Careful examination of the meadow will also as a rule show that its level rises very slightly towards the water's edge, the actual river bank being generally elevated a few feet farther. In consequence, when a flood occurs and the turbid flood water invades the meadows, it is there somewhat pounded up, and does not simply flow back into the river when its level falls. Instead the flood water sinks through the soil or oozes back under ground into the river bed; but in so doing it leaves behind on the surface of the meadow the load of silt it was carrying before. After a flood has subsided the grass of the river meadows will be found all sticky and muddy, and the whole surface of the meadow has really been raised to a very small extent by the deposit left behind. Thin as the layer may seem, the whole soil below the water meadow has been deposited in this way; it is made up of earth washed down from some district higher up the river's course, flood after flood it has grown and thickened until it has gradually spread across the valley. The river may still be seen cutting away its banks in places and removing what it has previously deposited, but provided that the slope of the valley is getting flatter so that the river is decreasing in velocity as it gets nearer the sea, it will always be leaving behind more than it takes away and gradually increasing the thickness of the soil over the stretch of meadows. Because the river sediment, however, has been derived from rocks higher up in the valley, and because it has been subjected to a certain amount of sorting by the running water,



A QUARRY IN CHARNWOOD FOREST SHOWING GLACIAL DRIFT, A, RESTING ON NEW RED SANDSTONE, B, WHICH ITSELF RESTS UPON AN OLD SYENITE, C

The soil is derived from the glacial drift. A soil of transport (*p.* 193).

the coarser particles being carried only by the swifter streams and dropped as soon as the velocity falls, it is probable that it will not resemble the soil we have already examined on the flanks of the valley, a soil which had grown out of the rock beneath it. There is bed rock beneath the river meadow soil if we cut down deep enough, but when we do find the point of junction the change from the rock to soil is clear and sharp, for the river silt has been deposited on a clean rock surface, usually of an entirely different character. We are now dealing with one of the cases alluded to before, where the soil has not grown out of the rock beneath it, but has been carried from a distance and deposited by water or some kindred agency, giving rise to a "soil of transport" or "drift soil," as it is termed, to distinguish it from the "sedentary" soil which has been formed where it lies. A soil of transport may be similar to the rock below it if it happens to have been originally derived from another area of similar rock, or it may be entirely different—as a rule the change from rock into soil is sharp and distinct. A soil of transport is usually further distinguishable by its uniform character; as one descends there is no increase in the number of the larger fragments of rock, etc., which characterise the lower depths of a sedentary soil. River meadow soils, indeed, are much of a type all over the country; they are a little lighter or a little heavier according to the nature of the rocks in the river basin, and they vary in their behaviour towards crops with the depth of the water and the existence or not of a bed of gravel below the surface; they are classed generally as alluvial soils. On the flanks of the valley, above the present alluvial level, areas more or less extensive are often seen, covered with sand or gravel or brick earth, which have obviously been originally water-borne into their present position; these are the remains of old alluvial deposits which formerly filled the valleys, but have been very largely removed through certain geographical or climatic changes that have altered the rainfall and so caused a newer valley to be carved out of the old alluvian. Again, over great parts of the north and midlands of England the surface of the country is covered with deposits, often of great thickness, which have been transported by moving ice during the last glacial epoch; it depends rather upon the thickness and uniformity of the glacial deposit whether the soils formed from them shall be termed sedentary or soils of transport. Other true "soils of transport" are wind borne, though almost the only examples we see of them in this country are the soils that have grown up on the inland side of the tracts of sand-dunes which border some parts of the coast. A peat bog, though entirely unlike the strata upon which it may be resting, has yet been formed *in situ*, and must be classified as sedentary. The causes which lead to such a formation will be considered later.

It is, in fact, impossible to draw any entirely satisfactory line of distinction, for soils, however sedentary they may be in their origin, are always in motion, and often in the end acquire the character of soils of transport. As an example it is instructive to compare two neighbouring fields, one arable and the other old pasture, on any soil where stones are abundant, as, for example, on the chalky soils of the south and east of England or the boulder clayland of the north and midlands. The arable land will be seen to be covered with stones, and even if they have been worth picking off they are as abundant as ever soon afterwards, until the old farmers aver that they "grow." In reality, the soil is being constantly stirred by the plough, and as the soil settles down again the washing rains carry down the fine particles and leave on the top the stones they cannot move. You have only to look at some spot where a water pipe drips on to a bed of bare soil to understand how on arable land the stones are always working to the surface.

On the old pasture alongside not a stone is to be seen, and if a trench be cut, the surface soil of the pasture will be found to be fine mould free from stones, down to a depth depending upon the age of the pasture. Yet the arable land and the pasture started alike, it is the action of the earthworms that has gradually brought the stones below the surface of the pasture land. Earthworms are always at work bringing up fine soil from below and ejecting it in the form of worm-casts on the top of the present surface, and small as the amounts brought up may seem to be, the action is yet so continuous that when the casts are spread over the surface the layer raised each year possesses a measurable thickness. In this way stones and any other objects lying on the surface of grassland gradually come to be buried; year by year they get deeper as the fine earth is carried up from beneath them and deposited above, until at last they reach the depth below which the worms do not work. The reality of this burying action, and even the rate at which it takes place, can often be detected on an old pasture or a lawn by opening a trench; at a slight depth may be seen a thin layer of chalk or cinders which represents an application of lime or ashes to the surface of the grassland some years previously. If the date of this application has been recorded it is easy to calculate the rate at which it has been sinking, or rather, at which it has been buried by the action of the earthworms; in this way Darwin was able to show that in one case materials had sunk three inches in fifteen years, and in another, seven inches in twenty-nine years.

The Properties of Soils.

In order to arrive at a proper understanding of the nature and behaviour of different kinds of soil in the field it is now necessary to do a few simple experiments, experiments which do not call for any elaborate apparatus, but which become particularly instructive if they are made quantitative by the use of a balance and some of the more common accessories of a laboratory. In the first place, it will be necessary to collect a few specimens of soil by making a hole so as to lay bare a face of the soil, and then taking out with a trowel vertical slices, nine inches deep for the soil, and from ten to eighteen inches for the subsoil, until two or three pounds have been collected. Samples are wanted from an alluvial meadow (soil and subsoil), from heavy clay and light sandy arable land (soil and subsoil), from peaty land (soil only). The soils should be spread out on sheets of brown paper and left to dry naturally in a room; they should be turned from time to time and crumbled between the fingers when they are just beginning to dry,—there is a certain stage in the drying of a clay soil when it can be easily reduced to a powder, a process which is a matter of some difficulty if the soil is once allowed to get thoroughly dry. The soils can then be stored away in bottles or tins. There will now be wanted a balance, a beaker or two, a pestle made by sticking a small rubber bung on the end of a glass rod, and two sieves, the first of the finest woven brass wire, 100 meshes to the inch, and the other made by cutting out a square from the bottom of a tin box and replacing it by soldering on a piece of perforated zinc with holes $\frac{1}{25}$ of an inch (= 1 mm.) in diameter.

Throw the soil on to this sieve, and when you have shaken as much as possible of the fine earth through put the sieve under the tap and let the water drip on its contents, which will be the stones contained in the soil together with a good many hard lumps of earth, especially with a clay soil. However, these will break up in the water and after a little shaking under the tap will wash away and leave behind the clean stones and fine gravel more than 1 mm. in diameter, together with a few fragments of roots and vegetation. The stones and gravel should be dried and examined to see what they are made of, whether they are water worn or angular, etc.; we can also take their weight and find what proportion they constitute of the original soil, though the results will not mean very much when the soil contains large stones.

From the fine earth that passed the sieve, five grams are now weighed out and put into a beaker on the side of which you have made a mark three inches from the bottom. Add a little water to the soil and churn it up into a smooth thin paste with the rubber pestle, add more water until the beaker is full to the mark; give a good stir and let the contents settle for one minute exactly, then pour the muddy water steadily and quickly into a jar without disturbing the sediment collected at the bottom of the beaker. Churn up again with the pestle, fill to the mark with water as before, and again wait one minute before pouring off the turbid top liquid. Repeat these operations until the top liquid becomes clear during the minute's wait, because the only material now left in the beaker is so coarse grained that it will fall to the bottom in less than a minute. It will now be seen that by this process the soil has been separated into clean sand that lies in the beaker and finer claylike stuff which has been poured away in the turbid top liquid. Keep a jar full of this turbid water for a few days; it will settle down very slowly, but when it does clear pour off as much of the water as possible and examine the layer at the bottom. It will be found to be scarcely gritty, but almost greasy to the touch, indicating that it is made of very fine particles; on drying it will shrink and crack and form a hard cake. Now take the beaker with the sand in it, put it in the oven, and when it is dry brush out the sand (it will be quite loose and show no tendency to cake) on to the fine sieve, and weigh the two portions, the coarse sand which is retained and the fine sand which passes through. Now tabulate the results:—

5 grams taken	= 100	per cent.
Coarse sand, 0·23 grams . .	= 4·6	„
Fine sand, 3·61 grams . .	= 72·2	„
Clay and silt (by difference)	= 23·2	„

Repeat this experiment for both soil and subsoil of the clay and sandy arable land, and set out all the results side by side.

The process just described is a rough version of the accepted method of analysing a soil mechanically by grading it into its constituent particles of clay and sand of various sizes. If even the simple appliances required are not available, a good deal of information can be got by adding a spoonful of each of the powdered soils to separate tea-cups, rubbing them up with water as described and pouring off the turbid water, using the finger as a pestle, and finally collecting the sand remaining at the bottoms of each cup on separate sheets of paper for comparison by the eye.

On examining the results it will be seen that the sandy soil is not all sand, but that a fair amount of clay and fine silt can be washed away from it, also that the clay soil often contains a considerable proportion of fine sand. We never find a purely clay soil, and only on the most barren of heaths will the sandy soils contain less than 10 per cent. of clay and silt. Next, we shall see that the sandy soil and its subsoil are much alike as regards the proportion of sand and clay they contain, but that the surface layer of the clay soil is distinctly more coarsely grained and contains a higher proportion of sand than the subsoil. This difference between soil and subsoil is due to the rain washing away the finest particles and leaving the coarser ones behind, just as we have seen the flint stones are left on the top of an arable field; the difference is less seen in the sandy soil, because it contains so little of the very finest stuff that can wash through the soil.

By repeating such experiments on a variety of soils we may learn that they all consist fundamentally of mixtures of clay and sand of various grades; in clays and heavy soils the finest particles predominate and there is very little coarse sand to keep the soil open; in the really barren sands the coarse sand predominates, but there are many sandy soils, made up, however, of the finest grades of sand, which are fertile enough. What a farmer calls a good free working loam is generally found to consist of a well balanced mixture of the finer grades of sand, bound together by clay and kept open by a sufficiency of coarse particles.

Having thus learned something of the constitution of soils, it becomes possible to begin to interpret their behaviour towards water. Take five ordinary glass funnels, fit them with filter papers or plug them with a little cotton wool, and pack on to four of them fifty grams each of the dry powdered sandy, clay, peaty, and alluvial soils respectively. Pour on to each an equal volume of water, one hundred cubic centimetres will serve, and catch in beakers the water that runs through; note the time taken, and the amount passing through in each case. In the fifth funnel take another fifty grams of clay soil, but work it up into a paste with a little of the 100 c.c. of water before putting it on the filter, and then add the rest of the water. The peat and clay soils retain the most water, the alluvial soil coming between them and the sand; the percolation will be slowest with the clay soil, while it will hardly take place at all with the clay that had been first of all pulped up in a wet condition. This shows how the rain falling on a sandy soil finds its way downwards very quickly, little being retained by the soil for the needs of the plant, so that a light sandy soil easily suffers from drought; it also shows how a peaty soil retains a great deal of water while allowing the excess to move through it pretty quickly. On a clay soil, however, because it is made up of very fine particles, both a large proportion of water is retained and the movements through the soil are very slow; moreover, the slowness of percolation is enormously increased if all the little clusters of fine particles, which gradually form in clay by the action of the weather, etc., are first of all broken up by kneading the soil in a wet state. The amount of water retained by a soil depends upon the extent of the surface of the particles that get wetted, and for an equal weight of matter the finer the grains are the greater will be their total surface.

But percolation downwards is not the only motion of the soil water; it is able also to move upwards in the same way as it will gradually wet the whole of a towel of which only the extreme end is actually dipping into water. To illustrate this action, separate by means of the fine sieve some sand into fine and coarse particles respectively; take four wide glass tubes eighteen inches or two feet long, tie a little fine muslin over the bottom or plug them with cotton wool and fill them with the coarse and fine sand, the alluvial and the clay soil respectively. Then stand the muslin-covered ends an inch deep in water, and note hour by hour the extent to which water has risen in each, finally plotting the results on a piece of squared paper. The motion is much quicker in the sand than in the clay, but in the coarse sand it extends only for a few inches. In the fine sand the water rises much farther, while in the clay, slow as the motion is, it will continue until the whole contents of the tube are wet. Now these observations can be applied to the study of soils; at some depth below the surface there is always a layer saturated with water, the level, in fact, at which water stands in the wells sunk thereabouts, and even when this "water table" is at some considerable depth the subsoil a few feet down is none the less highly charged with water. During a drought, as the surface soil loses its moisture, the water will begin to rise from the wet layers below in virtue of the property of capillarity or surface tension that we have just illustrated. When the soil is damp each particle is surrounded by a thin film of water in a state of tension, so that it exerts a pull on other water with which it may be in contact, the pull being greater the thinner and more stretched the film may be. Hence a particle with a thin film will draw water from a thicker film which it touches. As long as the thin films of water coating the soil particles remain continuous and unbroken, water will always creep from wetter to drier places, whether the motion has to be directed upwards, downwards, or sideways. And the greater the surface exposed, as in the fine grained soils, the greater will be the water-moving power; but when the particles are very small indeed, as in a clay soil, the rate of motion becomes extremely slow, because of the friction of the water moving between the very fine grained particles. It is this capillary power in soils which keeps plants growing during a drought; they would quickly use up all the water which the soil immediately round the roots had retained were not the surface soil constantly

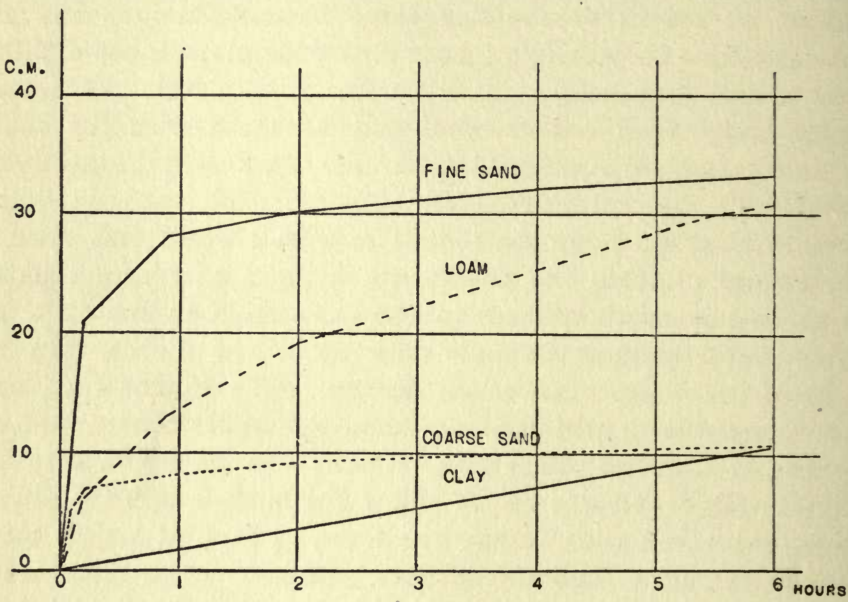


FIG. 77.—Rate of rise of water in different soils, due to capillarity or surface tension.

lifting water from the wetter layers below. Sandy soils suffer badly from drought, because both water retaining power and capillary lifting power are low; clay soils can stand a short drought because they retain so much water, but when this is exhausted they can only renew their supplies very slowly, and also begin to lose further by the big cracks that form. The best soils for keeping crops growing during drought are loams mainly composed of very fine sand; their water-retaining power may not be high, but the particles possess sufficient surface to lift water rapidly, and yet are not so small as to offer resistance to its movement.

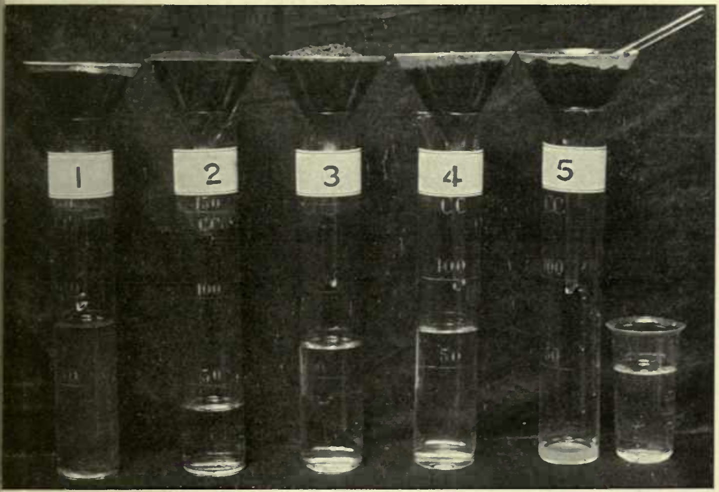
For the next experiment procure a piece of good clay; failing any in the neighbourhood, buy a few pounds of modelling clay. Knead a piece up and beat it into a little brick an inch or so square in section and about five inches long, mark two points on the surface exactly ten centimetres apart, and put the brick aside in a warm place to dry. Make up a second brick, but before you knead up the clay incorporate with it as fully as possible a few cubic centimetres of milk of lime, again mark off a length of ten centimetres on the surface. Moisten some of the clay soil used in the previous experiments by adding overnight about 20 per cent. of its weight of water, and with it build up another brick, this time knocking the clay about as little as may be consistent with pressing it firmly together into brick form. When the three bricks have dried it will be found from the relative position of the marks that they have all shrunk considerably, the raw well kneaded clay most of all. Then compare the hardness of the three bricks by breaking them between the fingers; the soil breaks and crumbles without much difficulty, whereas the clay proper is extremely hard and tough, though the tenacity of that which had been worked up with lime has been much reduced. These then are essential properties of clay,—shrinkage on drying and tenacity of the dried mass; they are linked with its imperviousness to water and its plasticity in a wet state, and all depend upon the fineness of grain of the particles making up the clay. Each property is most pronounced when the fineness of grain is fully developed by kneading the clay in a wet state. The particles of a piece of clay that has been subjected for a time to the action of the weather gradually rearrange themselves under the alternate wettings and dryings, freezings and thawings, and unite into loose groups, so that the whole mass simulates a coarser grained material which shrinks less on drying and is then more easily powdered.

Since compounds of lime act upon the clay in a similar way by causing the finest particles to clot together, it is necessary to examine our soils a little both as to the amount of lime they contain and their behaviour towards that substance. The most universal compound of lime is the carbonate, which exists in a comparatively pure state as chalk or limestone and when strongly heated parts with its carbonic acid to pass into the state of quicklime. Quicklime in its turn has a great attraction for water and carbonic acid; it greedily takes up water to become slaked lime, and slaked lime will quickly absorb carbonic acid to go back to carbonate of lime. Pour a little dilute hydrochloric acid upon a piece of chalk in a dish, there is a violent effervescence due to the carbonic acid expelled by the stronger hydrochloric acid; repeat the same experiment with the different samples of soil, some of them will be sure to effervesce a little, but with others the bubbles of carbonic acid will be barely perceptible because when there is less than about 1 per cent. of carbonate of lime in the soil the carbonic acid dissolves in the liquid as fast as it is set free. Take a little of the fine clay or even of the clay soil, rub it up into a paste with water, and then make up two large jars of turbid clayey water, using distilled or rain water; add to one of them a little lime or a few cubic centimetres of clear lime-water and put the jars aside to stand. As before, they will take some time to clear, but the lime in the one jar will bring about a much more complete and earlier clearing, as though it had transformed the clay into coarser particles more of the nature of fine sand. It is now easy to understand why the brick worked up with lime gave various indications of having been rendered more coarsely grained, such as its reduced shrinkage on drying; the lime compounds have the power of making the finest clay particles bunch up together or "flocculate," until they behave like a smaller number of larger ones. All the soluble salts of lime act thus, sulphate of lime or gypsum, for example, and carbonate of lime, because it becomes so readily bi-carbonated and dissolved by the carbonic acid in the soil water.

Flocculation of the clay particles is not, however, the only action brought about by the carbonate of lime we have recognised in the soil; it also behaves as an anti-acid or neutraliser of the injurious acids which are often produced by the decay of organic matter in the soil. Moisten a little of the peaty soil and leave it for some time in contact with a piece of blue litmus paper; as a rule the litmus will be reddened by the acids contained in the decaying vegetable matter of the peat. Now grind up a little chalk and mix it with the peat before applying it to the litmus paper; the red colour of the litmus will be changed again back to blue. Soils derived from chalk or limestone often contain large proportions of carbonate of lime, and the presence of a little is necessary to the building up of a fertile or even of a healthy soil, though sands and clays are to be found in which it can hardly be detected.

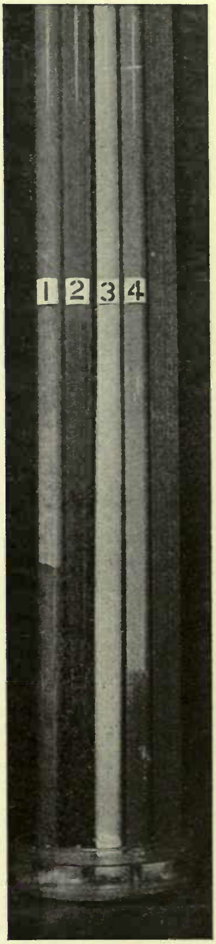
One other constituent which plays an important part in the soil, the organic matter or humus, the debris of vegetable origin, has already been noticed as giving the soil proper rather a darker colour than the subsoil. Weigh out into porcelain basins about ten grams each of the clay soil and subsoil, the alluvial soil and subsoil, and the peat soil, each of which had been put into the oven for a few hours previously to get thoroughly dry, then char them for some hours over a Bunsen burner, or best of all in a muffle furnace. At first the colour of the soil will darken, but gradually it will change to a bright red as the whole of the carbonaceous matter burns away. After cooling, re-weigh the dishes; the loss of weight represents the organic matter, though it includes also a certain amount of water that was previously in chemical combination with the clay and kindred constituents of the soil. However, by far the larger part of the loss is due to the organic matter, and from the experiment it will be safe to conclude that the peaty soil contains an exceptional amount of humus, and that clay soils generally contain more than sandy ones. Soils also are always much richer in humus than the subsoils, except in the case of alluvial soils, which do not differ much in composition from their subsoils, because both have been alike washed from other land, carried down by the stream, and redeposited. The smell given off in the early stages of charring by any of these soils suggests the presence of nitrogenous compounds, but this can be better demonstrated by mixing with some of the soil in a separate dish before heating a little soda-lime or even lime itself; the smell of ammonia will soon be palpable, and its presence may be confirmed by holding a reddened litmus paper in the escaping gases. Without pushing the matter further, all soils can be shown to possess a store of organic matter containing nitrogen—the humus as it is sometimes called—which constitutes the chief reserve of fertility in the soil.

It has been demonstrated, however, in previous chapters that the plant's roots can only take in nutriment which is dissolved in the water present in the soil, yet none of the substances hitherto described as making up the soil—the sand, the clay, the chalk, the humus—are capable of dissolving in water. As a matter of fact, the actual substances which go to feed the plant exist in comparatively small quantities in the soil, and at any time only traces of them are present in the soil water, though they may be constantly renewed as they are removed by the plant. Take the small quantities of water which have percolated through soil in a previous experiment, filter if need be, and evaporate them carefully to dryness in a clean porcelain basin—a very small quantity of saline residue will be left in the basin, but it represents the nutrient materials which were immediately available for plants living in those soils. It would be going beyond our present object to examine this residue in any detail, but one of the constituents is of so much importance that it cannot be entirely passed over. It is well known that nitre in some form or other—either the saltpetre that is extracted from Indian soils, the nitrate of soda which comes from Chile, or the nitrate of lime which can sometimes be scraped off old walls of buildings—is in certain places a product of the soil, and can be extracted from it on a commercial scale. To a small extent one of these nitrates is present in all fertile soils. The most sensitive test to apply is a solution of di-phenylamine in sulphuric acid, and if a little of this be poured on to the dry soil residue in the porcelain basin it will assume an intense blue colour, just the same colour as will be obtained by pouring the solution on a tiny crystal of nitre in another basin (di-phenylamine must only be used as a test with dry or nearly dry substances). This nitrate represents the final soluble state of the nitrogenous humus previously recognised in the soil; it is in this form the plants supply themselves with the nitrogen they want. At first sight it is not exactly easy to understand how the dark carbonaceous matter of the soil, though it does contain nitrogen, can ever pass into substances like nitre, and indeed in the laboratory the task of



WATER RETAINED BY EQUAL WEIGHTS OF VARIOUS SOILS

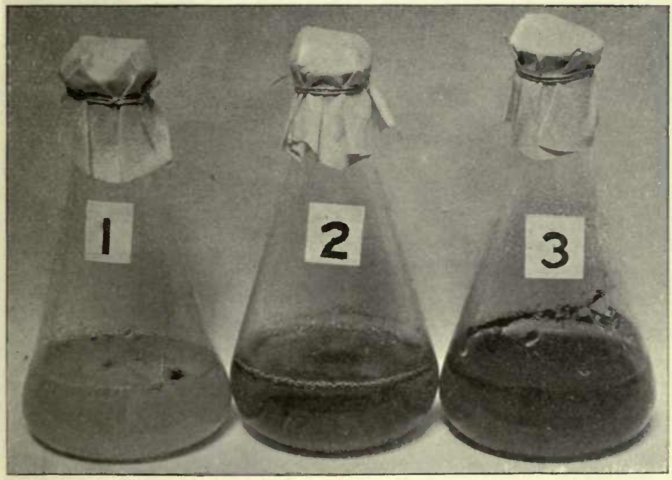
1 = a coarse sand, 2 = peaty soil, 3 = alluvial loam, 4 = clay, 5 = clay after puddling, in which case the bulk of the water has not percolated (*p.* 198).



EXPERIMENT TO ILLUSTRATE THE RISE OF WATER IN SOILS BY CAPILLARITY OR SURFACE TENSION

1 = clay,
2 = loam,
3 = fine sand,
4 = coarse sand.

Photograph taken twenty-four hours after starting the experiment (*p.* 199).



PHOTOGRAPHS OF CULTURES OF SOIL ORGANISMS

1 = Moulds growing in medium containing ammonium salts but no calcium carbonate (*p.* 206).
2 = Flask in which algæ have appeared; notice the bubbles of oxygen.
3 = Medium without nitrogen in which azolobacter has developed.

converting the one compound of nitrogen into the other by purely chemical means would be a matter of some difficulty. This brings to the front another aspect of the soil, one difficult to verify by simple personal observations, but one that requires to be appreciated before a proper understanding of some of the simplest problems of soil management can be reached. The soil is not merely a frame-work of sand and clay, in which the plants anchor themselves by their roots, and from which they draw water and a certain amount of nutriment circulating in that water; it is also a swarming laboratory of minute living agents —moulds, bacteria, and kindred organisms—some of which are always preparing the food for the higher plants, while others are wasting it or are injurious in other ways. A few simple experiments can be made to illustrate the living nature of the soil; all that is necessary is the preparation of a litre of a nutrient solution containing 0·1 gram of magnesium sulphate, 0·2 gram of potassium phosphate, and 0·1 gram of sodium chloride.

Thoroughly clean six small flasks, and add 100 centimetres of the nutrient solution to each; to three of them also add one gram of sugar; to the other three add 0·1 gram of ammonium sulphate; then to one flask in each set add about half a gram of calcium carbonate. Plug the mouths of the flasks fairly tightly with cotton wool, put them all in a vegetable steamer, and heat them up to the temperature of boiling water for half an hour or so. The heating sterilises the contents, and as the cotton wool plugs exclude all further entry of organisms no change will take place inside the flask, though the air has free access through the cotton wool. When the flasks are quite cold get ready a small quantity of fresh soil, say from a garden, and, lifting out the plug of cotton wool for a moment, drop in with a spatula a piece of soil about as big as a hazel nut and replace the plug. Now take two of the flasks without calcium carbonate, one with and the other without sugar, and heat it up to boiling-point for two or three minutes, repeating this operation on the following day. The double boiling will effectually sterilise the contents of the two flasks, which will now serve as checks containing dead instead of the living soil in the others. The scheme of the experiment is best summarised in a table.

No.	Contents alike as regards Nutrient Solution and Soil.		Treatment after Soil added.	Result.
1	+ Ammonium sulphate.	..	Boiled.	Nil.
2	..	..	..	Some moulds, sometimes nitrates.
3	..	+ Calcium carbonate.	..	Nitrates formed.
4	+ Sugar.	..	Boiled.	Nil.
5	+ Sugar.	..	..	Some moulds.
6	+ Sugar.	+ Calcium carbonate.	..	Gas and brown scum, eventually nitrates.

Place the flasks aside in a warm dark cupboard and examine those containing sugar after a week or ten days has elapsed. The liquid in the flask without carbonate of lime will be all covered with moulds, mostly white in colour, but others that are green and black and even pink may also be in evidence. The contents of the flask containing carbonate of lime will show a very different growth, probably a dirty skin much blown with bubbles of gas. Replace this flask in the cupboard for examination in two or three months' time. The soil introduced has evidently started very considerable actions, which are further of an entirely different type according as carbonate of lime had been added or not. The soil, in fact, contains a great variety of organisms, some of which flourish best in a slightly acid medium, while others can only develop where it is kept neutral. That it is the living soil which starts these changes is seen from the absence of action in the check flask which had been heated after the addition of the soil.

The other three flasks should be left for a month, and then a little of the clear liquid in each must be evaporated in a basin and tested with di-phenylamine for nitrates. Here again there will be no evidence of action in the flask which has been heated after the addition of the soil, and of the other two, inoculated with living soil, only the one containing carbonate of lime will show any marked reaction for nitrates; in the other a few moulds will be growing, and nitrates may be found if the added soil had contained much calcium carbonate. The soil contains bacteria which slowly change other compounds of nitrogen like ammonia into nitrates, but which can only work in a solution kept neutral by the presence of a base like carbonate of lime.

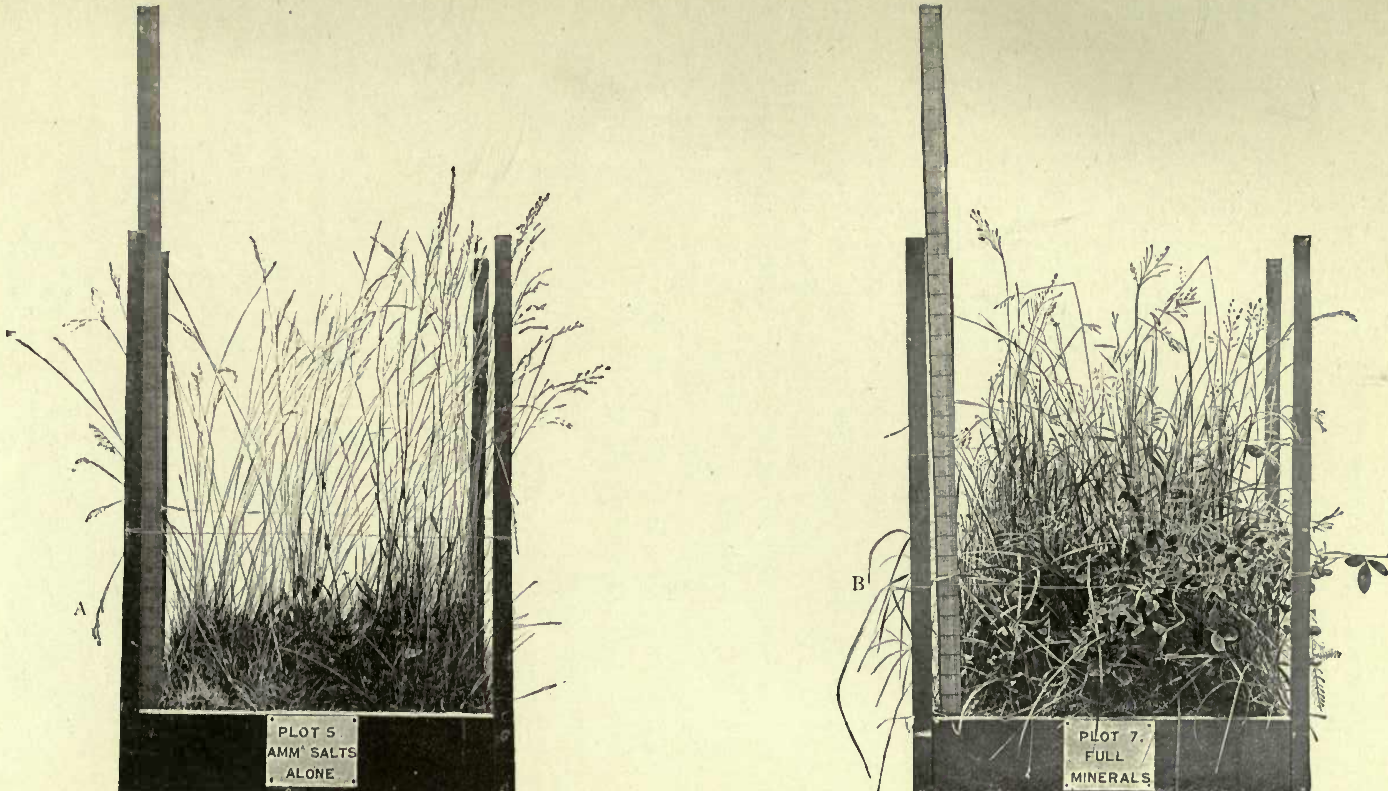
If the liquid in flask 6 be also examined when two or three months have elapsed it will show a reaction for nitrates, although no nitrogen compound had originally been added to the flask. The nitrogen it contains has been gathered from the atmosphere by the bacteria forming the brown skin first appearing, the transformation of which into nitrate is the later work of another group of bacteria.

A good example of the cycle of changes through which nitrogenous materials in the soil are always passing may be obtained by making up another flask of nutrient solution as previously described, and adding to it both the half gram of calcium carbonate and 0·2 of a gram of peptone (one of the most complex nitrogenous compounds), inoculating with soil as before. At the end of a week or so evidence of the first change to take place—putrefaction—will be obtained from the smell of the flask, while the liquid will be seen to be turbid with the numbers of putrefactive organisms that have developed. After another week or fortnight the putrefactive smell will be exchanged for a faint smell of ammonia, the formation of which represents a still further step in the break down of the peptone. Again, leave the flask in the dark for a month and its contents will begin to show the reaction for nitrates, which are now being produced from the ammonia. Now bring the flask into the light for some weeks; in time a green growth of algæ will appear, accompanied by the evolution of oxygen when the light is bright. At the same time both nitrates and ammonia will have disappeared from the liquid; they have been reconverted into protein in the substance of the algæ. Thus after the bacteria have taken the original protein and reduced it step by step to nitrates the plant steps in, and by the aid of the energy of light rebuilds another complex protein.

It is impossible at this stage to discuss with any particularity the various groups of organisms at work in the soil; some of them convert such materials as farmyard manure, roots, leaves, and the like into humus and simple compounds like the nitrates upon which plants can feed. Others rob the higher plants of the food that is in the soil and use it for their own nutriment, although in the end it must be returned into circulation for the use of the plant. One great group of bacteria, amongst which are those forming the brown skin in flask 6, enrich the soil by gathering nitrogen from the atmosphere, whilst others waste the nitrogenous compounds present in the soil by converting them back to gas. Others give rise to substances hurtful to the growth of plants; others, fortunately more rare, are capable of setting up disease in human beings if they find entrance through a wound. The relative predominance of one or other group depends upon many conditions,—upon the warmth of the soil, its degree of moisture and aeration, its supply of this or that nutrient material, etc.; in fact, bacteria are influenced by much the same set of factors as are the higher plants. Without bacteria in the soil the growth of our crops would be practically impossible, and many of the common operations of cultivation and management are unconsciously directed towards effecting some change in the bacterial actions in the soil that will eventually result in benefit to the plant.

The Characteristics of Different Soils

It has already been seen how different kinds of rock give rise to sedentary soils of various types, which again in their turn, after sorting by the river, result in one or two distinct alluvial soils; it is interesting and often valuable, from the farming and gardening point of view, to study what kind of vegetation is associated with each type of soil. We have seen how the water-retaining powers of soil vary with the materials from which it is made; its water-retaining power will affect its temperature and a dozen other factors, rendering it more suitable for one plant than for another. Differences of chemical composition act in the same way. In consequence, wherever plants have free play, as on uncultivated land or a meadow or amongst weeds of arable land, the vegetation varies very greatly in passing from one type of



Photograph of turf from two of the grass plots at Rothamsted, one of which, A, has been receiving an exclusively nitrogenous manure, and the other, B, phosphates and potash only for more than fifty years (*p.* 209).

(From the author's *Book of the Rothamsted Experiments* published by John Murray)

soil to another, and plants may be used as guides in deciding upon the nature and fertility of a given piece of land.

The photograph shows typical samples of turf taken from two of the experimental plots at Rothamsted, which have been receiving a different kind of manure every year for half a century before the photograph was taken. The great contrast in the character of the vegetation in the two plots has been brought about solely by a difference in the nature of the nitrogen compounds supplied; one compound has favoured certain species of grass which have become dominant, while in the other case a different set of species have been brought to the front by the particular manure that has been given so repeatedly.

It is not so much that the variations in composition, chemical or physical, between different soils are sufficient to prevent the growth of a given plant in one place while encouraging it in another; on the contrary, the differences are so small and the adaptability of most plants so great that, as we see in gardens, the same plants will flourish on almost all varieties of soil. In nature, however, the wild plant has not the scope and freedom possessed by the garden plant; food is scarcer and there is an enormous competition for it, under which conditions a given species only requires to receive a slight advantage over its neighbours to become dominant, while the least disadvantage will rapidly cause it to be pushed off the field altogether. The plant lives in a state of fierce competition, neighbours are encroaching on every side, some by their roots trying to rob it of food and water, others by their superior height depriving it of light. Every year the crowding is intensified by the vast number of new seeds that are shed and by the way each plant colony tries to push into fresh ground. How severe this competition becomes may be seen from the fact that our domesticated plants, either of farm or garden, are rarely able to get a footing outside cultivated land, and indeed only continue to exist there as long as they are kept free from the competition of weeds. Even wheat, with its vigour and adaptability to all sorts of conditions of soil and climate, is soon crowded out by our native weeds, as may be seen from the following account of an experiment at Rothamsted. "In 1882 about an acre of the upper end of the Broadbalk field, which had then been carrying wheat for forty years in succession, was not harvested; the crop was allowed to stand and shed its seed without cultivation of any kind. In the following season a fair quantity of wheat came up on this part of the field, but gradually got weaker as the season advanced and the weeds increased their hold on the land.

"The wheat was still left to struggle on without cultivation, and by the fourth season only three or four stunted plants could be found, each carrying but one or two grains in the ear. With these the wheat disappeared, and has never been seen again in that part of the field."

From this example it may be understood how strenuous is the competition existing in any meadow or hedge bottom, and how, if the conditions become ever so slightly less favourable to one species than to its neighbours it has very little chance of surviving, except sparsely and locally where some accident restores the balance in its favour. The differences which render one kind of soil suitable to a given plant or cause it to be displaced by a kindred species, are often very small indeed, so that it becomes difficult to ascertain their exact nature. For example, in most districts of England that are not too near the depredations of large towns few flowers are so plentiful as the Primrose; every copse, every bankside, the edges of every ditch are full of them. Yet here and there areas may be found where every condition seems to be suitable, yet the Primrose is either entirely absent or is only found in rare patches; in the woods its habitual companions, the Wood Anemone and the Bluebell, may be common enough, and outside in the open fields Cowslips may be abundant, but the Primrose itself is wanting.

Many reasons may be advanced for this erratic distribution but as yet the author has not found any one that is valid, and similar cases occur everywhere. Always, however, the element of competition is of more moment than any direct encouraging or injurious effect of the soil itself upon the plant. To take an example, one of the most striking cases of local distribution of a British plant is the way the Yellow Horned Poppy is confined to the otherwise almost bare shingle banks round our coasts; one would suppose it must love the salt spray and the wind, and the fierce alternations of heat and cold on those barren wastes. Yet if some of its seed be sown in an ordinary garden soil it will grow with a vigour and lavishness which show that it prefers a fat soil and an easy life as much as other plants do. The Horned Poppy is not established on the shingle because it likes either the food or the climate, but because it can there escape from a killing competition; inland it is soon crowded out by stronger forms of vegetation, out on the shingle its long tap root enables it to keep alive when all other plants, even the grasses, are unable to obtain any nutriment.

> It does not love the shower nor seek the cold,
> This neither is its courage nor its choice
> But its necessity in being old.

The study of the local distribution of plants and their association with particular types of soil is one of great interest, which may be taken up single handed in almost any part of Great Britain; it is also one in which real and needed contributions to knowledge may be made by the solitary worker. The requisites will include a sheet of the geological survey of the district, which can be obtained through any post office, though care should be taken to order what is termed the "drift" map, which shows the superficial deposits giving rise to "soils of transport," as well as the underlying solid deposits which give rise to "sedentary soils" wherever they come to the surface. This map will show how many different types of soil may be expected to occur in the area under examination, and typical examples should be studied by washing into sand and clay, and by testing with acid for carbonate of lime, until their essential characters are known. Two formations, geologically quite distinct; as shown on the map, may give rise to soils that are identical for all working purposes; on the other hand, the sedentary soils derived from one and the same formation may alternate between sand and clay, or be calcareous in one band and short of lime in another. But in a general way the soils will follow the geological map, although in order to make sure of the boundaries and to supplement the information conveyed by the map, it is often necessary to carry a long auger wherewith to bore out a little soil from a depth of eighteen inches or so. By examining this with acid or by rubbing it up with water, to see whether it is clayey or sandy, it can generally be allotted to one or other of the formations in question. The acidity or otherwise of the soil to litmus paper should also be tested in the field, and notes should be kept on a point that is not indicated either by the map or the examination of the soils in the laboratory, *i.e.* the wetness or dryness of the land, and whether the wetness is due to a local spring or to a high level of the ground water. A few preliminary walks will give a general idea of the distribution of the vegetation and will indicate certain species as suitable for detailed study. A small selection should be made from these — one for the hedgerows, another for the woods, a characteristic grass and a cornfield weed—and future walks should be wholly directed to recording the frequency or absence of these particular species from individual pieces of land. The records should be laid down on a rough tracing from the geological map, which, when the area has been thoroughly traversed, will at once show if any correlation exists between the nature of the soil and the occurrence of the particular species.

In considering the vegetation of different soils the factors that have chiefly to be taken into account are, on the physical side, the supply of water, and on the chemical, the acidity or alkalinity of the soil. Plants are often described as lime loving or lime hating, and though in some cases the carbonate of lime in the soil may have a direct effect for good or evil upon the plant, the really dominant factor is whether the soil contains enough carbonate of lime to keep it in a neutral or even a positively alkaline condition. As regards water supply, plants which frequent soils habitually short of water have devised various methods for reducing transpiration; the leaf is often constructed so as to expose a minimum of surface, or is covered with hairs or coated with wax, hence the hoary glaucous appearance the vegetation of a really dry region usually presents. Storage organs like bulbs have been devised to carry other plants through regularly recurring periods of drought. Although these structures, designed to save transpiration, are commonly found on plants growing in dry areas, they also occur where one would least expect them, on plants living on water-logged peaty land or on salt marshes. By reducing transpiration they reduce the intake of water, which is necessary when the soil water contains injurious substances, as it does in the peat bogs and the salt marshes.

Keeping these general principles in mind, we may now review briefly the characteristics of some of the main soil types and the vegetation associated with them.

Clay Soils.—There exist wide differences in structure between the various soils that are commonly called clays. A soil which is in the main composed of very fine sand without any admixture of coarser particles, bound together by only 10 to 15 per cent. of what may be termed true clay, will be so sticky and wet that it will be regarded as a clay; yet under cultivation it will behave in many respects differently from the heavy soils which on examination show 30 to 50 per cent. of true clay. The most pronounced clay soils occur in the Midlands and south and east of England; in these districts the Kimmeridge, Oxford, London and Weald clay formations give rise to extremely heavy soils; whereas in regions of higher rainfall the soils become so much more washed free of their finest particles that their texture is distinctly lighter. As clay soils are distinguished both by their power of retaining water and their imperviousness to percolation, it follows that they are generally wet throughout the winter months, when the rainfall is greater than the evaporation. As the spring advances such soils are slow to warm up because of the water with which they are laden; for not only does water require more heat than soil to raise its temperature by a given amount, but also it is always withdrawing heat from the land as it evaporates. To evaporate a pound of water requires more than thirty times the heat necessary to warm it up from freezing-point to summer temperature, and even this latter amount is five times as great as would be wanted to heat a pound of soil to the same extent. In consequence, clay soils are cold and tend also to cool the air in contact with them, and the less the water is able to get away from them the cooler they remain; drainage therefore warms a clay soil by freeing it of water more rapidly and keeping down the level of permanent water, thus reducing the capillary rise to the surface, and the consequent evaporation and cooling. Their coldness causes clay soils to be late and slow growing in the spring ; they are therefore unsuited to market gardening where a quick succession of crops is aimed at. As a set-off they hold their growth well into the summer, and do not suffer from short droughts ; a long-continued drought, however, punishes the plants on a clay soil very severely, because when once the original stock of water is exhausted its renewal by capillarity is very slow. The shrinkage of the clay on drying also results in deep and wide cracks, which further aggravate the loss of water. If a field section of a heavy clay soil be examined it will be seen that the plants are comparatively shallow rooted, partly owing to the difficulty of penetration, and partly to the abundance of water that is usually present. This shallowness of the root system contributes to the injurious effect of a long drought on a clay soil. Just as a clay soil is late to start, in the autumn its cooling is correspondingly slow, and in consequence plants continue to grow longer on clay than on sandy soils ; in some cases this is an advantage, in others maturity is apt to be deferred until bad weather sets in. Owing to the expense and uncertainty of spring cultivation on clay soils they have very largely been laid down to grass since the fall in agricultural prices, but very often they will not grow good grass, because of the deficient aeration brought about by the setting together of the soil that occurs a few years after the arable cultivation has ceased. It is not until a stock of humus has been built up and the soil has become thereby once more open and friable that grass really does well on these heavy soils. The typical crops of strong land are Wheat, Beans, and Mangolds ; of these large crops can be grown, and of good quality. Certain weeds are troublesome — "Black Bent Grass" and "Field Mint" in the arable land, but as a rule weeds are not abundant on cultivated clay land. In the pastures "Dyers Weed," Buttercups, and the thorny form of the "Rest-Harrow" are common weeds ; with many plants spines and thorns become strongly developed on clay land. Owing to the lack of aeration in the soil the grasses are apt to develop a stoloniferous surface-rooting habit, and "Bent Grass"—the stoloniferous creeping-rooted form of "Agrostis alba"—often usurps nearly the whole of the pasture. The characteristic tree of clay land is the Oak, and to a less degree the Hornbeam; conifers often grow well, especially those which like a soil inclined to acidity, for clay soils as a rule contain little carbonate of lime. On the banks and waste places the Wild Carrot and the Teazle are among the plants that are rather characteristic of clay land, as also is the Primrose.

Sandy Soils.—Sandy soils may be found of all degrees of intensity, varying from fine sandy loams, excellent for cultivation, to soils almost devoid of fine particles and worthless for farming. Common land is occasionally situated on clay but the majority of tracts of unenclosed common or heath or forest consist of sands so light that they have never been considered worthy of bringing into cultivation, but have been left clothed with their natural vegetation of Gorse and Heather. Such soils are generally found to be also devoid of carbonate of lime; in consequence they accumulate more humus than would be expected from their openness and warmth, especially where the drainage is imperfect. On examining a section of a really sandy soil it will be observed that the roots of the vegetation are abundant and penetrate comparatively deeply; as a rule also it will be seen that the sand for nine or ten inches down has been bleached by the removal of the brown oxide of iron which is the chief colouring matter of all soils. Below the bleached portion comes a thin band or pan of dark coloured oxide of iron, dissolved and redeposited from the sand above; this bleaching and iron pan occur only in soils short of carbonate of lime. Being so coarse grained and free from water, sandy soils warm up rapidly and are early; if plenty of manure can be given they induce very rapid growth, and so are well suited to market gardeners and small holders. They do not maintain their vegetation well through the summer, but growth is again rapid with the cooler and moister days of the early autumn.

Among the cereal crops, barley answers best on sandy land; grass is generally poor, the "Soft Brome" being a very characteristic species, while the "Wavy-Hair Grass" is a common weed of arable sandy land. Among trees the Spanish Chestnut, the Silver Birch, Holly, and several of the conifers are generally associated with the lighter soils, as are Gorse and Broom among shrubs. Foxgloves, Bracken, and Heather are typical plants. Ornithopus and one or two vetches are common, though the majority of leguminous plants do not grow freely when carbonate of lime is lacking. Among weeds, Spurrey, the small Sorrel Dock, Corn Marigold, and Knawel are characteristic; the two former being particularly indicative of lack of carbonate of lime in the soil.

Calcareous Soils.—Not all soils derived from chalk or limestone are calcareous, even though the rock may be found unaltered a very short distance below. Carbonate of lime is so readily dissolved by natural waters charged with carbonic acid from the soil that in many cases it has been washed out of the thin layer of surface soil existing on some of the calcareous formations. Hence it is necessary, when studying the vegetation of an area resting on chalk or limestone, to make certain of the presence or absence of carbonate of lime in an ostensibly calcareous soil before drawing any conclusions from the occurrence of a given plant.

Calcareous soils are generally dry, warm and early; most leguminous plants flourish well on them, notably Lucerne and Sainfoin in the warmer parts of the country. They are healthy for stock, though snails, slugs, and certain insect pests are troublesome to crops, and in the pastures worms are always specially abundant.

The most characteristic features of the vegetation on calcareous soils are its extreme variety and floriferousness; on no other soil can so many brilliantly coloured and strongly scented flowers be found at all periods of the year. The Beech, Yew, and Wild Cherry are typical trees; the hedgerows are full of characteristic shrubs like Dogwood, the Mealy Guelder Rose or Wayfaring tree, Clematis, the Beam tree, and Sweetbriar. Juniper occurs on the open downs, as also does Box in the few cases where it is truly wild. The Horseshoe Vetch, Burnet, the Dropwort, some of the gentians, various orchids, and Sheep's Scabious and many labiates are almost confined to calcareous pastures; while Chicory and Wild Parsnip are common in waste places. Several grasses are confined to calcareous soils, as are several ferns to calcareous rocks; in fact, the whole vegetation is one of the most interesting to study. A few plants also refuse to grow on calcareous soils; among these the most widely known are Rhododendrons and some of the Heaths.

ALLUVIAL SOILS.—On the alluvial soils the richest land of the country is to be found, though often, as it is subject to floods or has permanent water but a short distance below the surface, it is not suitable to arable cultivation but remains in permanent pasture. The fertility of these soils is due to the fact that neither coarse sand nor clay predominate in them; they consist of a very even mixture of particles of other soils that have been graded by running water. Moreover, the subsoil, as deep as the deposit extends, is enriched with humus, because it has once been soil. There is generally a sufficiency of carbonate of lime; indeed, without it really rich soil is hardly possible.

The rich pastures, and it is only on alluvium as a rule that true "fattening" land is to be found, are largely covered with Rye-grass, to which they owe their shining effect in the sunshine; on drier poorer areas Crested Dogstail and Squirreltail Grass are common. The spots where the drainage is deficient are generally marked by coarse tufts of Aira, or by the presence of Rushes and the small sedges known to the farmer as Carnation Grass.

The characteristics of the alluvial soils are also shared by certain loams that are of sedentary origin; these are the typical soils of arable cultivation, however they may have arisen—well tempered mixtures of sand and clay, not too stiff to hinder percolation and yet fine enough both to retain water and lift it by capillarity. They also contain sufficient carbonate of lime to remain healthy and work freely. Several weeds are characteristic of these soils, and are generally regarded as signs of fertile land in good cultivation,—such are Chickweed and Groundsel, Fat Hen, Stinking Mayweed and Sow Thistle, the Speedwells and the small Spurges, Pimpernel, and Goose Grass. The typical tree of the loamy soils is the Elm, while good land is also generally indicated by strong Hawthorn hedges, clean and free from lichen.

On the low-lying alluvial soils spots can often be found where either through insufficient drainage or the occurrence of springs, the level of the ground water remains permanently near the surface. When this is the case a deposit of peat or peaty soil will begin to accumulate, because the stagnant water cuts off all supply of air from the soil. Thereupon the roots and other vegetable debris begin to decay in an entirely different fashion from that normally experienced by such material when in contact with air, as may be seen by comparing a dead branch rotting away on the surface of the ground in a wood with a similar branch that has been buried many years in the mud of a pond. The black humus material that forms from vegetable matter in the absence of air is generally acid in character, and is accompanied by a deposit of oxide of iron, which in peaty boggy land forms a thin film over the water of the ditches and stains their banks with rust. Considerations of space will not allow of any detailed account of the flora of peaty and boggy land, but a student should attempt to discriminate between the flora cf the acid true peat soils and the mild peaty or boggy areas occurring where the water is naturally charged with carbonate of lime.

The Principles of Cultivation

In the cultivation of the land the prime object of both farmer and gardener is the preparation of a good seed bed, but what constitutes a good seed bed is easier perhaps to feel than to define. It should consist of some five or six inches of friable, mellow soil, naturally worked down into fine grains. It should rest on a firm basis and be compact in itself, because it contains neither rough unbroken clods nor large vacant spaces. On any but the lightest soils the preparation of a seed bed must begin before the winter, by ploughing or digging up the ground so as to leave it in a rough state to the action of the successive frosts and thaws. Even during this preliminary work strong land should not be moved nor trampled upon when it is wet, otherwise the clay gets into the puddled or tempered condition, whereupon it remains very sticky when wet and dries into hard clods. The subsoil as well as the soil should be moved, whenever the expense can be faced; but on most soils care should be taken only to stir the subsoil without bringing it up to the surface. There is a popular quasi-moral idea that the good soil lies below, and that a little hardy spade work and deep ploughing to bring it to the top will do wonders towards restoring and enriching the land. In the surface soil, however, rest the sources of fertility—the humus, which is the chief store of plant food, and the bacteria which prepare it for the plant. If they are buried and so rendered unavailable, years of work and manuring may be needed to bring the subsoil into condition, and store it with humus and bacteria. On clay land in particular the subsoils are harsh and infertile, and may even contain substances injurious to growth. It is good to loosen and break up the subsoil so as to let in the air and destroy any pans just below the surface, thus rendering it easier for the roots of vegetation to get down deeply. Valuable, however, as a deep soil is, it should be deepened very gradually by setting the plough only half an inch or so lower year by year. For the same reasons, while it is desirable that a garden should be trenched over deeply, so as to extend the layer available for roots, in all cases the surface soil should be restored to its old position as the top layer. Subsoiling or trenching should be done as early as possible, to give the earth time to settle down again ; otherwise, if the subsoil is left open, vegetation will suffer from drought, because the loose texture and the many gaps break the connection with the subsoil water and hinder its capillary rise to the roots of the crop.

The year's round of cultivation begins, then, with digging or ploughing before the winter, by which means the alternate freezings and thawings the soil experiences will not only crumble down the clods into a natural fine tilth, but will also draw the finest clay particles together and give the soil a better texture. At the same time, the rough surface retains more of the winter rainfall, which is absorbed and works down into the subsoil instead of running off, as much of it does when the land is left hard and trampled by the removal of the last crop. Even in Britain, where we may seem to have rainfall enough all the year round, it is yet desirable to conserve as much as possible for the summer crops, provided that we can get it down into the subsoil and leave the soil proper in a reasonably dry condition. Except in the wettest years and situations, our crops are more often checked and reduced by a want of water than by its excess. The weathering which a soil receives by its exposure during the winter in a rough condition also helps to render some of the plant food more available, but these chemical actions are secondary in importance to the effect upon the texture of the soil.

When the year has turned, an early opportunity should be taken to move the soil, which will have become a little set by the beating of the winter's rains; if it is sandy or a light loam there need be little delay, because a day or two without rain will dry it sufficiently for working, and even if it does get trampled about a little, the late frosts will easily bring it into condition again. But on the heavy soils and on the pure clays it is necessary to wait and watch for an opportunity very carefully, because one careless cultivation when the land is still wet will easily undo all the good work of the winter's exposure, by tempering the clay into a paste from which it has no longer a chance of recovering. As soon as the east winds begin such kneaded clay will dry into the toughest lumps, which no amount of cultivation will ever reduce to a proper seed bed; even though they are rolled and knocked into little pieces they remain still hard and unkind. But if the right moment be caught, this first spring cultivation breaks up the surface soil and leaves it, still perhaps rather rough, but lying loose upon the firmer unmoved land below.

As long as the land is solid and there is a continuity between the surface and the subsoil the top layer will tend to remain wet, although it may be constantly losing water by evaporation. Water can always rise by capillarity through compact earth in which soil grain touches soil grain and the water film is continuous; but after cultivation the loose earth that is left on the surface is cut off from the subsoil water by its imperfect contact with the firm layer below, and can therefore begin to dry. At the same time as the surface soil drys it becomes warm; as long as it remains wet through its connection with the subsoil the sun's rays does little towards raising its temperature, because they are spent in bringing about the evaporation of the water instead of turning to heat in the soil itself. But not only does the early cultivation enable the surface to dry and warm, it also saves the subsoil below from losing its stock of water by evaporation. The capillary rise only goes on as far as the soil is compact, it does not extend to the surface layer, which, dry itself, is exposed to the sun and wind; all the loss that can take place is the small evaporation of subsoil water into the interstices of the soil resting upon it. Such a layer of loose soil, which, although it may become dust dry itself, serves as a screen and protection against the evaporation of the subsoil water, is often called a "soil mulch," because it serves the same purpose as the mulches of straw or leaves or grass clippings used by a gardener. Soil mulches become of increasing importance as the season advances and evaporation increases with the higher temperatures and the longer days; it is the function of the hoe to establish and maintain such mulches.

The remaining acts of husbandry in spring are all directed towards making the seed bed, the number of cultivations necessary being determined by the fineness of the seed. The aim of each successive cultivation is to work the soil down into a finer condition, to get it more and more compact below, yet to leave a fine layer of loose material on the surface. Below the loose layer the soil must be both fine and compact and rest firmly on the subsoil, otherwise the rise of subsoil water by capillarity will be slow and imperfect and the crop will suffer from drought; it must also be fine, or the small seeds will be buried at all sorts of depths, so that some will be dried up before they make roots and others will be exhausted before they can reach the surface. The top inch or two of soil—the soil mulch—must be kept loose and powdery to protect the rest from evaporation; its value may easily be seen by treading firmly in a few places on a newly made seed bed. After a day or two the footprints will become and remain visibly damper than the rest of the land, so that they must be suffering a constant loss of water. It is at this stage—the preparation of the seed bed—that the skill of the farmer and gardener most shows itself; by experience he knows just the right stage and wetness or dryness when cultivation will be effective,—a little too wet and on strong land the result would be disastrous for the rest of the season, a little too dry and the clods will not crumble, so that the labour is wasted.

When the sowing stage is reached and the seed has been put in and covered at its appropriate depth, the next operation is generally to roll; indeed, if the weather remains dry, rolling is generally repeated at intervals until the plant is up and for a little time after. The object of rolling is, of course, to consolidate the land, especially the surface layer, a condition which facilitates the rise of water from the subsoil until it is brought up to the very surface which has been made firm and smooth. Consequently there is loss by evaporation, accompanied by a little cooling due to the evaporation, but these two disadvantages have to be faced in view of the necessity of maintaining a proper supply of water for the small seeds or tiny seedlings. The plant is at the most critical stage of its existence, and everything must be done to keep it going, even though the waste of subsoil water may be disproportionate to the growth at the time. In gardens it is often possible to check the evaporation, which is most intense during the strong easterly winds and bright sun occurring in most of our springs, by erecting wind screens or even by strewing a few light fir boughs and the like over the seed bed. In dry wind-swept districts it is astonishing to see the marked benefit that young vegetation derives from even the most trifling windbreak. As soon, however, as the plants are well above ground, hoeing should begin, so as to establish a mulch and save the loss of water and consequent cooling from all the unoccupied land between the plants. This, indeed, constitutes the routine of cultivation for the rest of the season, to maintain the firmest possible soil round the roots of the plant, and to keep renewing the loose surface mulch with the hoe. An old gardener used to say that he watered his plants with a hoe, and indeed if the cultivation is only good enough, artificial watering will rarely be needed. In one sense many gardens are over cultivated; it is never necessary to trench the soil deeply every year or even every other year; to do so only results in a loose condition of the subsoil, from which the crops will begin to suffer in the shortest drought. The commonest fault to be seen in the management of the soil in gardens is this over looseness of the subsoil as distinct from the loose mulch on the surface. A gardener will sometimes show you with pride that he can thrust his stick in his beds up to the handle,—it has all been waste of labour that has left things worse than they were before, waste only to be repaired by more waste in the shape of copious waterings whenever a dry spell comes. Watering, however, cannot always be avoided, but whenever necessary it should be thorough; a little sprinkling only brings up the capillary film of subsoil water to the surface and increases the loss to the soil in consequence—what is necessary is a good soaking to renew the stock of subsoil water. Then a mulch should be strewn over the wet ground or, on the next day as soon as the surface is dry, the hoe should be set to work to establish a soil mulch and save the water that has been added from evaporation except by way of the plant.

One last point in connection with management calls for a little discussion of principles, and that is the protection of somewhat tender plants against frost. The actual degree of cold attained in this country is rarely in itself sufficient to kill a plant like a Tea-Rose,—the plant does get killed sometimes, but it is by drought rather than by cold If there is a covering of snow to keep the plant in a moisture-laden atmosphere (and even at temperatures below the freezing-point snow is always evaporating and giving off moisture) the plant rarely suffers, however low the temperature may sink. Below the snow the plant remains sound, but the real mischief is done when a strong drying wind blows over a frozen ground unprotected by snow. When the soil is at or near freezing-point the plant's roots cease to take in any water, so that if evaporation is at the same time going on from the surface of the stems and branches there is nothing to repair the loss, and the plant may dry up completely and be killed. In the same way the sun is said to hurt a frozen plant by thawing it too quickly; it is not the thawing that does any harm, it is the additional drying effect of the sun when the plant is already almost without sap, and when the roots are still too cold to bring in any water from the soil. In protecting plants for the winter the great thing, then, is to shelter them as much as possible from the drying effects of the wind; plants cannot be made appreciably warmer, however much they may be wrapped up, but wind screens made of spruce branches, bracken, even dead leaves and loose straw, will check the dangerous evaporation caused by either wind or sun. If the conditions get very bad, or if a cherished plant still unprotected gets frozen and the sun comes out, bravely syringe it with water and bundle some loose stuff into its dripping head, for the same reasons as a nurseryman advises that a bundle of plants which come to hand in a frozen condition should be soaked with water and then buried.

It is impossible to do more than indicate the principles that underlie some of the main operations of the farmer and the gardener; the important thing to realise is that some reason generally exists for practices that are the outcome of experience and traditions that extend back to Adam. It is, however, necessary to distinguish between the undoubted secular tradition and occasional errors and misinterpretations which obtain a wide currency because of their plausibility or the authority of their originator. Both kinds of opinion claim to speak with the weight attaching to the practical man who *knows*; to form a judgment it is necessary to reason out which of the two conflicting views best fits in with the general scheme of knowledge. The cultivator who has at the back of his mind the few broad principles we have indicated about the movements of water in the soil, the relations of root extension to the water in the soil, and of evaporation to cooling, will be able continually to rationalise his observations in the field and garden, and will little by little become able to piece them into a scheme consistent both with itself and with the experience of others.

END OF VOL. V.

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