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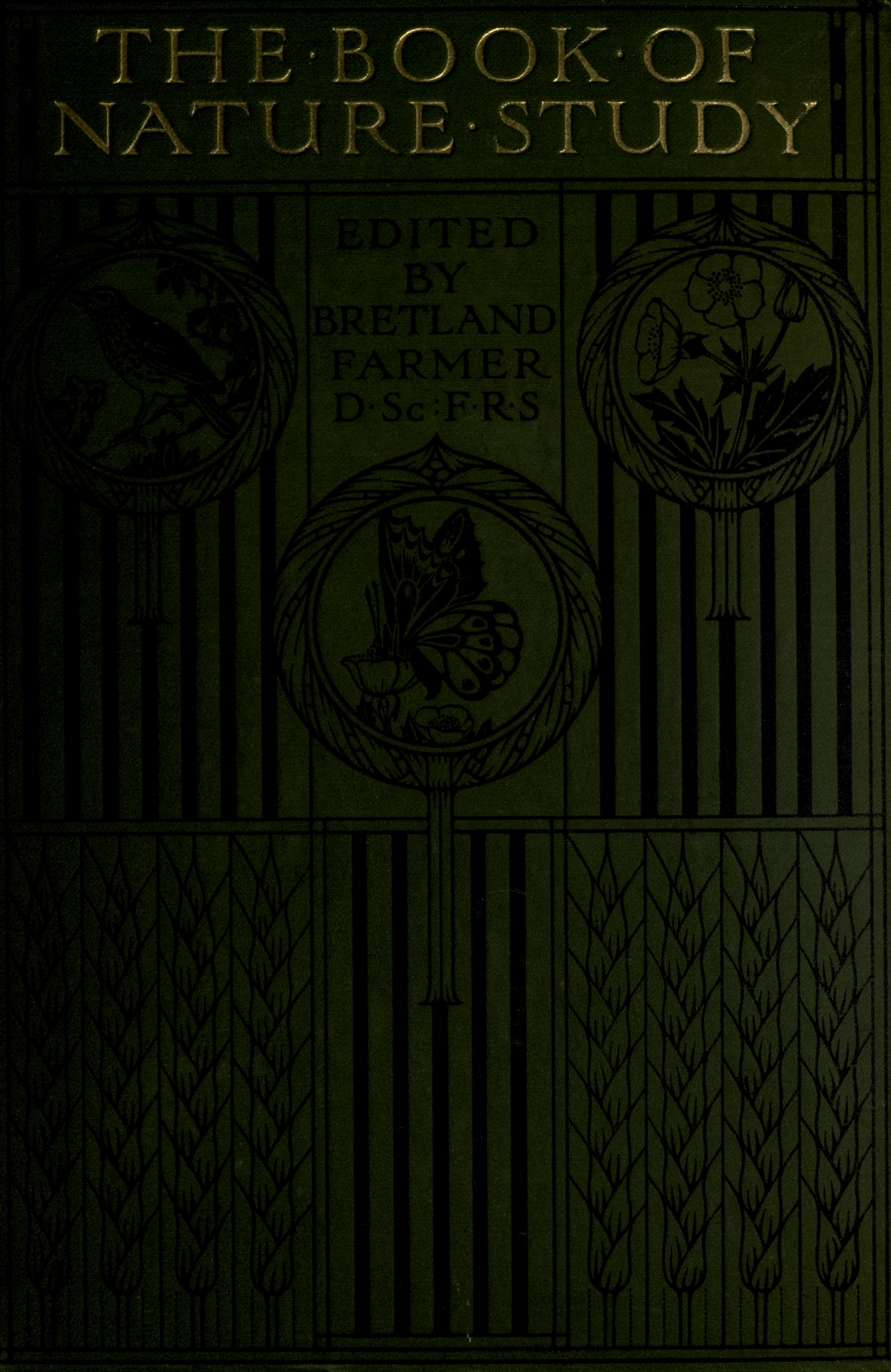

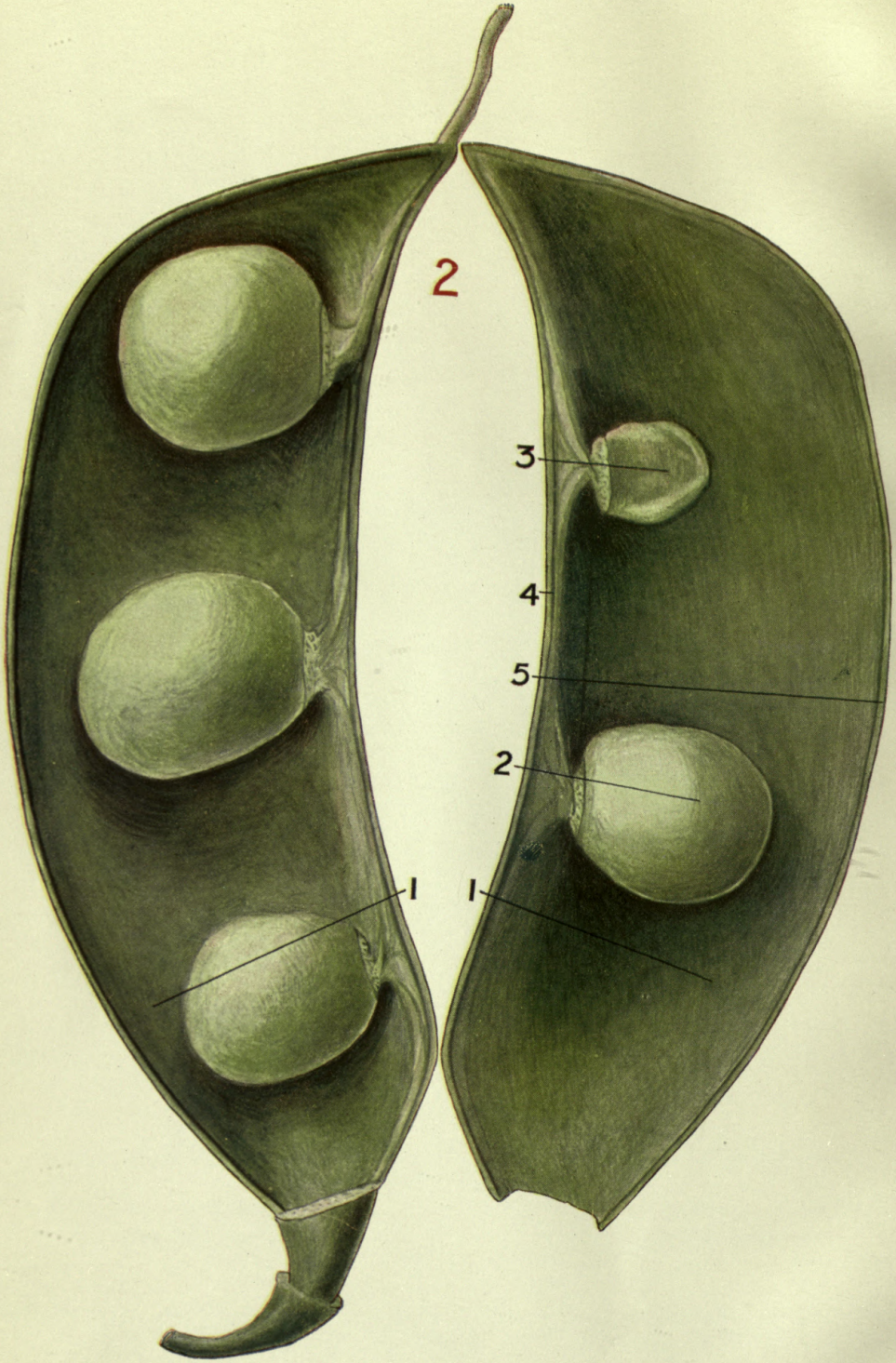
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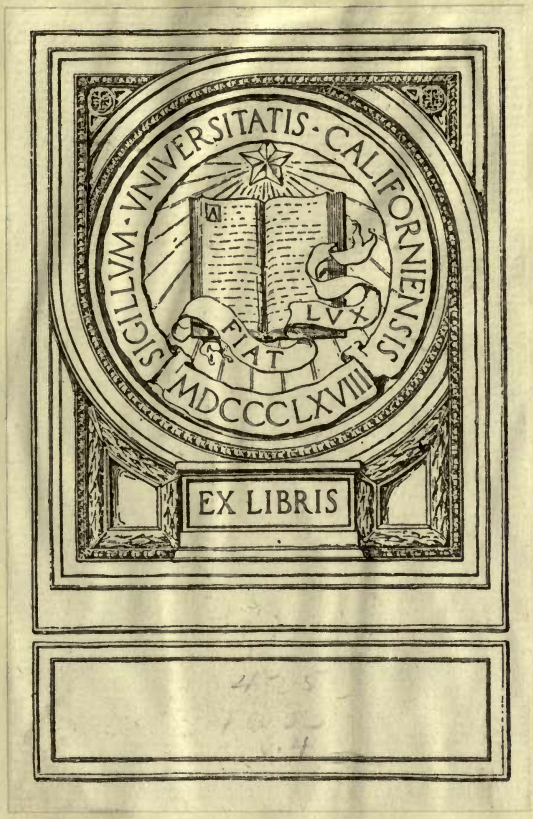
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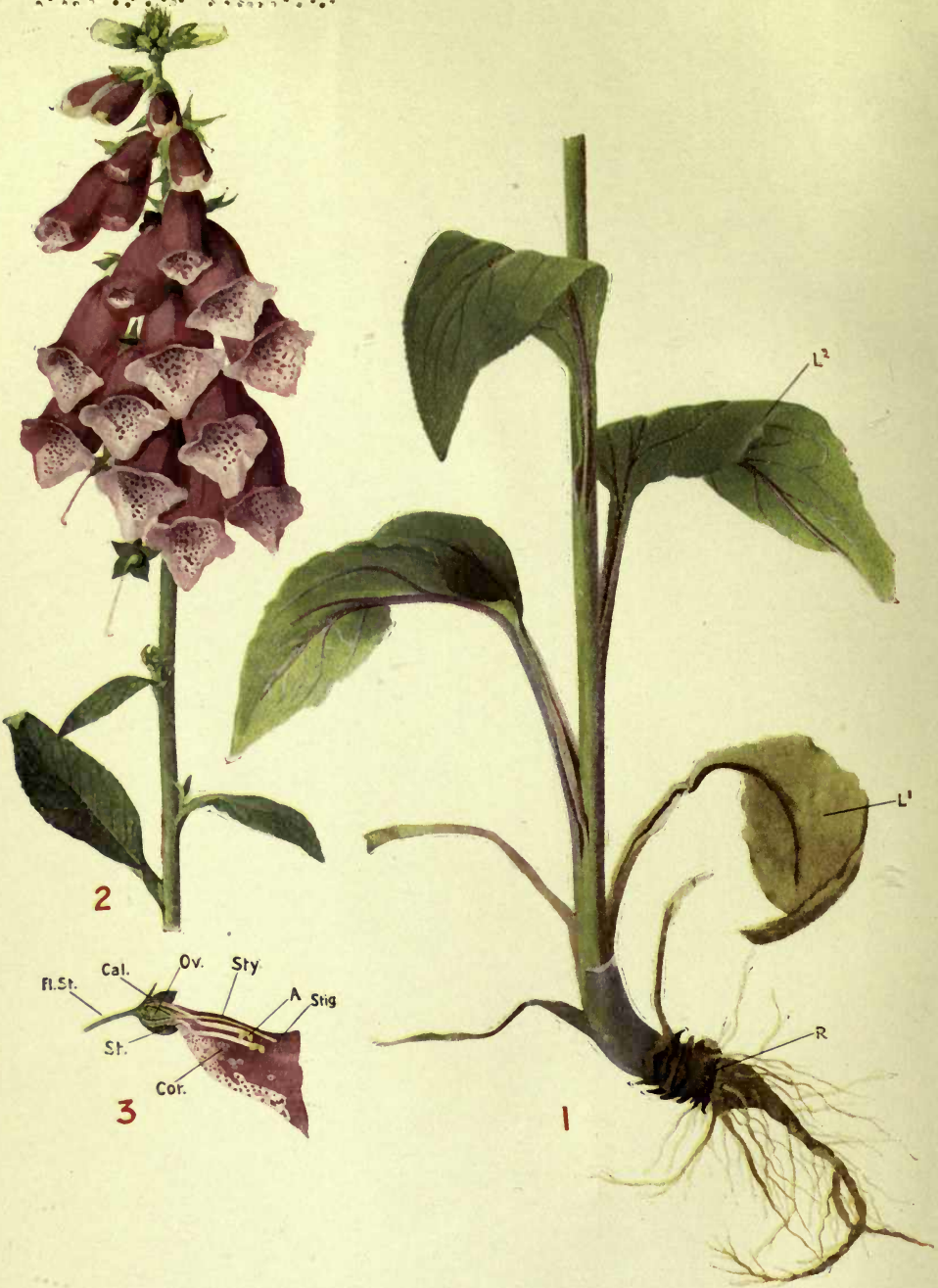

FOXGLOVE (*Digitalis purpurea*, *L.*).

I. Lower part of a flowering plant.

R. Root. L^1. Withered leaves of the first season. L^2. Leaves on the flowering shoot.

II. Upper part of the same plant.

III. Single flower cut in half.

Fl.-st. Flower-stalk. Cal. Calyx. Cor. Corolla. St. Stamens. A. Anthers. Ov. Ovary. Sty. Style. Stig. Stigma.

THE BOOK OF NATURE STUDY

EDITED BY

J. BRETLAND FARMER
M.A., D.Sc.(Oxon.), F.R.S.
PROFESSOR OF BOTANY, ROYAL COLLEGE OF SCIENCE, LONDON

ASSISTED BY

A STAFF OF SPECIALISTS

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THE BOOK OF NATURE STUDY

SOME COMMON FLOWERING PLANTS

(*Continued*)

By William H. Lang, M.B., D.Sc.,
Professor of Cryptogamic Botany in the University of Manchester

CHAPTER I

Introductory—The Cow-Parsnip—The Potato—The Foxglove—The Heather—The Rose Bay Willow Herb —The Common Red Poppy—The Garden Pea—The Ivy—The Honeysuckle—The Dodder and the Mistletoe—The Sundew and the Butterwort—The Goat Willow—The Apple and Pear—The Dog Rose—The Ash.

In the last chapters of the preceding volume of this book a number of plants which flower in the spring or early summer were described. Many of them can be found in flower throughout the summer, and in view of the special needs of teachers it seemed best to select the majority of types of flowering plants from those in flower before the summer vacation commences. In this chapter a few plants which flower later in the season will be described together with some others remarkable on account of peculiarities in their mode of life, and a few examples of trees and shrubs.

The Cow-Parsnip (*Heracleum Sphondylium*, L.)

The Cow-Parsnip or Hog-weed can be found in flower throughout the country from June to August. It occurs by waysides, in woods, in meadows and hay-fields, and is conspicuous even among related plants by its large size and broad flat inflorescences of

white flowers. It is a perennial plant, and all the parts above ground die down in the autumn. Growth is, however, rapid in the early summer months, so that the fully grown plant is usually three to six feet high.

If a plant is dug up and the underground parts freed from the soil the green leafy shoot will be found to have arisen from a thick brown underground stem of rather irregular shape. The surface of this is marked with narrow scars left by scale-leaves, and a little examination will throw light on the mode of growth of the plant. The leafy shoot grows straight up from the thin anterior portion of the underground stem, and appears to be the development of the apex of the latter. In the axil of a scale-leaf at the base of the shoot is a large bud, which is destined to grow into next year's shoot. On looking at the older portion of the underground stem we recognise the large circular scars left by the aerial stem at the end of each annual joint or segment, further growth having always been carried on by a lateral bud. A number of thick roots grow out from the underground stem, and the latter increases in thickness, its tissues serving as a place of storage for reserve food material. This is used in the earlier stages of the growth of the leafy shoots. The Cow-Parsnip is thus a perennial herb, the leafy shoots of which die down each autumn, leaving the old underground stem and the bud which continues the growth next season. When more than one bud is established the underground stem becomes branched, and more than one leafy shoot is sent up from it each year.

The leafy shoot consists of a short stem bearing a number of large foliage-leaves, and branching above in the region bearing the inflorescences. The stem is green, marked by numerous ridges, and covered with coarse hairs. The internodes have a central hollow, which is shown on cutting the stem across, but the nodes are solid. Each leaf consists of a large leaf-sheath which surrounds the stem almost completely, of a leaf-stalk and of a branched or compound leaf-blade, composed of a few pairs of large leaflets borne on a continuation of the leaf-stalk. The lower leaves are often very large and have long stalks, but higher up, in the region of the inflorescence (Fig. 1), the smaller leaf-blades are borne directly on the sheath, no stalk being developed. On

looking at one of the foliage-leaves in more detail we find that the sheath is a wide concave structure of uniform thickness, which joins the stem by an extended base. The lower or outer surface is coarsely hairy, and is ribbed over the numerous vascular bundles; the inner surface is smooth. The transition from sheath to leaf-stalk is a sudden one. The latter is strongly convex below, while on the upper surface it has a well-marked groove bounded by two marginal ridges. The leaf-stalk bears two or more pairs of pinnæ, and ends in a large terminal leaflet resembling in general form the lateral pinnæ. Each of these is dark green above, lighter below, and hairy on both surfaces. The toothed margin is deeply cut into lobes, but the divisions do not extend to the midrib. The midrib projects strongly below, and from it main branches run out to the lobes, the intervening thin parts of the blade being supplied by a finer network of veins.

FIG. 1.—Shoot of the Cow-Parsnip bearing several umbels. (After Baillon.)

The main stem ends in an inflorescence, and the branches, which stand in the axils of the upper leaves, similarly bear inflorescences, so that the plant is in flower for a considerable period. The stalk of the inflorescence is similar to the ribbed stem, but more slender. The inflorescence itself is of a peculiar and characteristic type found in all the relations of the Cow-Parsnip. It

is called an *umbel*, and the family of plants gets the name Umbelliferæ, from the prevalence in it of this type of inflorescence. It will be found that at the end of the main stalk a number of thin ribbed stems arise close together and diverge on all sides. Each of these bears at its summit a number of stalked flowers, which similarly form an umbel. Since the whole inflorescence is thus an umbel of umbels, it is spoken of as a *compound umbel*. At the base of each of the small umbels some small narrow green bracts will be found. In the Cow-Parsnip these are few in number, and no bracts are found at the base of the whole umbel.

Each flower consists of a slender hairy stalk, which widens out just below the flower into a somewhat flattened green body also bearing coarse white hairs. This is the inferior ovary upon which all the other parts of the flower stand. The most conspicuous of these parts are five white petals, but if the flower is looked at from below with the lens indications of five minute green teeth alternating with the petals will be seen. These are the sepals, which in some plants of the family are better represented, in others even more completely reduced. The petals are white, and the free edge of each is notched ; they are not joined together. In the flowers towards the centre of the umbel all the petals are about the same size, though even here the outer three petals tend to be slightly larger than the other two. This is much more marked in the outer flowers of each umbel, and especially in the flowers that fringe the whole inflorescence. In these the outermost petals are greatly enlarged, and assist in rendering the whole group of flowers conspicuous. The five stamens alternate with the petals (Fig. 2, A). In the bud they are bent inwards, but as the flower opens their filaments straighten and diverge, bearing the small greenish anthers. In the centre of the flower is a two-lobed, yellowish-green swelling, from which two short stalk-like styles, each ending in a small stigma, project. The swelling around the bases of the styles is the nectary. As the number of styles indicates, the inferior ovary is composed of two carpels. It is more easily dissected when enlarging to form the fruit, but can be studied quite well in the flower. If this is cut in half (Fig. 2, B) the ovary will be seen to have two cavities, in each of which a single ovule hangs.

If the inflorescence is now regarded as a whole we shall obtain an explanation of its use in pollination. The flowers are not very large or individually conspicuous, but by being grouped in a compound umbel and all brought to one level they form a conspicuous white expanse readily seen from a distance. The greater development of the petals of the marginal flowers assists in this. The crowding of the flowers in the young condition lessens the need of individual protection by means of a calyx, and the sepals are reduced to useless rudiments or are wanting. Even the development of an investment of protective bracts is very slight in the Cow-Parsnip. The reduction of the calyx and the conspicuousness, not of single flowers but of the whole inflorescence, should be compared with what was seen in such plants as the Dandelion and Daisy.

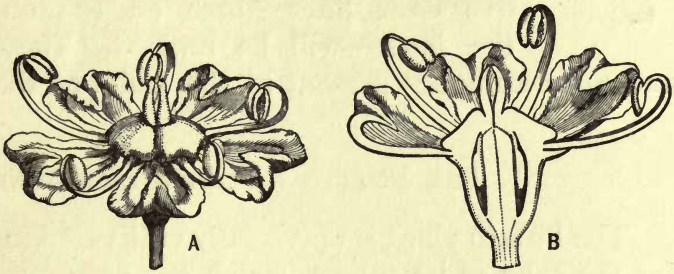


FIG. 2.—Flowers of the Cow-Parsnip. A, entire; B, cut in half lengthwise. (After Baillon.)

The conspicuousness of the umbel is of use in attracting insects, which effect the pollination of the flowers. The Cow-Parsnip is visited by a large number of insects of different kinds. There is here no exclusion of the shorter-tongued insects by the nectar being concealed at some depth, since this is secreted by the freely exposed surface of the nectaries in the centre of the flower. The stamens open and shed their pollen before the stigmas are ready to receive pollen, but the stigmas mature rapidly and thus the possibility of the flower being self-pollinated is not excluded. As the insects pass from flower to flower cross-pollination is, however, more likely to take place. In the umbels formed later, while the marginal flowers have stamens and stigmas, the pistil of the central flowers is in a degenerate and useless condition. These flowers are thus practically male flowers, and, while they do not develop fruit, supply pollen which will be carried by insects to the stigmas of other flowers.

After pollination the petals and stamens fall off, and the ovary, still crowned by the stigmas and the withered remains of the nectary, develops into the fruit. This is a flattened oval body (Fig. 3) consisting of two halves, in each of which is a single seed. As the fruit ripens the two halves split apart from below, but do not open to liberate the seeds. They remain for a time attached to a slender cylindrical middle column, from which they ultimately fall off and, being light and flat, may be carried by the wind. On each half of the fruit five dark lines—three on the outer face, two on the inner—will be noticed. These are oil glands, and are commonly present in the fruits of the Umbelliferæ.

FIG. 3.—Fruit of the Cow-Parsnip. (After Baillon.)

THE POTATO (*Solanum tuberosum*, L.)

The Potato plant is universally cultivated in temperate regions for the sake of its tubers, which not only form one of our most important vegetables, but are of economic importance as a source of starch and in other ways. The plant is not a native of Europe, but was introduced from South America in the sixteenth century. It is still found wild in the Andes. Any of the very numerous varieties will serve for study. Like other flowering plants, the Potato is reproduced by seeds formed in the fruit, but this method is not practically used nor was it probably the chief means of reproduction in the natural state. In cultivation seedlings are only raised for the purpose of obtaining new varieties. These when obtained are multiplied and grown by means of the tubers; this is not only quicker and easier than growing the plants from seed, but has the great advantage of transmitting unchanged the characters of the particular variety.

In ordinary cultivation the Potato is grown from the tuber, which is planted in the spring or sometimes in the preceding autumn. The tubers, the origin of which will be described below, are the swollen ends of underground branches. The swollen stem bears a number of small scale-leaves, which soon fall off leaving curved scars. In the axil of each leaf is a bud, usually

POTATO (*Solanum tuberosum*, *L.*).

I. Whole plant in flower.
SS. Level of soil. R. Roots. Br. Underground branches. T. Tubers.

II. Flower from the side, partially closed.

III. Flower from in front.

situated in a slight depression. These buds are known as the "eyes" of the potato. The tuber, which may be whitish, brown, or red on the surface, has a covering layer of cork, which prevents any serious loss of water when the tuber is exposed on the surface of the ground. The substance of the tuber is white, all the cells being packed full of grains of starch. The presence of this gives value to the tuber as an article of human food. It supplies, however, only the starchy constituent of the food, the proportion of stored nitrogenous substance being almost negligible. The existence of the tubers is not explained by the accident that they have been found of use to man. They are developed for the use of the plant as a special means of its vegetative reproduction. In reproducing the plant in cultivation the tubers are thus put to the use for which they were evolved in nature.

To grow a Potato plant, the gardener takes a medium sized tuber and plants it some inches below the surface of the soil. It is not absolutely necessary to take an entire tuber. It is sufficient that the portion should have at least one bud or "eye" upon it. The bud starts to grow into a shoot at the expense of the starch stored within the tuber. When the shoot has expanded above the soil, and roots have developed from the lower portions of the stem, the plant is independent of this store, which by this time is exhausted. The old tuber then decays. In nature, when plants died down after flowering and fruiting, tubers, borne on underground branches, would remain in the soil and give rise to plants in the next season. The tubers thus serve to carry on the growth of the plant from year to year, and also, since a number are formed, to multiply the plant. The new plants will spring up on the spot occupied by the parent, but if the soil is disturbed, as might occur by animals rooting up the tubers for food, they may be displaced to some distance and spread the plant. Here and there in a garden a plant may be seen springing up from a tuber left unnoticed in the soil from last year. Such stray Potato plants illustrate the way in which the plant would be naturally reproduced.

If a plant developed from a tuber when fully grown is carefully dug up and examined it will be found to show the parts represented in the accompanying plate. The one or more main

stems spring from the old tuber, which by now has almost decayed, only the corky layer which resists decomposition remaining. The main stem continues up through the soil into the green foliage-shoot. The lower portions covered by the soil and not exposed to the light have a whitish colour, and bear only small scale-leaves. In the axils of some of the scales thin cylindrical branches arise which grow out horizontally around the base of the plant, and in turn bear scale-leaves and branch. These branches swell at the ends, and form the round or oval tubers. Many of the tubers remain small, but a number, varying with the strength of the plant and the particular kind, enlarge greatly. The roots of the plant spring chiefly from the main stem. A number arise from the base of this just where it emerged from the parent tuber, but others spring from the nodes, so that the base of each underground branch is accompanied by a group of roots.

The shoot consists of a soft green stem bearing the foliage-leaves singly at the nodes. The stem is winged, the thin ridges or wings continuing down from either side of the insertion of each leaf. A bud stands in each leaf-axil, and the shoot may be more or less branched. The leaf is a compound one, its blade being pinnately branched. The leaflets, which stand in pairs on the continuation of the almost cylindrical leaf-stalk, are oval and pointed. A noticeable peculiarity of the leaf is the occurrence of small leaflets between the pairs of full-sized ones.

The aerial shoots of the Potato end in inflorescences. The inflorescence has a long bare stalk, at the summit of which is a rather complicated branch system bearing the flowers. Only minute bracts are present in relation to the flower-stalks. The purple or white flowers open in succession, the terminal one being the first to expand. Each flower is borne on a rather long stalk, which has a distinct joint dividing a lower from an upper portion. The latter, which belongs more intimately to the flower, may have a purplish colour and falls off with the withered flower. The flower-stalks, like the stem of the whole inflorescence, are hairy.

Each flower consists of a calyx composed of five long pointed sepals, which are free for the greater part of their length, but united at the base. Within this comes the corolla composed of five united petals, which alternate with the sepals. The corolla-

tube widens out suddenly from a very short straight tubular part at the base. Its colour is purple or white with a yellow centre. Attached to the corolla-tube are the five stamens, which stand up prominently in the centre of the flower around the style. Each of these has a short filament and a large yellow anther. The anthers open by round pores at the tip. The pistil consists of two carpels united together to form a slightly two-lobed ovary surmounted by the style bearing a green, sticky, two-lobed stigma. The ovary has two cavities almost filled by the projections of the partition which bear the numerous ovules. The two carpels are placed obliquely in the flower.

The flowers secrete no honey, and though conspicuous are rarely visited by insects. In the open flower the stigma projects some distance in front of the stamens, and is curved downwards. An insect approaching the flower would thus touch the stigma first and then come in contact with the tips of the stamens where the pores, by which the pollen escapes, are situated. In studying the pollination arrangements of this flower we must bear in mind that we are dealing with cultivated varieties, and also that the plant is an exotic one and is not being studied in its natural surroundings.

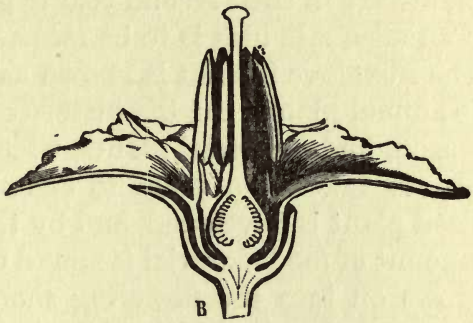


FIG. 4.—Flower of the Potato cut in half lengthwise. (After Baillon.)

Unfertilised flowers wither and fall off, but when fertilisation has been effected this only happens to the corolla and stamens. The style becomes detached from the summit of the ovary, leaving a small scar, and the ovary enlarges into the fruit. This is a berry, the two component carpels of which are indicated from the outside by a slight groove. On cutting it across, the seeds in the two cavities will be seen surrounded by the thick, more or less succulent walls of the ovary.

The seedling plant carries up the pair of seedling leaves, which expand and turn green. The buds in the axils of the seed-leaves

grow into cylindrical branches, which penetrate the soil and expand at their ends into the first tubers.

The Foxglove (*Digitalis purpurea*, L.)

The Foxglove is one of our showiest and most familiar flowering plants, its tall stem bearing numerous purplish red flowers, being conspicuous in June and July in open spots in woods, by hedgerows, and on banks throughout Britain. Along with the plants in flower others will be found which have no elongated flowering shoot, but merely a large rosette of leaves close to the ground. These are plants in their first season, while the flowering plants are in their second year of growth; both must be examined if an adequate idea is to be formed of the life-history of the plant. The Foxglove is what is known as a "biennial" plant in contrast to annual plants, the life-history of which is completed in a single season, and perennial plants, which live year after year. Its life-history takes two years to complete. In the first year a good sized plant is developed, and by the activity of its leaves a certain amount of food material is stored up; in the second year the plant grows on into the flowering shoot, and with the production of flowers and fruit the life of the individual is normally over.

If one of the plants in the first year be dug up and examined it will be found to have a well-developed root-system, consisting of a strong main-root or tap-root from which numerous lateral branches spring. This root-system enables the plant to obtain the water needed to supply the loss from the large leaf surface. The stem of the young plant is short, and bears the leaves, closely crowded into a rosette. The leaves are large and simple. Each is inserted on the stem by a somewhat widened base. This continues into a longer or shorter leaf-stalk, which is grooved above and convex below, while at the sides it thins out into narrow wings. The leaf-blade gradually widens out from the stalk, the thick portion of the latter continuing as the midrib. After increasing in width for about one-third of its length the blade gradually narrows to the tip. The margin is cut into a number of small teeth, at the tip of each of which is a minute pore; drops of water exude from these pores under certain conditions. The veins form

an elaborate network, and are depressed on the upper surface, while they project strongly below. Both upper and lower surfaces of the blade are covered with fine short hairs, which are most noticeable on the veins below. In the axil of each leaf a bud is, as usual, present, but most of these do not develop farther.

In a plant in flower, such as is represented in the accompanying coloured plate, the shoot has elongated greatly and bears a number of foliage-leaves below, and above this the inflorescence. In strong plants smaller additional inflorescences, developed from the buds in the axils of some of the lower leaves, will be found. By the time a plant has reached this stage the leaves of the basal rosette are usually withered and brown, but their remains or the scars they leave can still be made out at the base of the stem. The foliage-leaves on the stem above this resemble those of the rosette, but are separated by distinct internodes. The stem bearing them appears slightly ridged, the ridges continuing down from the sides of the leaf-base. Like the other parts of the plant, it bears fine hairs, and is either green or more or less purple in colour. On proceeding up the stem the leaves become successively smaller (Plate, Fig 2), and the uppermost ones often have small lateral flowering shoots in their axils. These small leaves lead to the bracts, which are small pointed leaves of a green or purplish colour; they have no stalks. In the axil of each bract is a single flower. The bracts are arranged spirally around the stem, but the flowers appear to stand on one side only. This is due to bending of the flower-stalks which causes all the flowers to face the strongest source of light. The flowers open in regular order from below upwards, and as the inflorescence is of considerable length the plant is in flower for a long time. The lateral inflorescences found in strong plants resemble the main flowering shoot.

Each flower has a thin cylindrical hairy stalk. The calyx consists of five green sepals, one of which is much smaller than the others, and stands in the middle line behind. Within the calyx comes the irregular corolla, the five petals forming this being completely united into a wide tubular or bell-shaped structure. This is rounded and bulged out below, while it is flattened on the upper side. The upper lip is composed, as a slight

indentation shows, of two petals. Two other petals form the sides of the corolla, while the lower lip, which projects farther forward, corresponds to the fifth petal. The basal portion of the corolla narrows suddenly, and this part, which is surrounded by the sepals, is colourless, while the rest is of a uniform purplish red colour with paler blotches. On looking into the tube the lower lip, and to a less extent the sides, will be seen to be marked by dark spots, around each of which is a pale area. A short distance within the mouth of the bell long white hairs will be noticed standing up from the lower lip and sides.

No trace of the parts within the corolla can be seen from the outside, but on looking into the tube the stamens and the style will be found bent against the upper lip, but not reaching nearly to the opening. Their position will be clear from Fig. 3 on the plate, which represents a flower cut in half lengthwise. The stamens are four in number, and are attached to the inner surface of the corolla. They will be found, on considering their places of attachment, to alternate with the lobes of the corolla; the stamen opposite to the notch in the upper lip is wanting. The filaments of the four stamens are of such lengths and are so bent that their anthers stand in two pairs below the upper lip; the stamens of the more anterior pair have the longer filaments. Each anther consists of two very distinct lobes, which open by slits on the surface, and face downwards; the anthers of the longer pair of stamens open first. When the corolla with the stamens has been pulled off the pistil can be examined, and will be found to consist of a large greenish ovary which bears a long style ending in a stigma with two short lobes. The ovary is covered with fine white hairs, and the half towards the back of the flower is less strongly developed than the front half. The style is curved backwards, so that it, like the stamens, lies against the upper lip. As the presence of a two-lobed stigma suggests, the pistil is formed of two carpels standing front and back in the flower. On cutting across the ovary, and looking at it with a lens, two cavities will be seen, each practically filled by a projection of the partition bearing the numerous ovules. The detailed study of the flower confirms the impression given by the general view that it is irregular and can only be divided into equal halves by a

plane which, as usual, passes from the front to the back of the flower.

The flower is adapted for pollination by humble-bees, the body of which is just of the right size to fill the corolla-tube when they creep into it. They visit the flower for nectar, which is secreted by a greenish-yellow ridge around the base of the ovary, and accumulates in the narrow part of the corolla-tube. When a humble-bee comes to the flower, and its behaviour can be watched on any sunny day by standing for a few minutes beside a Foxglove, it alights on the lower lip and creeps along the floor of the horizontal or sloping tunnel formed by the corolla-tube. Its back will rub against the upper wall of the tunnel, and the stigma and anthers which lie flat against this (Fig. 3 of Plate). Since the anthers open before the stigma is mature a bee on visiting a flower in an early stage may only receive pollen. On its creeping into another flower, in which the lobes of the stigma have separated, this would be deposited on the inner receptive surface of the stigmatic lobes. When well visited by humble-bees the flowers are usually cross-pollinated, but when visits are few the anthers do not become emptied of their pollen before the stigma has opened. In this case, when cross-pollination is not effected, the flower's own pollen will get on the stigma, when the corolla falls off. Pollination is thus practically certain, and this explains the production of fruit by almost every flower of the inflorescence.

The fruit of the Foxglove develops from the ovary after the corolla of the flower with the attached stamens has fallen. The calyx remains, and surrounds the young fruit. This becomes a dry capsule with two cavities. When ripe it opens by splitting in the plane of the partition, and the two halves of the wall gape apart, allowing the numerous small seeds developed from the ovules to fall out as the stem sways in the wind.

Heather or Ling (*Calluna vulgaris*, Salisb.)

The Common Heather or Ling is widely distributed in Britain. In the north it covers large tracts of moorland as the dominant plant, and it takes a similar place in the bogs of the west of Ireland. Further south it occurs on sandy soil, and in the open parts of the

New Forest and similar localities attains its greatest size and luxuriance. The Heather is a small perennial shrub with a woody stem and evergreen leaves. If a plant is dug up it will be found to send down a stout, tapering tap-root from which fine roots pass off on all sides into the soil. There is no single main stem, but the shoot system consists of numerous woody branches, which in well-grown plants attain a height of one to two feet. The older portions of the stems are leafless, and the surface is brown owing to the protective layer of cork.

On following up any twig we come to the region which has grown in the present season. The thin stem is here reddish or less commonly green in colour, and the surface when looked at with a lens is seen to be studded with small white hairs. The small green leaves are borne in pairs, and, as is so commonly the case, the successive pairs alternate. The leaves borne on the main shoots, though small, are larger than those on the lateral shoots. The pairs also stand at a greater distance from one another, and show the internodes more clearly. The form of the leaf is peculiar. It is short and needle-shaped, narrowing from the base to a blunt tip. The leaf-blade is triangular in cross section, with a flat surface turned towards the stem and a median ridge on the lower side. This ridge bears a whitish line or groove, and this is the whole extent of the true lower surface of the leaf, which is greatly reduced in comparison with the upper surface. Below its attachment to the stem the leaf base continues on either side into a tail-like appendage lying close against the surface. At the base of the year's growth are a number of smaller leaves, closely crowded on the stem. These occupy the same position relatively to the leaves above as do the bud scales in the shoots of most of our shrubs and trees, but do not here enclose and protect the shoot.

All the buds standing in the axils of the leaves of a main shoot develop further in the first season. Sometimes all of them grow into short vegetative shoots with four rows of crowded small green leaves. More commonly vegetative shoots of this kind occupy the axils of the lower leaves on the shoot, and above this come flowers either borne on axillary shoots or singly in the axils of the leaves. The region of the main shoot above the flowers has

THE HEATHER (*Calluna vulgaris*, Salisb.)

again vegetative shoots in the leaf axils. Passing back from the shoot of the current year to the portion produced in the preceding season, we find that the stem has thickened and become covered with cork and the leaves have withered. The middle region of this portion of the shoot, from which the flowers have fallen, appears bare, but towards its base the scattered vegetative branches persist, while the upper portion of last year's growth bears crowded vegetative branches, many of which are growing on and bear flowers like the main shoot. Passing farther back to the region of the shoot produced in the season before last, we find the stem thicker and practically bare. Evidently the main shoots grow on year after year, and bear in the axils of their leaves some branches which persist and grow, but for the most part short shoots of limited duration. The short shoots of the middle region of each year's growth bear the flowers.

The flowers have been seen to stand either singly in the leaf axils or on short shoots which bear a number of flowers. They spring all round the shoot, but usually bend so that all face to one side. The flower-stalk bears several pairs of small green leaves or bracts below the calyx. There are first two small bracts on the stalk, and then just below the flower itself two pairs of smaller green leaves without appendages. These might readily be mistaken for the calyx.

The true calyx is, however, coloured, and consists of four relatively large concave sepals of a pink colour. Within the calyx, which forms the most conspicuous part of the flower, is the corolla, composed of four petals alternating with the sepals. These are joined for some distance at the base, but are free above. Looking into the flower we see the projecting style, and around it the brown anthers. The eight stamens spring from below the ovary, just above the insertion of the corolla. The delicate filament curves round the side of the ovary and brings the anther close to the style. From the base of each anther spring two pointed white appendages, which suggest a comparison with the appendages at the base of the vegetative leaves. These appendages diverge outwards so that their tips touch the inside of the corolla-tube. The anther opens by long slit-like pores extending from the summit. The pistil consists of the ovary, which has

four lobes, each enclosing a cavity in which are a number of ovules, a long style, and a small four-lobed stigma. It is formed of four united carpels.

The flowers stand as a rule horizontally on the inflorescence, and the style, and to a lesser degree the stamens, usually bend somewhat upward. The stigma is borne on the long style well in front of the stamens, so that the pollen is not likely to reach the stigma of the same flower by accident. The small brightly coloured flowers are so massed together and the plants grow so commonly associated together that the purple patches are conspicuous from a distance when the Heather is in bloom. This is from July to September, and at its height in August. Insect visitors of various kinds—bees, butterflies, moths, and flies—come in numbers to the flowers, and may all effect pollination. They come in search of the nectar. This is secreted by the nectaries, which alternate with the stamens, and it accumulates at the base of the short corolla-tube. The way to the nectar lies between the stamens, and it has been seen that the appendages of the anthers extend so as to touch the corolla-tube on all sides. An insect's tongue can hardly fail to touch the appendages, and so disturb the anthers, from which the loose pollen will readily fall on the head of the visitor.

An insect on approaching a flower will meet the stigma first, and thus deposit any pollen it may bring from another flower upon this. Heavy insects, such as bees, grasp the flower and their weight pulls it down into a vertical position, so that the pollen will readily fall on the head of the visitor and be deposited on the stigma of a flower subsequently visited. Smaller flies creep into the horizontal flower and obtain the honey by the wider opening beneath the stamens. The result is, however, the same.

After pollination the pistil develops into a small four-lobed capsule, each cavity of which contains a number of very minute seeds. The fruit remains on the plant through the winter enclosed by the withered brown calyx and corolla. In the following spring it opens and liberates the seeds. These germinate under suitable conditions, but the plants do not reach a size at which they bear flowers for a number of years. Seedlings can always be found in numbers on areas where the heather has been burned.

The prevalence of Heather over wide areas is an indication of its suitability to the peculiar conditions of life to which it is exposed. These will be more fully discussed in another section of this work, but it may be mentioned that the whole build of this low shrub, with very small leaves, the lower surface of which is reduced, is such as to lessen the loss of water in transpiration. This is necessary, for, while evaporation is favoured by the wind, the peaty soil in which the plant grows makes the absorption of water by the roots difficult.

Two common species of Heath will usually be found growing in the same districts as the Heather, and may be mentioned. They are the Fine-leaved Heath (*Erica cinerea*, L.) and the cross-leaved Heath (*Erica tetralix*, L.).

Rose Bay Willow-Herb (*Epilobium angustifolium*, L.)

There are a number of British species of Willow-Herb, but the largest and showiest is the Rose Bay or French Willow. This occurs wild in many districts throughout the country, and can also be readily obtained in cultivation. The plant is a perennial herb, all the parts above ground dying down in the autumn. New aerial shoots are sent up from the underground stem in the spring. These attain a height of three or four feet, and, since numerous shoots often grow together, the plant forms a conspicuous mass of foliage, which becomes a more prominent object in the landscape when the rose-coloured flowers are open.

The aerial shoots consist of a cylindrical green or reddish stem, bearing long, narrow, oval, pointed leaves which have practically no stalks. The leaves stand either singly at the nodes or form whorls of three. The blade, which is deep green above, paler beneath, has a well-marked midrib, and this, with the larger branches of the network of veins, projects on the lower surface.

The flowers are borne in inflorescences, which terminate the main shoot and lateral branches. In the region bearing the flowers the leaves are reduced to small elongated bracts, in the axil of each of which a single flower stands. The lowest flowers open first, and there is a long succession of buds, so that old inflorescences bear almost mature fruits below, while there are still unopened buds at the summit.

The flower has a short stalk, which widens out into the long inferior ovary, upon which the calyx, corolla, stamens, and style are seated. The ovary is four-angled. Its upwardly directed surface is frequently of a pink colour, while the lower face is green. Like the flower-stalk, its surface is covered with very short white hairs. The calyx consists of four narrow pointed sepals, deep pink within and brownish-pink on the outside. One of the sepals stands in the middle line at the back of the flower. In the bud the sepals join edge to edge, and completely protect the parts within. The corolla consists of four petals, which alternate with the sepals and thus stand diagonally in the flower. Each petal has a narrow stalk-like base, widening out into an almost circular portion of a rose-pink colour. When fully open the flower is a very conspicuous one.

Within the petals we come to the eight stamens forming two whorls, though this is only evident in the order of opening of the anthers. Each filament bears a large red anther, which on opening reveals the bluish-green pollen. The lower portions of the filaments are slightly broader and flatter than the upper portions. They stand closely, edge to edge, around the base of the style, and serve to protect the nectar, which is secreted by the upper surface of the ovary. The nectar is visible as a glistening fluid on the surface of the green nectary if some of the stamens are carefully removed. It will be evident that, while the nectar is protected from injury by rain, access to it is easy between the stalks of the stamens. In the centre of the flower is the style, springing from the inferior ovary. The style is short and cylindrical, and bears at the summit a large four-lobed stigma. The lowest part of the style around which the nectar accumulates is smooth, but above this comes a region clothed with hairs which complete the enclosure and protection of the nectar. The smooth outer surface of each lobe of the stigma has the same pink colour as the rest of the flower, while the receptive inner face is rough and white.

When the flower first opens (Fig. 5, 2) the style bends downwards, and the lobes of the stigma are still closed together. The stamens which stand up in the centre of the flower then open, the outer four shedding their pollen before the inner ones. During

this process, which takes a number of days, the stigma gradually opens, and by the time the pollen has been shed is raised by the

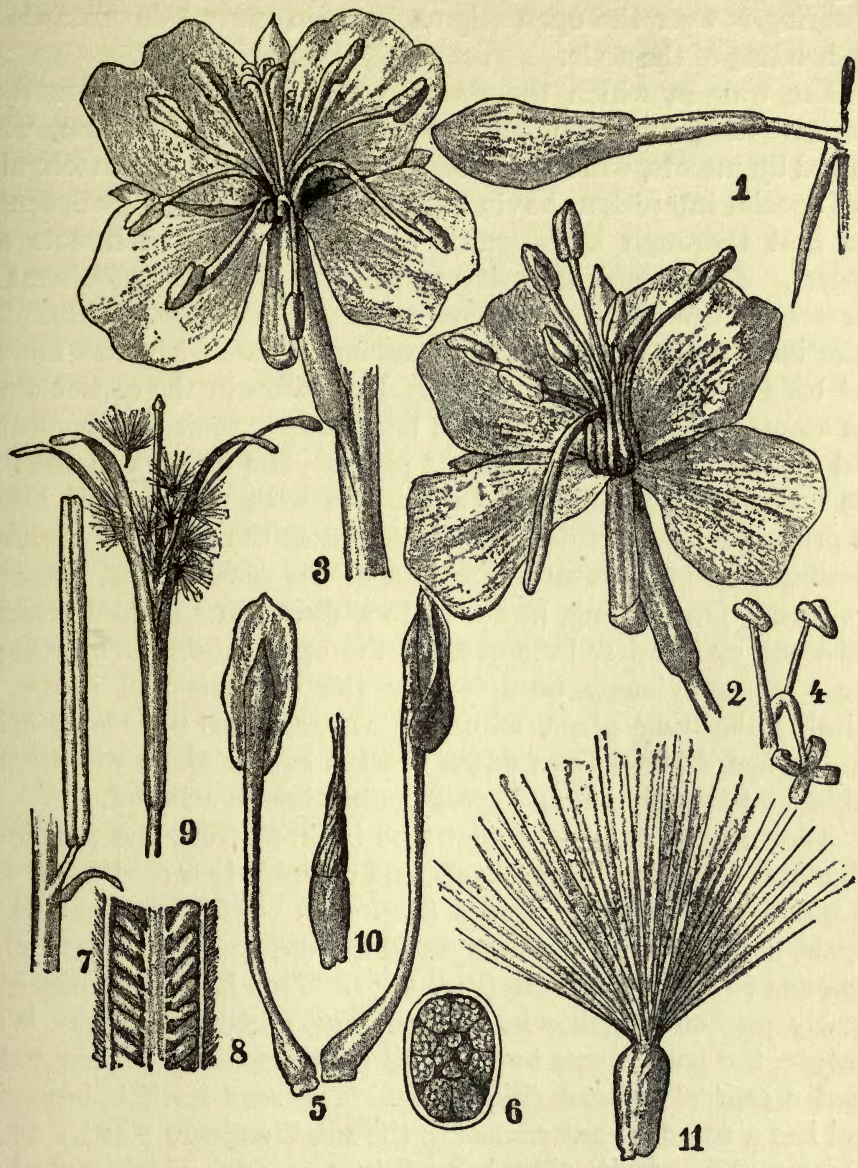


FIG. 5.—The Rose Bay Willow-Herb. 1, bud about to open; 2, flower in the earlier pollen-shedding stage; 3, flower in the later stage, with the stigma expanded; 4, style again bent after flowering; 5, stamens; 6, cross section of the bud; 7, young fruit; 8, fruit cut lengthwise to show the ovules; 9, mature fruit opening to liberate the seeds; 10, seed removed from a fruit; 11, seed as it escapes from the fruit, with the crown of hairs expanded. (After Schumann.)

straightening of the style, and projects in the centre of the flower (Fig. 5, 3) with the stigmatic lobes widely expanded. When the flowering is over the open stigma is again moved downwards by the bending of the style.

The way in which the flower works as an arrangement to prevent self-pollination, and to ensure cross-pollination, when visited by insects, will now be easily understood. The mechanism is of special interest, as having been carefully studied by Sprengel, the first thorough investigator of the relations of insects and flowers. The conspicuous flowers grouped in large prominent inflorescences are highly attractive to insects, and offer an abundant secretion of nectar. Insects of various kinds visit the flowers, but bees are the most numerous. In flowers in the earlier stage, the stamens, some of which will be shedding their pollen, project and form a convenient alighting place. The insect will thus get the under surface of its body smeared with pollen as it inserts its proboscis between the stamens to get at the nectar. It cannot possibly place pollen on the stigma of the same flower, since this is closed. On passing, however, to a flower in the later stage on the same or another inflorescence the open stigma projecting in the place previously occupied by the stamens will prove the suitable alighting place, while the stamens are now bent aside. Any pollen derived from flowers in the earlier stage will thus be rubbed on the stigma, and cross-pollination be effected.

The inferior ovary, as might be inferred from the four-lobed stigma, is formed of four carpels, and encloses four cavities in each of which are numerous ovules (Fig. 5, 8). After pollination the sepals, petals, stamens, and style all fall off, and the inferior ovary enlarges to form the fruit (Fig. 5, 7). This has numerous seeds closely packed together in its four long narrow cavities. When mature, the fruit opens by the wall splitting away as four valves from a central column (Fig. 5, 9). The seed itself is brownish, and has a smooth coat enclosing the small embryo plant. It has a crown of fine white silky hairs (Fig. 5, 10, 11) which spread out and form a parachute, assisting in the dispersion of the seeds by the wind.

The similarity of the seeds of *Epilobium* to those of the Willow accounts for the name Willow-Herb given to the plant we are

considering. There is, of course, no near relationship between the Willow and the Willow-Herb. A number of smaller species of Willow-Herb occur in Britain. While the general construction of flower, fruit, and seed is similar, differences occur in the mode of pollination. Some species with relatively inconspicuous flowers do not prevent self-fertilisation by the maturing of the stamens and stigma at different times, and in some cases the flowers are regularly self-pollinated.

The Common Red Poppy (*Papaver Rhœas*, L.)

Unlike most of the plants described here, the Red Poppy, familiar to everyone in our cornfields and waste land, is an annual plant. It grows from seed, attains its full size, flowers, ripens its fruit and sheds its seeds in one season. The plants then die, and a new generation springs up next year from the seeds left in the soil. Many of the weeds of cultivated land will be found to be annual plants, only these being able to get a footing in the soil which is yearly turned over by the plough.

If a flowering plant of the Poppy is examined it will be found to have a stout tapering main root bearing lateral branches. At the base of the stem are a number of leaves crowded closely together, and above this region the stem has elongated internodes, and bears at each node a single foliage-leaf. Still further up the leaves have no stalks, and differ in shape from those below, and the main stem continues into the long bare flower-stalk ending in a flower. Small plants may be unbranched, but a bud is formed in the axil of each leaf and, while many remain undeveloped, branching occurs in larger plants. The lateral shoots bear only two reduced leaves or bracts, and like the main shoot end in flowers.

The stem, which tapers from below upwards, is green, often with a purple tinge at the base. It bears scattered white hairs projecting from the surface. The leaves have a widened leaf-base, a narrowly winged leaf-stalk, grooved above, and a deeply divided but not compound leaf-blade. The leaf-stalk passes gradually into the blade, the central region continuing as the midrib, while the green margins widen out. The margins of the

lobes into which the blade is cut are themselves notched; the lobes stand alternately right and left, and the leaf ends in a broadly winged region, the divisions in which do not extend so far in towards the midrib. The leaf bears coarse hairs like those on the stem, especially on the lower surface of the leaf-stalk and midrib. The stalks of the lower leaves are long. On passing upwards the stalks become shorter, the leaf retaining the same form, though its segments tend to become narrower and more deeply notched.

The flower-stalk is bent some distance below the flower, and when in the bud the flower hangs downwards. This is not merely due to the weight of the bud, for the curvature takes place even when this is counterbalanced by a suitable weight. When the flower is ready to open the stalk straightens and remains erect during flowering and in the fruit.

To see the sepals, a flower-bud must be examined, as no trace of them will be found in the open flower. The bud is completely enclosed by two stout green sepals, the outer surface of which is covered by stout hairs. The sepals fit closely together, and efficiently protect the delicate parts within. Since the bud is exposed for a long time, this protection is especially important. As the bud opens the sepals become detached from the floral receptacle and split apart from below upwards, the red petals appearing between them. The sepals do not become completely separated from one another, but fall off, their use being over, as the petals unfold (Fig. 6).

The corolla consists of four large delicate petals arranged in two pairs. These are wrinkled up when packed closely in the bud, and even when fully expanded retain a trace of the wrinkled surface. They have a beautiful bright scarlet colour, and owing to their large size make the flower a very conspicuous one. At the base of each petal is a larger or smaller dark-coloured region showing both on the upper and lower sides.

Within the corolla we come to the very numerous stamens. The stalks of these are slender and red, and each bears a greenish-black anther from which on opening the greenish pollen is liberated. The stamens stand around the large pistil, which occupies the centre of the flower and the summit of the floral receptacle. The

green ovary widens out from a relatively narrow base, and is capped by the large flat stigma. This shows eight to twelve dark ridges radiating out from a central point, and projecting slightly at the edge. These ridges have a rough surface, and are the receptive portions, the stigmatic surface itself. The spaces between the radiating stigmatic lobes are pinkish. If the surface of the green ovary is now looked at again it will be found to be marked by faint ridges. These come between the rays of the stigma, and each marks the position of one of the numerous carpels, which are joined together to form the pistil. The stigmatic rays thus come over the lines of junction of the carpels. The ovary when cut across will be found to have only one cavity, but beneath each stigmatic ray, *i.e.* at the junctions of the carpels, a flat partition extends

FIG. 6.—Flower of the Red Poppy. A, entire; B, cut in half lengthwise. (After Baillon.)

inwards towards the centre, but does not reach it. The small ovules are borne all over the surface of these inwardly projecting plates, and an enormous number of them are present in the ovary.

As might be expected from its size and conspicuousness, the flower of the Poppy is pollinated by insects. These come to collect or feed off the abundant pollen, since no nectar is secreted by the flower. In doing so they get their bodies dusted with pollen, and going from flower to flower will effect cross-pollination. The stamens begin to open while in the bud, and the stigma is inevitably dusted with the flower's own pollen. Probably seeds are produced as a result either of cross- or self-pollination. After pollination the petals and stamens are shed, and the ovary alone remains on the summit of the flower-stalk. It enlarges and develops into the similarly shaped fruit (Fig. 7), which contains the numerous small seeds developed from the ovules. The wall

of the fruit becomes dry, and when ripe the upper parts of the carpels below the projecting rim bend back, leaving a number of small holes leading into the cavity of the ovary. Through them, as the fruit sways on its long stalk, the small seeds are shaken out like pepper from a pepper-castor.

FIG. 7.—Fruit of the Red Poppy. The pores by which the seeds escape are seen just below the margin of the stigma. (After Baillon.)

If a leaf of the Poppy be broken off or the flower-stalk cut across, drops of white milky juice will exude from the cut surfaces. Cutting across the tissues has broken a number of minute tubes containing this fluid, which then oozes out, much as blood does when the minute capillary vessels of the human skin are injured. A similar milky juice is found in the Dandelion, the Periwinkle, and some other plants. In the Poppy this juice, the use of which to the plant is not properly understood, is of special interest, since opium is obtained from the dried milk exuding from cuts made in the young fruits of the Opium Poppy (*Papaver somniferum*).

THE GARDEN PEA (*Pisum sativum*, L.)

The ordinary Garden or Edible Pea, material of which can be obtained from any kitchen garden, is a most interesting plant to study. It can readily be followed through its complete life-history by sowing seeds in spring or early summer in the school garden. The seeds, which have been removed from pods borne on plants of the preceding year, are large, and their structure should be carefully made out. The seed-coat will be found to show the scar of the stalk by which it was attached to the pod. Within the seed-coat will be found the large embryo plant, ready to continue its growth when the seed is planted. In this we distinguish already the young root and shoot, and a pair of seed-leaves or cotyledons. These are swollen hemispherical structures very unlike ordinary leaves. They have become devoted to the function of store-houses for the food material at the expense of which the young plant will commence to grow. The structure of the seed is shown in the model which forms the frontispiece to this volume.

In germination the root extends down into the soil and

gives off lateral branches, while the shoot grows up into the air and light. The seed leaves remain beneath the soil in the seed-coat, and are gradually depleted of their food material. The plant grows up rapidly from the seedling and attains a considerable height, which differs in the numerous varieties of this extensively cultivated plant. The Pea is an annual plant bearing flowers and fruiting in its first season and then dying. The seeds are left to carry on the race in the next year.

The root system of the Pea consists of the tap-root and its lateral branches, which in turn branch. It calls for no special description, save to refer to the nodular swellings found on some of the finer branches. Similar nodules or root-tubercles are found in most of the plants belonging to the same family as the Pea, and have been mentioned in describing the Bird's-foot Trefoil. These swellings are inhabited by innumerable minute Bacteria, the association of which with the plant enables it to utilise as food the nitrogen which forms a large proportion of the air. Ordinary green plants are unable to do this, and depend for this important constituent of their food upon nitrates and other nitrogenous compounds in the soil.

The shoot of the Garden Pea consists of the stem bearing large leaves of complicated form and construction. These are inserted singly at the nodes and separated by fairly long internodes. Each leaf stands on the opposite side of the stem to the one immediately below. The stem itself is somewhat flattened, so that the cross-section is oval and not circular. Cutting the stem across also shows that it is not solid, but is traversed by a central cavity, which is not interrupted, as in many plants, at the nodes, but continuous throughout the length of the stem. The surface of the stem and leaves is quite smooth and free from hairs, but is covered with a "bloom" such as is familiar in many fruits. As in these, the bloom is due to a covering of minute particles of wax, and can be readily removed by rubbing the surface with the finger, when the greyish-green tint disappears.

The leaves are compound. The leaf-stalk gradually tapers, and bears pairs of leaflets; it ends in a thin cylindrical structure known as a *tendril*. Below this are one to three pairs of similar tendrils. Lower down still we come to two or three

pairs of leaflets. These stand opposite to one another, and each is borne on a short, translucent, swollen, stalk from which the oval leaf-blade widens out. The leaflet is traversed by a midrib, and its margin may be slightly toothed. The tip of the leaflet may either be pointed or truncated, appearing as if cut off. The stout leaf-stalk below the lowest pair of leaflets is of considerable length. To either side of the base of the leaf-stalk where it springs from the stem is a large leafy stipule. The stipules are much larger than the leaflets, and provide a considerable part of the green leafy surface of the plant. Each stipule is inserted by a wide base, and, though the two do not join, extends for some distance round the stem. The outline of the stipule is oval, the lower side being more developed especially at the base, where also the margin is toothed.

On considering the construction of this leaf we can readily see that it is derived from the compound pinnate leaf with a pair of stipules at the base, so common in the family to which the Pea belongs. The terminal leaflet and one or more of the uppermost pairs of leaflets have been modified into tendrils. These are sensitive to contact, and wind round any slender support so as to grasp it firmly. They thus serve, as an examination of the relation of the Pea plant to the supporting pea-stakes will show, to sustain the whole plant and render unnecessary the development of a stem strong enough to support the weight above. That the tendrils are here modified leaflets is shown by the not infrequent occurrence of intermediate structures or the presence of a leaflet on one side and a tendril on the other.

In the axil of each leaf is a bud, some of which may develop further as lateral branches resembling the main shoot. The buds in the axils of the upper leaves develop into inflorescences. The inflorescence has a long smooth stalk, and ends in a pointed tip. Towards the upper end it bears one, two, or sometimes more flowers, which stand laterally, though the bracts below the flowers are merely represented by a slight projecting rim.

The flower itself has a short but distinct flower-stalk, and is of the characteristic irregular form already studied in the Bird's-foot Trefoil. It consists of calyx, corolla, stamens, and pistil. If a flower is cut through the middle, the flower-stalk will be seen to

widen out so that the calyx, petals, and stamens spring from the margin of a flat plate, while the carpel is attached in the centre. The calyx is large and green. It consists of five sepals joined together in the lower third. One of the five sepals stands in the middle line in front. Within the calyx come the five petals, alternating in position with the sepals and forming the corolla.

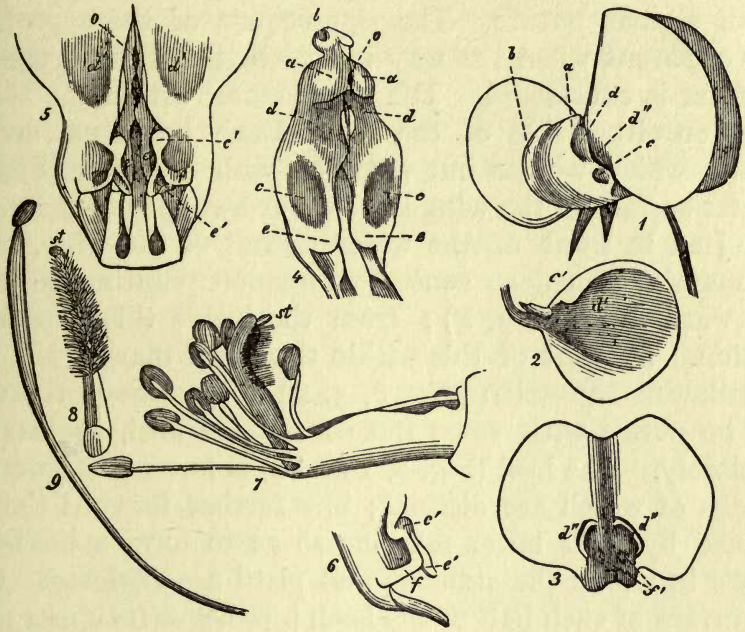


FIG. 8.—Flower of the Garden Pea. 1, Seen from the side, one wing removed; 2, inner view of wing; 3, standard looked at from in front; 4, the keel looked at from above; 5, the keel, with the wings seen from above; 6, outer view of the basal part of one wing; 7, the stamens and pistil seen from the side; 8, front end of style seen from above; 9, a single stamen. *a*, Swelling near front end of keel; *b*, swelling of the ridge of the keel; *c'*, bulge on wing which fits into the depression in the keel (*c*); *d'*, bulge in wing which fits into the depression in the keel (*d*), and is overlaid by the ridge on the standard (*d''*); *e*, lobe at base of keel; *e'*, backwardly projecting lobe of the wing; *f*, portion of wing which is held in place by the median swelling on the standard (*f'*); *l*, tip of keel; *o*, opening by which the style protrudes; *st*, stigma. (From Müller's *Befruchtung der Blumen.*)

One large petal, called the *standard*, is situated at the back of the flower and overlaps with its edges the other petals. Then come two lateral petals called the *wings*, and within these again two petals partially fused together and forming what is known as the

keel. The form of these petals and their relations to one another require the most careful study. The standard widens out rather suddenly from a short concave basal part. This basal region is green in colour, as are the veins on the white expanded portion. If the inner surface of the standard be looked at, two green ridges formed by indentation of its outer surface will be seen converging forwards, and further back in the middle line a short transverse bulge of similar nature. The significance of these projections will be apparent when the way in which the parts of the flower fit together is considered. The wings stand within the standard and one on either side of the keel. Each has a narrow stalk-like part, which widens out into the white portion (Fig 8, 2). The outer surface of the wing is irregular owing to certain depressions. Just in front of the widening out of the wing, near its upper margin, is a deep conical depression pointing downwards and forwards (Fig. 8, 5, *c′*) ; from the inside this appears as a projection. In front of this within the upper margin is a longer and shallower depression (Fig. 8, 5, *d′*). To remove the wing it has to be pulled with some force from the keel, against which it fits closely. The keel (Fig. 8, 1 and 4) is formed of two petals, the stalks of which are distinct; but further forward the petals are joined by their lower margins so as to form a boat-shaped structure in which the stamens and pistil are enclosed. On the outer surface of each half of the keel, just below its upper margin, are two depressions, one just where the petal widens from the stalk (Fig. 8, 4, *c*), the other farther forward (*d*). The two depressions in the wing (*c′* and *d′*) correspond with and fit into these depressions in the keel. Into the anterior grooves formed by the fitting together of wings and keel at *d*, there fit also the two ridges (*d″*) on the inner face of the standard. The wings and keel are so closely locked together that anything which depresses the wings will depress the whole structure.

The ten stamens are enclosed within the keel. The one towards the back of the flower is separate from the others. Its stalk is broad below, thin and cylindrical below the anther. The stalks of the other nine are joined for half their length to form a trough-like structure around the pistil. The upper portions of the filaments bearing the yellow anthers are free (Fig. 8, 7). Within

the stamens is the pistil, composed of a single carpel. The ovary is green and smooth, and stands horizontally in the trough formed by the united filaments. The style stands almost at right angles to the ovary, occupying the bent tip of the keel. The small stigma at the end of the style is bent so as to point backwards to the base of the flower. Just below the stigma the upper surface of the style for about one-third of its length is hairy. On opening the ovary a row of ovules will be found attached along the upper edge, where the margins of the carpel joined.

The complicated structure of this flower, which has been described above without entering into all the details shown in Fig. 8, finds its explanation in the relation of the flower to the visits of insects. To attract these, nectar is secreted around the base of the ovary. The beauty of the complex mechanism can be appreciated, even though in this country the flowers are rarely visited by insects and are normally self-pollinated. To put it as briefly as possible, when an insect strong enough to force up the standard and get at the honey comes to the flower it will depress the wings and keel. On this happening, the style (carrying pollen on the brush of hairs) will emerge from the keel and dust the under surface of the insect with pollen. Should the insect already have pollen on its lower surface, this will be scraped off on the stigma. On the departure of the insect the keel again springs up and encloses the style, so that the process can be repeated.

The fruit of the Pea is the pod (see Model Plate at the beginning of the volume), developed from the ovary. This is surrounded at the base by the calyx, and often by the remains of the stamens, but the corolla has fallen off and the style has also withered. The pod can readily be seen to correspond to a folded leaf with the seeds developed from the ovules attached along the joined upper margin. When mature it opens by splitting along both the margin and also the line corresponding to the midrib of the carpel. The large seeds are thus liberated. They have no special means of distribution, but this is compensated for by the large store of reserve material the young plant has to start its growth with.

The Pea is a specially suitable plant for detailed study throughout its life-history, and has been rather fully described. The student will be able, however, to supplement the description in many points by his own observations.

The Ivy (*Hedera Helix*, L.)

A number of varieties of the Common Ivy occur in Britain, and many more are in cultivation, since the plant is widely grown as a creeper covering the surfaces of walls and houses. In nature it often grows as a climbing plant covering the trunks of trees or the faces of rocks, but it is also found creeping on the soil of banks, especially in the shade of woods. It is described here, since it illustrates another way in which plants climb, and should be compared in this respect with the Pea and the Honeysuckle.

When the plant creeps on the soil of woods no main root will as a rule be distinguishable. The trailing stem is fastened to the soil by numerous roots which spring from its lower side, and on entering the soil branch freely. In plants climbing up the surface of trees or walls, on the other hand, a well-developed root system will be found. This in plants which have grown from seed comes from the main root, but in those which in cultivation have been produced from cuttings consists of roots springing from the base of the stem. The plant is evergreen and perennial, and the roots continue to extend and their older parts to grow in thickness year after year. Such plants also show a main stem, which branches freely, and this in old plants has often the thickness of a small tree trunk.

Roots are also produced very freely from the stem. These roots are short and usually unbranched. The old stems are commonly clothed on all sides with a dense covering of them, but on the finer branches they are confined to the shaded side which faces the supporting surface. Here they spring not only from the nodes, but along the length of the internodes. These roots are of use in fastening the plant to the rough surface of the rock or tree-trunk, and may be regarded as special climbing organs. The Ivy, in contrast to the Pea, which climbs by the help of tendrils, and the Honeysuckle, which has a twining stem,

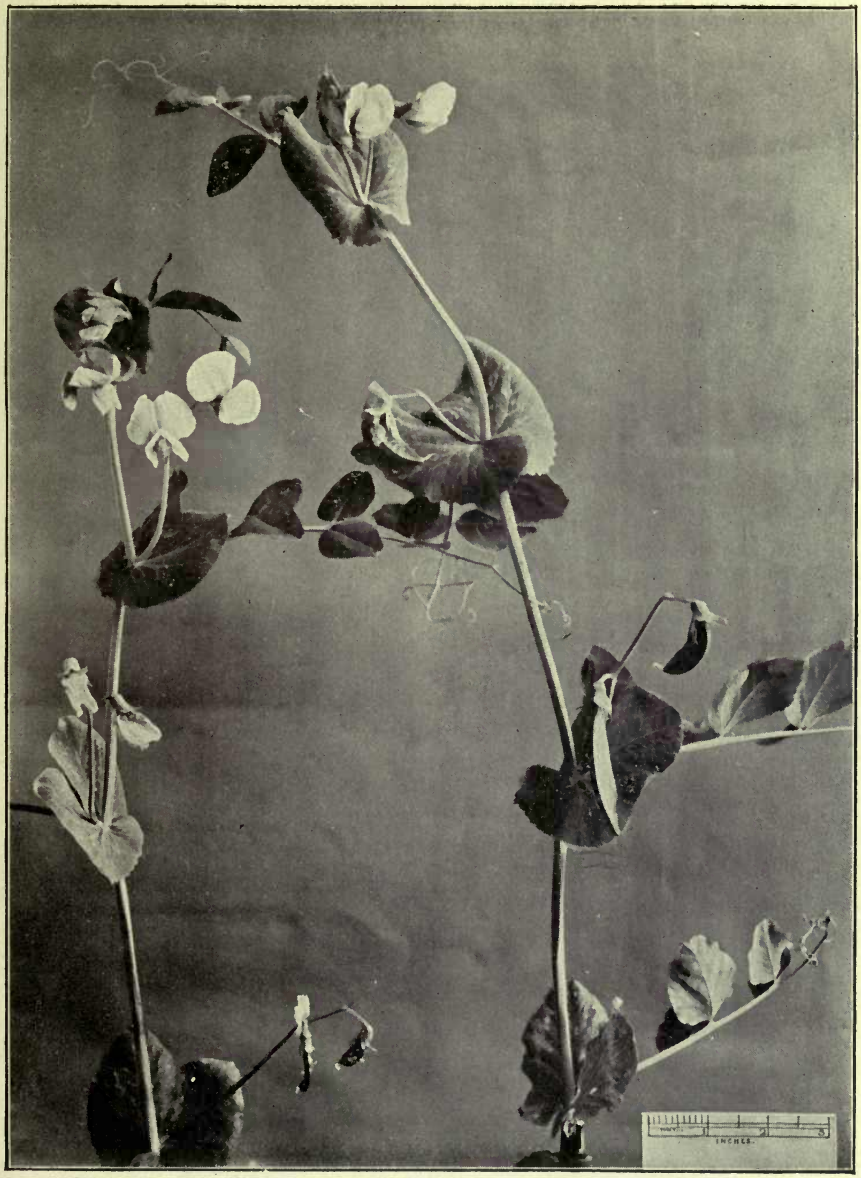
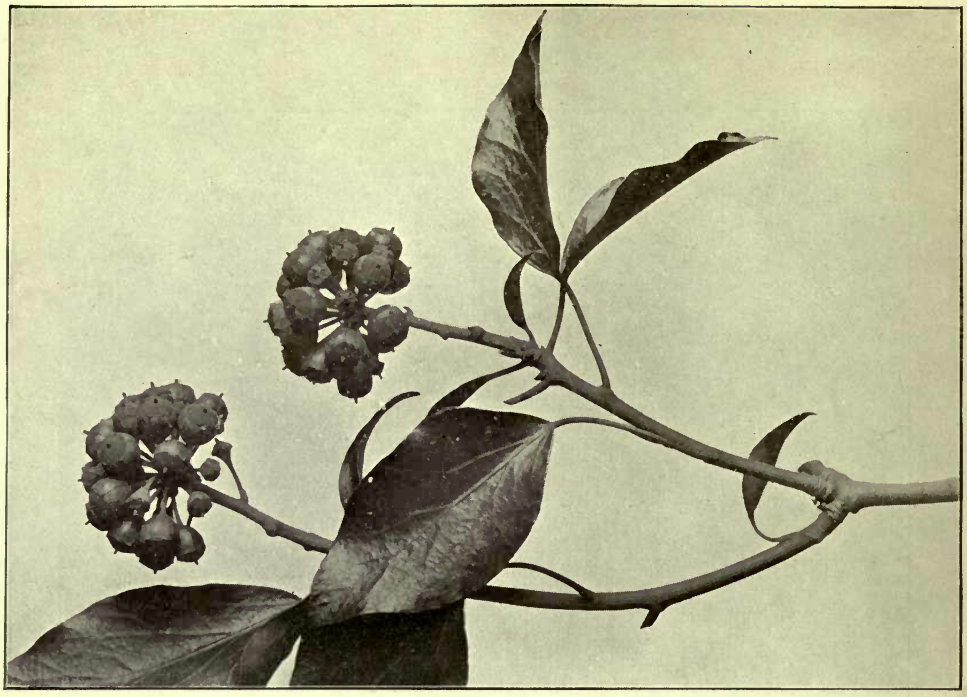


Photo by Henry Irving, Horley.

THE PEA (*Pisum sativum*)



THE IVY (*Hedera Helix*, L.)

is a root-climber. The climbing roots press into all the inequalities of the surface, against which they grow and become so firmly attached to this that when the shoot is pulled off they remain attached to the support.

The shoot of the Ivy consists of a stem with elongated internodes bearing one leaf at each node. The stem retains its green colour for a long time, but the older branches with their covering of cork are brown. The creeping or climbing shoots lie close to the substratum, and their leaves are so arranged as to display the leaf-blades to the light without overshadowing one another. The leaves have long leaf-stalks, and the simple blade is of a triangular shape divided into three or five lobes. Main veins supplying these lobes diverge from the base of the leaf. When a plant has attained a considerable height, other shoots are developed which do not cling closely to the supporting surface, but stand out from this. These branches bear the leaves on all sides of the stem, and the leaves are oval and pointed, not lobed like those on the climbing shoots. The existence of two types of shoot, a climbing and a freely projecting, is characteristic of many climbing plants, but the Ivy is the best example in our flora. The inflorescences are borne on the freely projecting shoots.

All the projecting branches end in inflorescences, and others are developed in the axils of the small bracts borne on the stalk of each main inflorescence. The end of the stalk is somewhat dilated, and from it in the axils of small bracts a number of long stalked flowers spring, forming an umbel (Plate). These flowers do not open until October or November, and, though not very conspicuous, and greenish-yellow in colour, are visited by numerous insects in search of the abundant nectar. The flower-stalk widens above into the almost globular, inferior ovary marked by five projecting ribs. These ribs run down from the five small triangular teeth which represent the sepals. Alternating with these are five relatively large greenish-yellow petals which form the most conspicuous part of the flower. The centre of the flower is occupied by the large, yellowish, nectar-secreting disc, from the middle of which rises the short style. The five stamens which alternate with the petals stand at the edge of the disc. All these parts can

be made out in the upper figure of the accompanying plate, which represents a shoot of the Ivy bearing inflorescences with fully open flowers. Sometimes the number of sepals, petals, and stamens is six instead of five.

When the flower opens the anthers shed their pollen, and when this is over they drop off. The flower has thus a first pollen-shedding stage, which is followed by a pollen-receiving one as the stigma matures. When visited by flies and bees in search of the nectar, cross-pollination is almost certain to occur, since the insects will get the under sides of their bodies dusted with pollen from flowers in the first stage, and will, on visiting flowers in the second stage, deposit this on the stigma.

When the flowers have been pollinated the ovary enlarges and develops into the fruit. The inflorescences now have the appearance represented in the lower photograph on the plate. The petals and stamens have dropped away from the flowers, and the ovary has developed into a bluish-black berry. Round the flattened upper surface of this are the minute sepals, while in the centre the withered style projects. The fruit, like the ovary from which it developed, is divided into five cavities, in each of which is a single seed. The berries are eaten by birds, and the seeds thus distributed.

The Honeysuckle (*Lonicera Periclymenum*, L.)

Although there are a considerable number of British plants that support a relatively slender stem by climbing on rocks or other plants, very few are perennial plants with a woody stem increasing in thickness year after year. Such woody climbers form a very prominent feature in tropical forests. The Ivy, which has been described above, and the Honeysuckle or Woodbine, are among the few woody climbers in Britain. The Honeysuckle occurs throughout the country in copses and hedgerows, where it obtains the support of the bushes or trees. The plant is firmly rooted in the soil, and the main stems persist season after season and grow in thickness. They are not, however, capable of supporting the mass of branches and foliage of the plant, which frequently extends over the summit of the supporting tree. The main stem of the

Honeysuckle when young twines spirally round the support, and thus carries up its foliage to the light. In old plants the main stem will be found wound round the supporting stem, and often cutting deeply into this and injuring it.

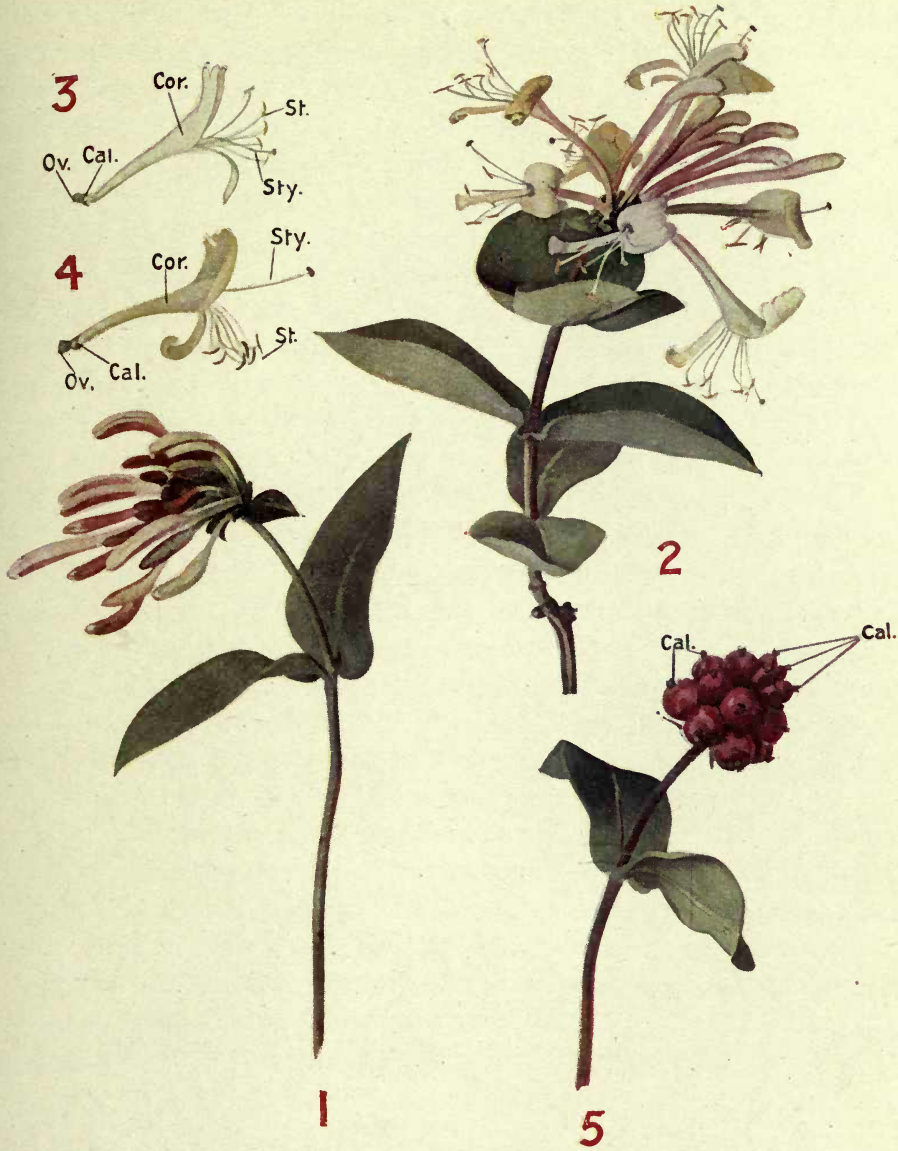
The leaves fall off in autumn, but the new buds will be found beginning to unfold their leaves very early in the spring. The shoots developed from these buds bear the foliage-leaves in the summer, and often end in inflorescences. The Honeysuckle comes into flower about June, and can be obtained from this month onwards through the summer. If shoots of the plant bearing inflorescences are examined the smaller leaves, which enclosed the bud, will be found crowded together at the base. Following upon these come pairs of foliage-leaves, which alternate at the successive nodes and gradually increase in size on passing upwards, to diminish in size again below the inflorescence. The leaves are similar, and have a simple oval leaf-blade, but the lower ones have short stalks which are wanting in the upper ones. There are no stipules. The leaf-blade has a distinct midrib, from which lateral veins spring, and the fine network formed by the smaller veins can be very clearly seen. The upper surface is of a much darker green tint than the lower surface. The general appearance of the leaves on a small flowering shoot is represented in Fig. 2 of the accompanying coloured plate.

The inflorescence consists of a variable number of closely crowded flowers. At the base stand two small bracts alternating in position with the uppermost pair of foliage-leaves. The two lowest flowers stand in the axils of these bracts. To either side of each of these flowers in the axils of a minute bracteole another flower is borne. Each of these flowers has a pair of bracteoles. Above this tier of flowers comes a second similar tier, while in the centre of the inflorescence is the arrested tip of the shoot. The appearance of the inflorescence at two ages is shown in Figs. 1 and 2 on the plate.

Each flower has at the base a small globular green ovary (Plate, Figs. 3, 4, *ov*), which is thus inferior. Above this comes the small calyx (*cal*), which is far too small to protect the parts within in the bud. The calyx is composed of five united sepals, the position of which is indicated by the small tooth-like tips.

The bracts, ovary, and calyx bear short sticky glandular hairs, and similar hairs are scattered on the outside of the corolla tube. The corolla is the conspicuous part of the flower. It consists of a long, gradually widening, tubular portion, which is split at the wider free end into two lips. The lower lip is very narrow, and is formed of one petal, while the broad upper lip has its margin divided into four narrow lobes, showing that it is composed of four petals. The five petals alternate in position with the sepals. Projecting from the opening of the corolla tube are the five stamens (*st*) and the style (*sty*). Each stamen has a long stalk, to the end of which the anther is attached by its middle, so that it swings freely. On carefully slitting up a corolla tube it will be seen that the stamens are attached to the inner surface, alternating in position with the petals. The style, which springs from the summit of the inferior ovary, projects even farther forward than the stamens; it ends in a dilated, three-lobed stigma. On cutting across the inferior ovary it will be found to have three cavities, in each of which are several ovules. This fact, taken together with the three-lobed stigma, shows that the pistil is composed of three carpels.

Having learnt by the dissection of a flower the parts of which it is composed, the relative positions of these in flowers of various ages must be clearly ascertained if we are to understand the way in which pollination takes place. If an inflorescence is looked at in the middle of the day, flowers in two stages will be readily distinguished by their colour. Some are paler and appear almost white in comparison with others, the corolla of which has a full yellow tint. The flower for some time after it opens has the former appearance (Plate, Fig. 3). The two lips of the corolla are not rolled far back; the style ending in the stigma is bent down parallel to the lower lip, and the stamens stand out in the opening of the flower and are shedding their pollen. The flower is in the early pollen-shedding stage. In the older yellow flowers (Fig. 4), on the other hand, the stamens have shed their pollen, and are bent downwards and the style has risen up and bears the stigma full in front of the opening of the flower. The flower is now in a purely pollen-receiving stage. The bud opens one evening, and the flower is in the first stage; by the next evening, *i.e.* when new



HONEYSUCKLE (*Lonicera periclymenum, L.*).

I. Inflorescence with flowers in bud.

II. Inflorescence with open flowers in both stages.

III. Flower in first stage.

IV. Flower in second stage.

Ov. Ovary. Cal. Calyx. Cor. Corolla. St. Stamens. Sty. Style.

V. Group of fruits. Cal. Remains of Calyx.

buds are opening the flower is in the second stage. Thus flowers in both stages are to be found together on the same inflorescence. The flower-buds stand more or less erect, and, since the stigma projects further than the anthers, it is not self-pollinated when the anthers open in the bud. As the flowers open they move downwards into the horizontal position.

The flowers exhale a strong and attractive scent, especially in the evening, and nectar is secreted by a nectary, which can be seen as a yellow ridge on the floor of the tubular part of the corolla if this is carefully slit open along the back. They are adapted to be visited by hawk-moths, which suck the nectar from the corolla-tube when poised on the wing in front of the flowers. The Humming-bird Hawk-moth may sometimes be seen feeding in the daytime, but most of the hawk-moths feed at dusk. If the moth goes first, as is probable, to the more prominent flowers in the first stage, it is unlikely to touch the stigma but will get dusted with pollen. If it then proceeds to a flower in the second stage, the stigma of this will come in contact with the region of the insect's body on which the pollen was deposited. Cross-pollination will thus result. Self-pollination is possible, but the adaptations are all such as to favour cross-pollination. The flowers are visited by other moths and by humble-bees, which also effect pollination, though less neatly than the hawk-moths.

After pollination the corolla falls off, and the inferior ovary develops into the fruit. This becomes a red succulent berry enclosing the hard seeds. The berry is crowned with the dark calyx, which persists. The appearance of the conspicuous group of fruits on the summit of the inflorescence is represented in Fig. 5 of the Plate. The fruits are eaten by birds, and the hard indigestible seeds thus dispersed.

The Dodder (*Cuscuta Epithymum*, Muir) and the Mistletoe (*Viscum album*, L.)

The two plants which will be considered together here are not at all closely related, but show a similar departure from the usual mode of life and nutrition of ordinary flowering plants. As was seen in the introductory chapter (Vol. III. p. 94), an ordinary flower-

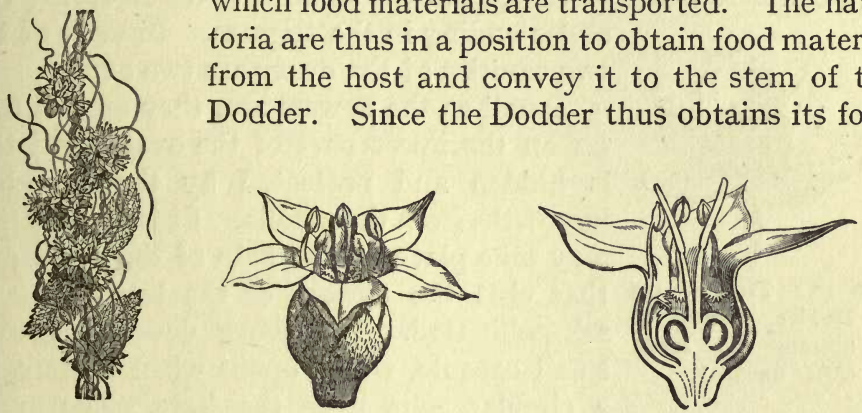
ing plant obtains by its roots water and salts from the soil. It obtains the carbon it requires, not from the soil but from the carbon dioxide present in the air. From those simple raw materials an independently living green plant builds up the complex substances it needs for its growth. The construction of the root system and the shoot with its expanded green leaves was seen to stand in relation to this mode of nutrition or feeding. The two plants to be described do not grow rooted in the soil, but attached to other plants which are spoken of as *host plants*. They derive their food from the host plant, and are termed *parasites* or parasitic plants. Their form and structure will be found to be more or less modified according to their more or less complete parasitism.

The Dodder is a total parasite, and derives all its food ready made from the host plant on which it lives. It departs more widely from the ordinary appearance of a flowering plant than does the Mistletoe. There are several species of Dodder found in Britain, but they differ only in minute features, and any one will serve for study. The commonest kind is *Cuscuta Epithymum*, found growing on Heather, Furze, Thyme, etc. on heaths and commons. *C. europea* often occurs on Nettles, while *C. Epilinum* is a parasite upon Flax, and may be found where this plant is cultivated. The appearance of the Dodder is so peculiar and characteristic that little difficulty will arise in identifying it when it is met with. The mature plant has no connection with the soil, and consists of thread-like pink stems twined round the plant on which it is growing and spreading to neighbouring plants. The host plant always suffers from the growth of the parasite on it, and the infected areas in a field of Clover or Flax may be visible from some distance.

If portions of the host plant with the Dodder attached are collected in summer, complete material for the study of the mature plant will be obtained (Fig. 9, A). The whole plant has a pinkish colour. The green colour so characteristic of most plants is practically absent, only a trace being found even on the most careful examination. The slender stem twines round that of the host plant, grasping it firmly at places in two or three coils. Other portions of the shoot hang free from the host, and may come into relation with adjoining plants, thus spreading the Dodder locally.

When looked at carefully, the stems will be found to bear minute pointed reddish scale-leaves, which are so reduced as to have no veins.

Where the stem of the Dodder twines round the host it is firmly attached to the latter. The attached portion is usually thicker than the free regions. On pulling the parasite apart from the host-plant small outgrowths will be found on the side which lay against the host. These suckers or *haustoria* are borne like roots on the stem of the Dodder, and actually penetrate the tissues of the host. Their tips come into connection with the conducting strands of the latter, which form the main lines along which food materials are transported. The haustoria are thus in a position to obtain food material from the host and convey it to the stem of the Dodder. Since the Dodder thus obtains its food



A B C

FIG. 9.—The Dodder. A, Plant in flower attached to the host plant; B, complete flower; C, flower cut in half lengthwise. (After Baillon.)

ready made, and has no need to obtain the raw materials and manufacture its food from them as does an ordinary green plant, we can understand the peculiarities of its vegetative organs. The absence of roots, the minute size of the leaves, and the absence of the green colouring matter by the help of which an ordinary plant builds up its food when exposed to sunlight are all possible because the Dodder gets its food direct from the host plant.

The reproduction of the plant has, however, to be carried on, and the flowers of the Dodder though small are perfectly constructed and show no reduction. They stand in little globular clusters in the axils of most of the scale-leaves on the upper parts of the shoots. Each flower, as Fig. 9, B shows, is composed of calyx,

corolla, stamens, and pistil. The calyx and corolla are pinkish white. The five sepals are united together below to form a cup-shaped calyx, and similarly the petals, which alternate with the sepals, form a bell-shaped corolla. The five stamens alternate with the petals, and are attached to the inner surface of the corolla. From this surface, lower down and in the same vertical lines as the stamens, spring five small scale-like teeth. These curve inwards and cover the ovary, so that this is not seen on looking into the flower. The attachment of the stamens and scales is best seen if the corolla is removed and carefully slit up. The pistil will be left on the receptacle, and be clearly seen to consist of a globular reddish ovary, from the summit of which spring two styles ending in the stigmas. In each of the two cavities of the ovary are two ovules.

FIG. 10. — Fruit of the Dodder opening to liberate the seeds. (After Baillon.)

Small as the flowers are, they secrete nectar on the lower part of the ovary, and this is hidden and protected by the scale-like ingrowths from the corolla. Cross-pollination may take place by the help of the small flies that visit the flowers, or the latter may be self-pollinated. The ovary develops into a small capsule, which opens when mature by a circular split near the base. The upper portion comes off like a lid, and liberates the relatively large seeds (Fig. 10).

Each seed contains an embryo plant surrounded by food material. On germination a small and imperfectly formed root is sent down into the soil while the slender stem lengthens. The seed-leaves never expand or turn green. The stem undergoes circling movements, and should it come in contact with a suitable host plant it twines round it and becomes attached at first by hair-like outgrowths and later by haustoria. The further growth and spread of the plant has been described above.

The Mistletoe, in contrast to the Dodder, is only a partial parasite. It grows attached to various kinds of trees, very commonly to the Apple or Poplar. The general appearance of a plant of the Mistletoe on the tree which serves as a host is well shown in the plate. The photograph has been taken in winter,

so that the evergreen foliage of the parasite stands out prominently in contrast to the leafless branches of the tree. Specimens of Mistletoe for study are most easily obtained during the Christmas season from the shops, and it is often possible to get a portion of the host plant and study the insertion of the parasite upon it.

The thick base of the Mistletoe shoot will be found to send a root-like absorbent structure into the softer tissues of the branch of the host. This extends through the rind till it reaches the outer limit of the wood. At this level branches are formed, which run in the direction of the length of the branch of the host. From these branches pointed suckers, or *sinkers* as they are called, project into the wood of the tree. The wood is too hard to be penetrated by the sinkers, but these become embedded in it as new layers of wood are formed year after year. The growth of the sinker to keep pace with this proceeds at the base, not at the tip. By means of this peculiar system of root-like parts, which has only been briefly described, the Mistletoe is so closely connected with the wood of the host plant as to be able to absorb from it the water and other materials it needs.

The Mistletoe is, however, not wholly dependent on the host plant. It obtains water and salts from this, but can take in carbon dioxide from the air and manufacture complex food substances in its green leaves. The shoot consists of a persistent woody stem, the older parts of which have grown in thickness, bearing long oval leathery green leaves. The stems remain green for a long time, but ultimately become covered with a brown layer of cork. The leaves are borne at the nodes in whorls of two, and each has a bud in its axil. These buds develop as branches, and since the terminal bud usually forms an inflorescence and does not form a leafy shoot we obtain the peculiar forked branch-system of the plant. Inflorescences also form in the axils of the leaves at the base of lateral shoots.

Some plants of the Mistletoe bear male or staminate flowers, others female or pistillate flowers. The inflorescence is inconspicuous. It bears a terminal flower with two small scale-like bracts. In the axils of these are flowers, and these may in turn bear lateral flowers, so that there are usually three or five flowers in the inflorescence. The general appearance of the male and

female inflorescences and flowers will be gathered from Fig. 11, A, B. Each flower consists of four thick leathery sepals; there is no corolla. In the male flower there are four stamens, joined to the inner faces of the sepals; the anthers are peculiar in consisting of numerous rounded pollen sacs. In the centre of the female flower is a greatly modified pistil with an inferior ovary.

The fruit, developed from the ovary, is an opalescent white berry crowned by the remains of the flower (Fig. 11, C). It contains a seed, often with more than one embryo, embedded in a very viscid succulent mass. The fruits are greedily eaten by birds, and the seeds may be deposited in the slimy tenacious droppings on the branches of trees. By the running of the fluid excrement the seeds are usually carried to the sides of the branch, and may become fixed there. They may also be deposited on the branches when the birds are cleaning their bills of the viscid mucilage. On germination an attaching disc is formed pressed against the bark, and from the centre of this the first sucker is sent into the rind of the host. The cotyledons, which are already green in the seed, expand, and the further growth of the plant proceeds in successive seasons.

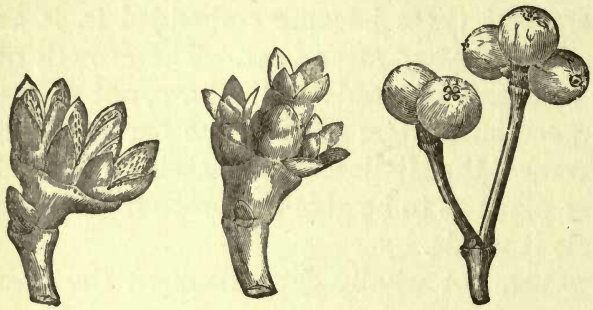


FIG. 11.—Mistletoe. A, Male inflorescence with open staminate flowers; B, female inflorescence with pistillate flowers; C, ripe fruits developed from the female flowers.

The Mistletoe, as will be gathered even from the brief description which is all that space permits, is a highly specialised plant in relation to its parasitic mode of life. It is a good example of a partial parasite, of which we have a number in Britain. These, however, are mostly connected with their host plants by suckers formed on the roots in the soil. Such plants as the Eyebright and the Yellow Rattle agree, however, in their mode of life with the Mistletoe in that, while they have green leaves and are capable of manufacturing food for themselves, they are partially

dependent on what they obtain from the host plants to which they become attached. Complete parasites, such as the Dodder or the Broom-Rapes (which grow on the roots of a number of different host plants), are more profoundly altered in relation to their mode of life than are the partial parasites.

The Sundew (*Drosera rotundifolia*, L.) and the Butterwort (*Pinguicula vulgaris*, L.)

The two plants just described were chosen because they illustrated some of the modifications and adaptations found in plants which live as parasites upon others, that is, take up the more or less complex food substances they require from the living host plant. Another interesting and well-known biological group of plants is formed by those which obtain part of their food from the complex substances forming the bodies of insects and other small animals. These are known as insectivorous plants, and two of the commonest to be met with on any moor or heath, especially in mountainous regions, are the Sundew and the Butterwort. (See *frontispiece* to Vol. III.)

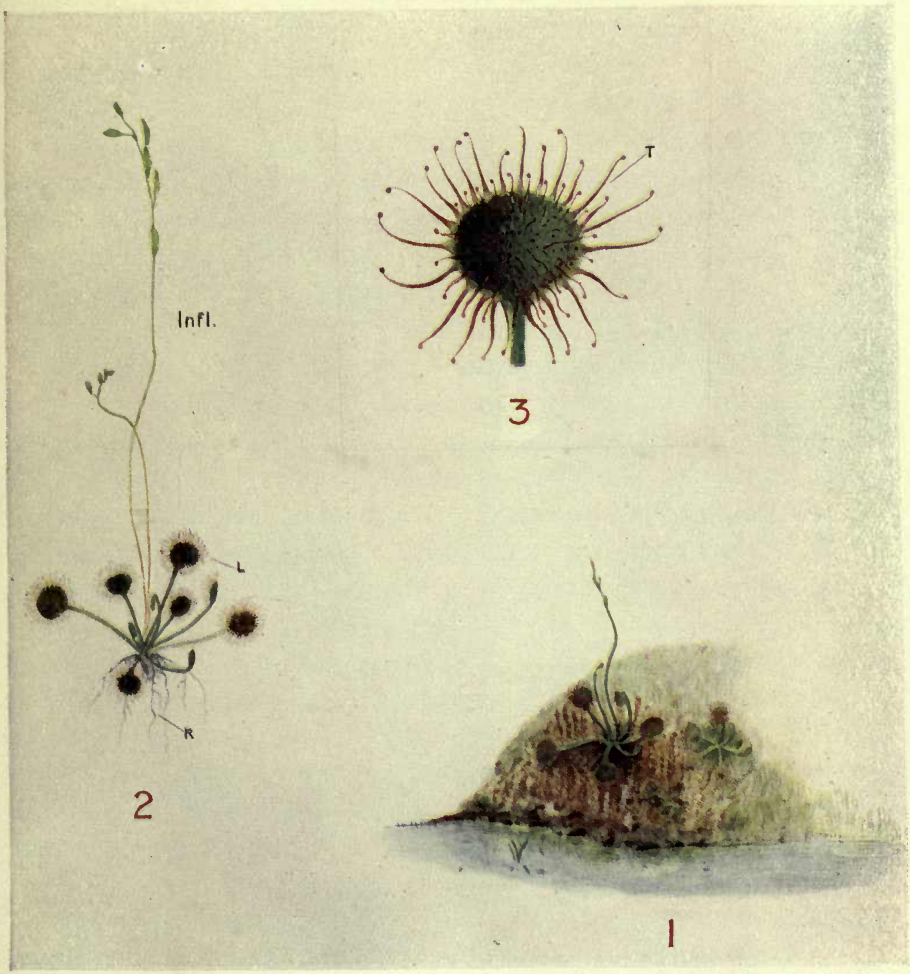
The Round-leaved Sundew (*Drosera rotundifolia*), which is represented in the accompanying plate, is the commonest British species of the genus, but any of the others will do equally well for study. It grows rooted in the peaty soil or very commonly in a clump of Bog-Moss. To properly study the plant, patches of the moss in which the Sundew is growing should be brought home, placed in a soup plate with water, and covered with an inverted tumbler or a bell-jar. They can thus be grown for a time and experiments made upon them.

The Sundew is a perennial plant, persisting over the winter in the form of a resting bud. A well-grown plant bearing inflorescences such as can be found throughout the summer is best examined in the first instance, but the attempt should be made to follow the history of the development during the year. Such a plant consists of a short stem bearing a rosette of foliage-leaves, and connected to the soil by a few thin sparingly branched roots; most of the roots are dark coloured, and have ceased to be of use, while one is usually lighter in colour and functional. The foliage-leaves are of peculiar shape, and construction and every detail

should be attended to. If one is pulled away from the stem it will be found to consist of a flattened base, a fairly long leaf-stalk, and the small and almost circular leaf-blade. Just where the sheath joins the stalk a number of narrow pointed scales extend across the upper surface like a ligule, and similar structures are found on the margins of the sheath. The scales are believed to collectively correspond to the stipules, which are thus joined across the upper surface of the leaf-base. The cylindrical leaf-stalk has a narrow wing to either side, and widens gradually into the leaf-blade. Its upper surface bears a number of fine hairs. The circular blade has a pale green colour. The lower surface is smooth, but its margins and the upper surface are covered with peculiar hair-like organs or tentacles. The marginal tentacles are much longer than those in the centre of the leaf, and their stalks have a red colour. The cylindrical stalk tapers from the base, and supports an oval reddish glandular head. When the plant is growing healthily this gland is surrounded by a transparent secretion, which forms a glistening drop. The secretion is sticky and viscid, and pulls out into long threads if the leaf is touched and the finger gently withdrawn. The appearance of the drops of secretion glistening in the sunlight has given the plant its popular name. The tentacles gradually diminish in length on passing inwards from the margin, and the centre of the blade is occupied by short straight tentacles with greenish stalks (Plate, Fig. 3).

Within the rosette of expanded leaves we come to young unfolding leaves. These take up a peculiar position in the bud, the blade being rolled inwards from either side and the whole blade bent down against the stalk.

The plant bears one or several inflorescences in the axils of the foliage-leaves. The inflorescence has a long slender bare stalk, on which the flowers appear as if borne laterally. Each flower has a small narrow bract at its base. The flowers face to one side of the inflorescence, which when its development is followed will be found to be a cymose one. The small flowers are only rarely found fully open. The calyx consists of five narrow green sepals united at the base. Narrow white petals alternate with the stamens, and further in come five stamens. The pistil in the centre of the flower consists of an egg-shaped ovary surmounted



ROUND-LEAVED SUNDEW (*Drosera rotundifolia, L.*).

I. PLANT GROWING AMONG BOG-MOSS.

II. COMPLETE PLANT. R. Root. L. Leaf. Infl. Inflorescence.

III. LEAF-BLADE SEEN FROM UPPER SURFACE. T. Tentacles.

by three bifid white stigmas. The ovary has a single cavity, the numerous ovules being attached along three lines of the wall, which correspond to the junctions of the three carpels. The fruit is a capsule which when young is protected by the surrounding parts of the flower, and ultimately opens by splitting into three valves. The numerous minute seeds are readily dispersed by the wind.

Besides the development of seedlings, the plant is perpetuated and sometimes increased in number by the development of winter buds. The apex of the main shoot forms a globular bud with crowded leaves closely packed together, and similar buds may form laterally. When the rest of the plant dies away the winter bud persists, and in the spring forms roots while the leaves unfold.

The chief interest of the plant lies in its insectivorous method of obtaining food. The plant can obtain water and salts by its roots, and can form food substances in its green leaves. But in addition it is specially adapted to attract, catch, and digest insects by means of the leaves. Small flies especially settle on the leaves when expanded in the sunlight. They are held fast by the sticky secretion on the tentacles, and their presence causes the long marginal tentacles to bend over and surround the body of the insect, applying the glands on all sides of the latter. These glands now secrete a digestive juice similar to that formed in the stomach of the higher animals. By means of this the substance of the insect is rendered soluble and absorbed by the leaf. When the leaf expands again only the indigestible remains of the insect are present on its surface. The behaviour of the leaves on being fed with minute particles of meat or white of egg can be studied in plants kept in the house.

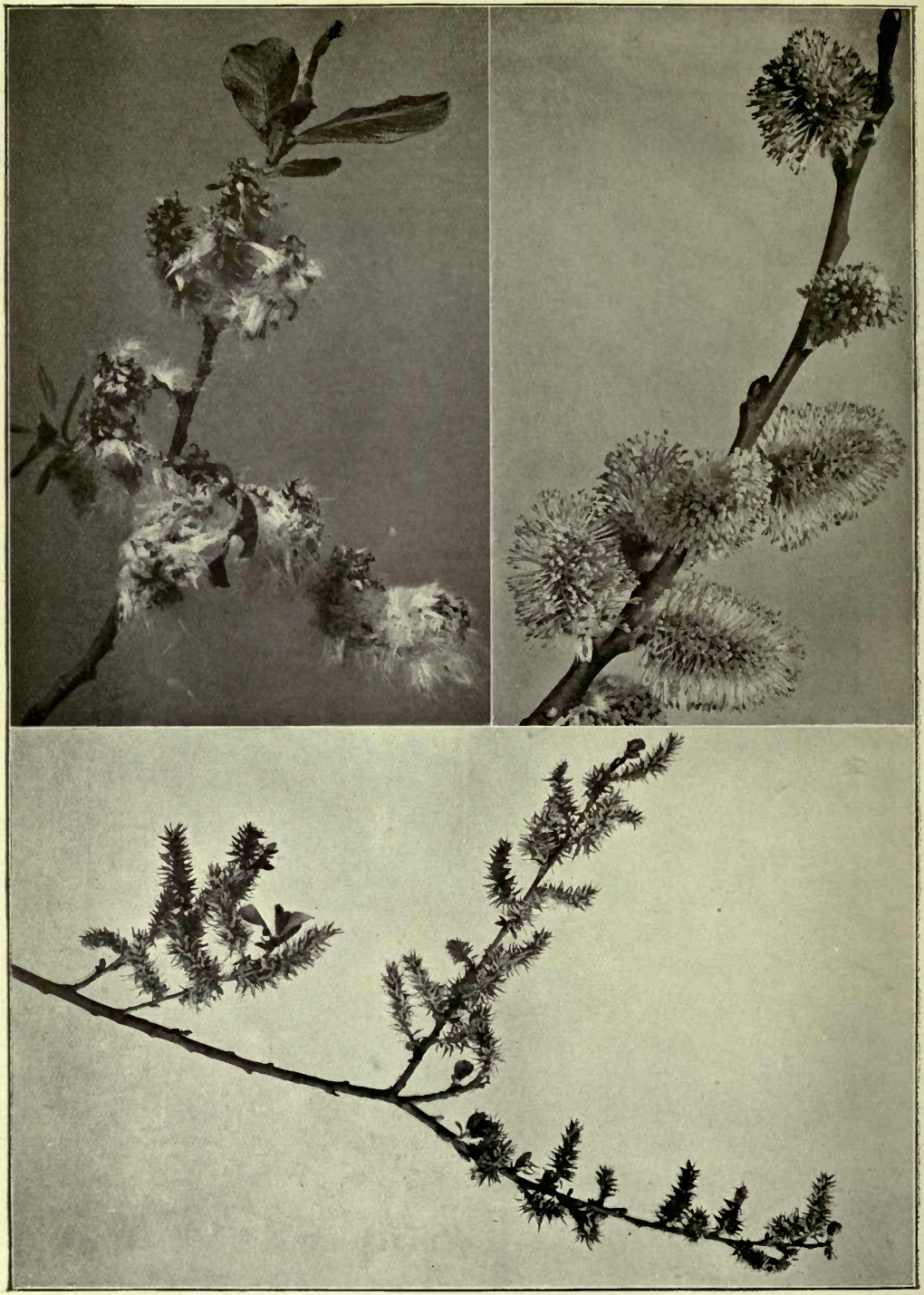
The Common Butterwort is another insectivorous plant often found growing along with the Sundew. Its appearance is shown in Fig. 12, which will assist the student in identifying the plant if he meets with it. Space will only permit of a very brief description. The plant consists of a short stem attached to the soil by roots, and bearing closely crowded, oval, pale yellowish-green leaves. The leaves, which are about an inch and a half in length and three-quarters of an inch across, are pressed firmly against the soil. The margins are usually slightly rolled in. The lower

surface is smooth, but the upper surface is studded with an enormous number of small glands. These are of two kinds, as can just be seen with a good lens, though microscopical study is needed to show their structure. Some of the glands are on the surface of the leaf, while others are raised on a stalk-like cell. These glands secrete a sticky mucilage, as can be shown by touching the upper surface of the leaf. It is easy to withdraw the finger from the leaf, but when a small midge or other insect lights or crawls on the leaf it is held fast by the sticky secretion and dies. Leaves may often be found studded over with the insects thus captured. The presence of the insects (or of small pieces of meat or egg placed experimentally on a leaf) causes the edges of the leaf to roll in somewhat and the glands to pour out a digestive secretion, which, as in the Sundew, renders the substance of the animal soluble. This is then absorbed into the plant by the leaf. The digestive secretion is only poured out when the substances placed on the leaf are of a meat-like or albuminous nature. The plant, as in the case of the Sundew, can live without insect food. Its leaves are green and it can manufacture food like any ordinary green plant, though it doubtless benefits by the addition to its food supply that it is specially adapted to obtain.

FIG. 12.—Plant of the Common Butterwort in flower. (After Baillon.)

Slender leafless branches, each of which bears a single large blue flower, stand in the axils of the foliage-leaves. The structure of the irregular flower will be understood from Fig. 13 with the aid of a brief description. There is a calyx of five small sepals. Within this comes the large irregular corolla, composed of five united petals. The lower portion of the corolla is continued back as a long pointed spur, in which the nectar is contained. The two very short stamens are attached to the anterior side of the corolla near its base, and their anthers face downwards. The globular green ovary surmounted by a short style and a two-lobed stigma

THE MISTLETOE (*Viscum album*, L.)



THE GOAT WILLOW (*Salix Capræa*, L.)

stands above the stamens. The relative positions of the parts is shown in Fig. 13, B, which represents a flower cut in half lengthwise. The flower is visited by bees, which on creeping into the flower in search of the nectar will first come in contact with the stigma and then get dusted with pollen. Cross-pollination thus results on the insect going to another flower.

The ovary has a single cavity, and bears numerous ovules on a

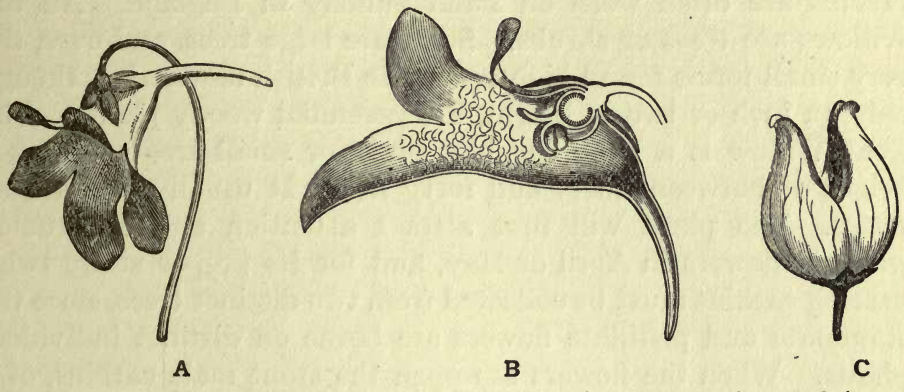


FIG. 13.—A, Flower of the Butterwort; B, flower cut in half lengthwise; C, fruit opening to liberate the seeds.

globular placenta projecting from its base. The dry fruit opens by splitting into two halves to liberate the seeds (Fig. 13, C).

The Butterwort, like the Sundew, grows on from year to year, and passes the winter in the form of a large yellowish-green winter bud developed from the apex of the plant at the end of the summer. This in spring develops roots, and unfolds as the shoot of the new plant.

THE GOAT WILLOW (*Salix Caprea*, L.)

The plants which will be described in the remainder of this chapter are all trees or shrubs. In these woody plants the system of shoots remains, and grows further year after year, the stems and roots increase in thickness annually, and the surface becomes covered with a protective layer of *cork*, and later in the trunk and larger branches with *bark*. These and other peculiarities of woody plants are dealt with in another section of this work. Only the features of the particular plants selected will be considered here.

There are a large number of different kinds of Willow to be

met with in Britain, and almost any of them will serve for study in the light of the description of one species. The following description may therefore be made somewhat general, but we shall take as our special example a very common species, the Goat Willow (*Salix caprea*), which is also known as the Sallow. This can easily be recognised by the fact that its flowers appear early in the spring before any leaves are on the tree. The shoots bearing the catkins are often worn on Palm Sunday in England. All the Willows are trees or shrubs. Some are large trees, and even the very small forms found high up on the British mountains, though only an inch or two in height, are perennial woody plants. The Goat Willow is a large shrubby plant or small tree reaching a height of between thirty and forty feet. It usually grows near water. The plant will first attract attention and be studied when it flowers in April or May, and for its proper study twigs bearing catkins must be collected from two distinct trees, since the staminate and pistillate flowers are borne on distinct individual plants. When the flowers are open the stout male catkins, of a bright yellow colour owing to the projecting stamens, are readily distinguished from the more slender olive-green female catkins. The two kinds are represented on the accompanying plate, the female catkins below, the male above and to the right. The catkins unfold from large lateral buds standing in the axils of leaves which fell off in the preceding autumn. During the winter they were enclosed and protected by hard brown bud-scales.

The catkin is a specially modified shoot bearing numerous flowers, an inflorescence. It consists of a main stem bearing a few scale-leaves at the base, but in this particular species no foliage-leaves. In the upper part the stem of the catkin bears numerous spirally arranged bracts, in the axil of each of which a single flower stands. The general construction is the same in the male and female catkins. The lower surface and margins of the bracts are clothed with long silky white hairs. These hairs increase the protection afforded by the bud-scales and render the young catkins as they burst from the bud white and silky. When the catkins have reached their full size the bracts are separated slightly by the growth of the stem,and the flowers project from between the bracts.

The male flowers consist of a very short stem bearing two stamens. These have long stalks, and the yellow anthers project freely from the catkin and make it conspicuous. There is no trace of either calyx or corolla, but at the base of the stamens on the side next the main stem of the catkin is a small yellowish scale. This is the nectary, and, simple as the flower is, nectar is secreted in abundance and serves as an attraction to insects.

The female flowers are equally simple, and also have a nectary in the same position as in the male flowers. The flower consists simply of the pistil. This has a short stalk which widens out into the green ovary. The ovary tapers gradually into the style, which bears a two-lobed stigma. As this indicates, the pistil is formed of two carpels, which are joined together by their margins to enclose a single cavity. On the inner surface of the wall of this are a number of ovules attached in two rows, corresponding to the lines of junction of the carpels.

The flowers are abundantly visited by insects, which come in search of nectar or of pollen from the male catkins. These are very conspicuous on the bare twigs, and the early period of the year at which the flowers open leads to many insects devoting their attention almost entirely to them. The long list of visitors includes bees by day and moths by night. Every collector of moths knows what a useful hunting ground the neighbourhood of Sallows in flower is. On visiting a male tree the insects will become dusted with pollen, which will be transferred to the stigmas when the female catkins are visited. The separation of the flowers on distinct trees makes self-pollination impossible, so that the efficiency of the insect pollination is shown by the number of fruits set in nearly every catkin.

After the catkins have developed and pollination is over the terminal bud of the twig and some of the lateral buds grow out as vegetative shoots. The stem of the shoot in its first year is cylindrical, and the surface is downy owing to a covering of short hairs. The leaves, attached singly at the nodes, have a wide sheathing base, to either side of which a large green stipule is usually developed. The short but distinct leaf-stalk widens into the simple oval leaf-blade, which has usually a pointed tip. The

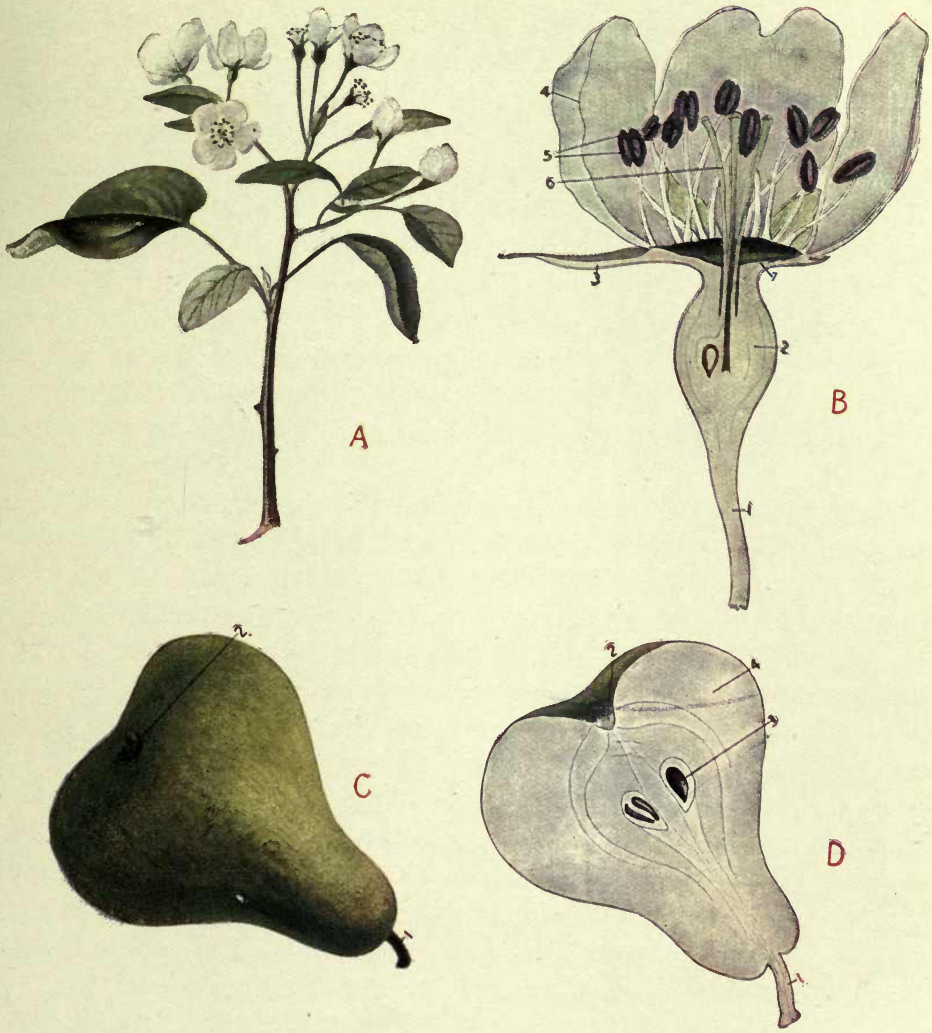
leaf-blade has a distinct midrib giving off lateral veins, and the surface is wrinkled between the meshes of the fine reticulate venation.

The male catkins fall off entire after flowering, but the pollinated female catkins persist, and their pistils enlarge and develop into the fruits. These have the same shape as the pistil, and when mature later in the year open to liberate the seeds. They then have the appearance represented in the third figure of the plate. The cottony white appearance is due to the seeds, which are being liberated from the open fruits. Each seed has a tuft of white hairs around its base. These cause the seeds to be readily carried by the wind and thus dispersed. In the autumn the Willow sheds its leaves, and the branches are, as in so many trees, bare until the next spring.

The Apple (*Pyrus Malus*, L.) and the Pear (*Pyrus communis*, L.)

The Apple and Pear trees are close relatives belonging to the same genus, and attention may be directed to some of the many features of interest they possess, though space will not allow of a complete description of either plant. It will be convenient to base the description on the Apple, pointing out features in which the Pear differs. Both are trees of moderate size, the main trunk and older branches being covered with bark, while all the branches except the leafy twigs in their first season have a brown covering of cork. We may limit our study here to the smaller branches and the flowers and fruits. Material for this can be obtained from any garden, the trees flowering in May and fruits being developed before the autumn. Both the Apple and Pear are found wild in Britain, but specimens of cultivated forms will be more readily obtained.

As is not uncommon in trees, we can distinguish several kinds of shoot making up the branch system. In the first place, there are the shoots from which all the increase in length of the branches proceeds. These have well-developed internodes separating the leaves, and the terminal bud carries on similar growth in the next season. Where lateral buds develop into shoots of this type



THE PEAR (*Pyrus communis*).

A.—Twig Bearing a Number of Small Branches with Foliage Leaves and Flowers.
B.—A Single Flower Cut in Half to show the Relative Positions of the Parts.
1. The flower-stalk. 2. The inferior ovary composed of the lower portions of the carpels enclosed by the receptacle of the flower. 3. Sepals. 4. Petals. 5. Stamens. 6. The upper portions of the carpels (style) ending in the stigmas. 7. The place where the nectar is secreted.
C.—Fruit of the Pear. 1. Stalk. 2. Remains of the calyx.
D.—Fruit Cut in Half. 1. Stalk. 2. Remains of the calyx. 3. Seeds. 4. The succulent portion of the fruit developed mainly from the receptacle of the flower.

they extend the branch system. In addition, however, to these shoots, the growth of which is unlimited, there are others into which the majority of the lateral buds develop. These short shoots only grow a small amount in length each year, and bear their leaves closely crowded. The shoot, which does not bear fruits in the accompanying plate, is of this kind. The slow growth of these shoots can be traced by observing how close the scars left by the scale-leaves enclosing the buds of successive years are. In the Wild Apple the tip of such a shoot may become hard and pointed and cease to grow; it is then modified into a thorn. Other short shoots bear a few foliage-leaves, and end in an inflorescence. All the flowers of an Apple or Pear tree are borne on short shoots of this nature, mostly produced in the axils of the leaves of the preceding season. Since the inflorescence terminates the flowering shoot, it is clear that when the latter continues to grow it must be from a lateral bud that the new growth proceeds.

The foliage-leaves are simple, with a slightly widened base, a well-marked leaf-stalk, and an oval blade which usually narrows to a point. The margin of the leaf-blade is cut into little teeth. At the base of each leaf is a pair of small narrow stipules that soon shrivel up. In contrast to the Wild Apple, which is almost hairless, the stems and the pale lower surface of the leaf in the cultivated varieties bear short whitish hairs.

The short flowering shoot, as was said above, bears a few foliage-leaves, and above them a few small leaves, each provided with a pair of stipules. The shoot terminates in a flower, while other flowers are borne laterally in the axils of the scale-leaves just mentioned and the uppermost foliage-leaves. The terminal flower opens first, and the others follow in order from below upwards. The group of flowers is conspicuous by reason of the large almost white petals, which are flushed with pink on the outer sides where they were exposed in the opening bud. The flower of the Pear, which resembles that of the Apple in its general construction, is white. Its appearance is shown in the accompanying coloured plate. Each flower has a stout downy flower-stalk that bears two bracteoles. The flower-stalk widens just below the flower into the inferior ovary, and the sepals, petals,

and stamens all appear to stand upon this. As the section of the flower of the Pear shows (Plate, Fig. B), this is a very instructive inferior ovary to study, for the hollow receptacle can be easily distinguished from the carpels with which it is fused. The calyx consists of five long pointed sepals, which are hairy both on the inner and outer surfaces. When the flower has opened and the protective function of the calyx is over, the sepals bend backwards and lie against the sides of the inferior ovary. The large petals are thin and delicate. They alternate with the sepals, and each has a short, narrow, stalk-like region, expanding into the oval conspicuous part. Within the corolla come the numerous stamens, the anthers of which are red in the Apple, yellow in the Pear. Surrounded by the stamens are the five styles, belonging to the five carpels which form the pistil. The styles are more or less united together below, where they are covered with soft white hairs, but their upper parts are free. Each style ends in a small stigma.

The surface of the concave disc between the insertion of the stamens and the base of the styles is the nectary, and is best seen when a flower is cut in half lengthwise. Such a section (Plate, Fig. B) also shows well the general relations of the various parts of the flower to one another. The flower-stalk is seen to widen into the hollow floral receptacle which closely surrounds and is united with the carpels to form the inferior ovary. Above this the receptacle continues as a thick rim, the inner sloping face of which is the nectary, while the sepals, petals, and stamens stand on the edge of the rim. Within the hollow receptacle are the lower portions of the carpels, the upper portions projecting as the styles in the centre of the flower. Within the carpels are the small ovules. Only two carpels will be cut through in this section of the flower, but on cutting the ovary of another flower across and looking at it with a lens five carpels will be seen. These can be more easily studied if the ovaries of flowers which are enlarging in the course of the development of the fruit are taken for examination.

The flowers of an Apple or Pear tree are very conspicuous. Not only are the individual flowers fairly large, but their association in inflorescences and the numbers borne on the tree increase

WILD APPLE (*Pyrus Malus*, L.)

Photo by Henry Irving, Horley.

HAWTHORN (*Cratægus Oxyacantha*, L.)

the prominence and attractiveness of the tree when in flower. Insects of various kinds—flies, bees, and moths—visit the flowers, and it is largely by their agency that pollination is effected. Self-pollination, while not entirely prevented, appears to be much less satisfactory than cross-pollination. The stamens and stigmas of the flower of the Apple are mature at the same time, but in the Pear the stigmas are mature for some days before the stamens open, so that self-pollination is rendered less likely. The insects pass from flower to flower, sucking nectar or collecting pollen, and a spell of favourable weather at the time the flowers are opening has its result in efficient pollination, and the consequent development of many fruits.

The fruits of the Apple and Pear, while differing in shape and details, are constructed on the same plan. The petals have fallen off, but the fruit, which corresponds to the further developed inferior ovary, is borne on the thickened flower-stalk, and crowned with the remains of the calyx and stamens. Its structure is seen if cut across or lengthwise (Plate, Fig. D). The succulent portion within the skin is mainly derived from the further development of the hollow receptacle. The carpels, which are only indistinctly marked off from this, contribute, but their inner walls are distinct, forming the "core" of the apple. Each of the five chambers of this usually encloses two black seeds. The fruit is evidently adapted to be eaten by animals, which would carry the seeds to a distance from the parent tree. In the cultivated varieties the succulent portion has been enlarged and become more palatable than in the wild form, a photograph of the fruits of which is represented on the plate.

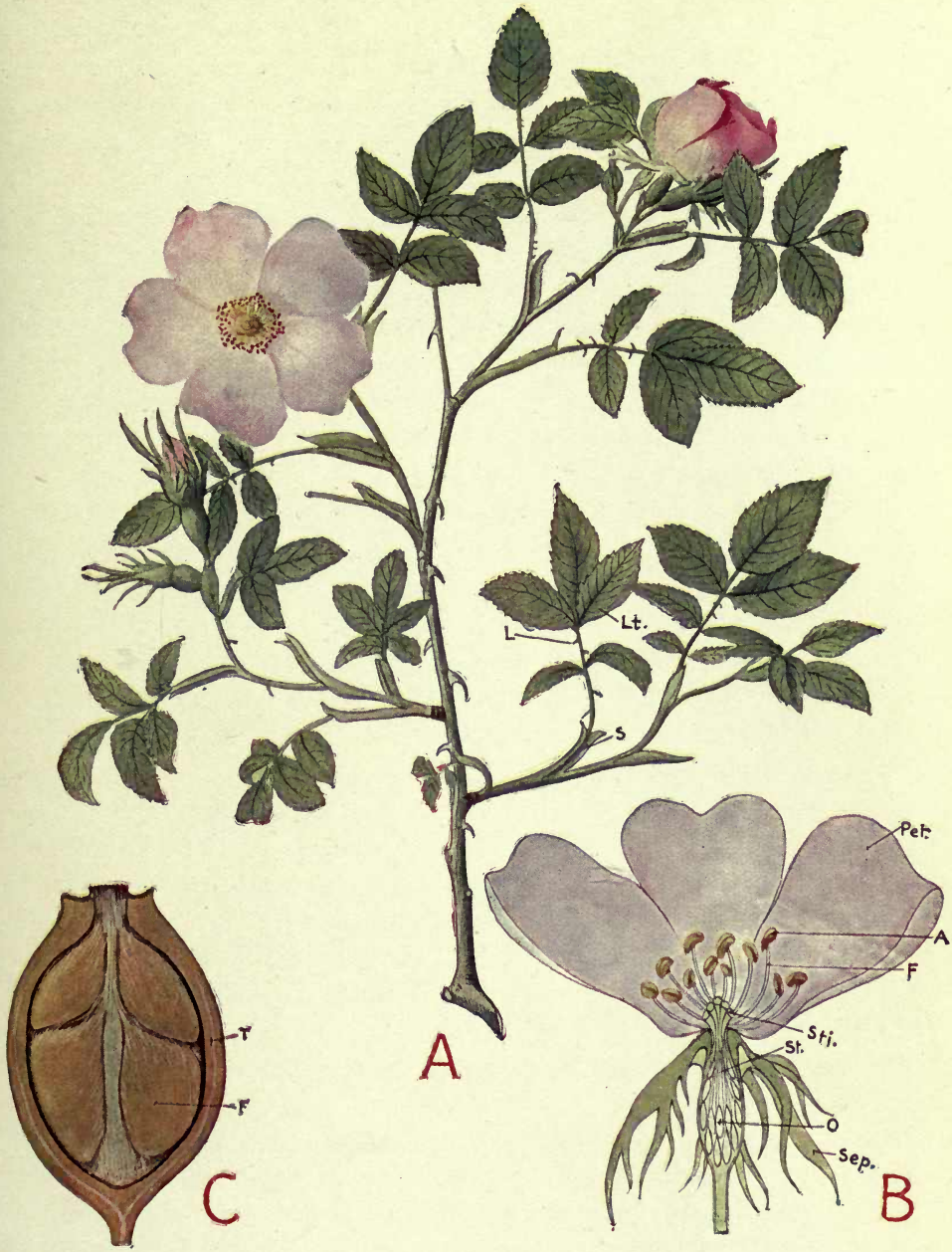
The Hawthorn is a near relative of the Apple and Pear and will repay careful study. Space will not allow of its description, but it may be pointed out that the flowers are constructed on the same general plan. The ovary, however, contains only one carpel, or two or three. The fruit has a succulent outer layer, enclosed in which is a stony core protecting the seeds. The fruits are adapted to be eaten by birds, the stone protecting the seeds when passing through their digestive tracts. The conspicuous inflorescences of the Hawthorn are represented in the accompanying plate.

The Dog Rose (*Rosa canina*, L.)

The wild Roses of Britain are represented by numerous more or less distinct kinds which have been variously grouped by systematic botanists, some recognising only a few species with numerous varieties, while others regard most of the minor forms as species. The occurrence of these numerous forms must be borne in mind when differences in detail are found between the specimen studied and the following description. Some details, which vary in the different forms of the Dog Rose, have been passed over to make the account serviceable as a guide to the study of almost any specimen.

The Dog Rose is a shrub, the shoots of which are profusely branched and persist from year to year. The older woody stems attain a considerable thickness, but no single main stem increases beyond the others in thickness, as in trees as distinguished from shrubs, nor does the plant reach the size of a tree. The long branches either hang down or straggle over neighbouring shrubs, from which they obtain support. The *prickles* of the Rose are of assistance in this. They are bulky structures of the nature of hairs that arise from the outer layers of the stems and leaf-stalks. As is shown in the plate, the prickles are flattened from side to side and taper from an oval base to a sharp point ; they are curved so as to point towards the base of the stem. It is easy to see that, while they offer no obstruction to a branch of the Rose growing up between other herbage, they will interfere with its being pulled back from the position it takes up. The general appearance and mode of growth of the plant should be studied in the field, while shoots, including both the growth of former years and the foliage and flowering shoots of the current season, should be cut off and brought home for detailed study. This is best done in July when the plant is in full flower, but later in the season the fruits must be collected and examined in order to complete the study of the plant.

The parts of the shoot which grew in former years can be distinguished at once from the growths of the present season. The older parts are brown, from the presence of a layer of cork protecting the surface, and they have lost their leaves. The small



THE WILD ROSE (*Rosa canina, L.*)

A.—Flowering Shoot. L. Leaf. Lt. Leaflet. S. Stipule.

B.—Flower Cut in Half. Sep. Sepal. Pet. Petal. F. Filament. A. Anther. O. Ovaries. St. Styles. Sti. Stigmas.

C.—Fruit Cut in Half. F. Fruitlet. T. Succulent receptacle.

leaf-scars, where the latter separated from the stem, can be distinguished, and immediately above each scar is a bud, or the shoot developed from it. Other markings on the smooth surface of the internode are the small reddish-brown lenticels, which allow of ventilation taking place through the layer of cork. The amount of growth in length of the shoot in each of the preceding years can be ascertained by noting the closely crowded scars left by the bud-scales. These mark the lower limit of each season's growth. The growth of the present year continuing a main shoot has, on the other hand, a smooth green surface, and bears foliage-leaves singly at the nodes. At the base are the marks of the bud-scales, and earlier in the season these can be found and studied. Each scale corresponds to the enlarged leaf-base and stipules of a leaf, the leaf-blade of which is not developed. Above these come one or two leaves intermediate between the scales and the fully developed foliage-leaves, then a number of the latter, and the shoot ends either in a vegetative bud or in a flower. The lateral shoots arising from the buds borne on the shoot of the previous year mostly bear, after the bud-scales, a limited number (three to five) of foliage-leaves, and end in a flower (Plate, Fig. A).

The foliage-leaves are compound and pinnate. In the Dog Rose there are two or three pairs of lateral leaflets and a terminal leaflet. The leaf appears to join the stem by a wide sheath. This corresponds, however, to the leaf-base and the pair of large stipules, the latter being joined to either side of the base of the leaf, leaving only the tips free. The lower surface and margins of the stipules in most varieties bear reddish glandular hairs. The leaf-stalk is almost cylindrical, with a narrow groove on the upper surface. It continues into the spindle of the leaf bearing the leaflets. These have practically no stalks ; each has a well marked midrib, and the two halves of the leaf-blade differ slightly in size and outline. The margin is toothed, a minute pore, from which water is excreted under certain circumstances, occupying the tip of each tooth.

The flowers are often solitary at the ends of lateral shoots, but additional flowers may be developed in the axils of the leaves immediately below the terminal flower. The flower itself is a large and conspicuous one, owing especially to the widely spreading pink petals surrounding the numerous yellow stamens. The

green flower-stalk widens out below the calyx and corolla into an elongated green body which resembles an inferior ovary. This is really only a cup-shaped development of the receptacle of the flower, as can be seen by splitting a flower in half (Plate, Fig. B), when the separate carpels will be found springing from the inner surface of the cup. The calyx, corolla, and stamens spring from the margin of the cup.

The five sepals are green, dotted with red glandular hairs on the outside, and covered with a growth of short silky hairs on the inner surface. They do not stand at exactly the same level, but form a spiral, the outermost sepals having rudimentary pinnæ on one or both margins. The five large and delicate petals, which alternate with the sepals, are more or less rounded and widen out from a narrow attachment. This is yellowish; the lower part of the petal is almost white, while nearer the edge it becomes a delicate pink. Immediately within the regular corolla come the numerous stamens, which also stand on the margin of the cup-shaped receptacle. Both filaments and anthers are yellow, so that the flower has a conspicuous yellow centre. The anthers stand at about the same level, since the filaments of the outer stamens are longer and more inclined, while those of the inner ones are shorter and more erect. In the centre of the flower is the group of stigmas projecting from the narrow opening of the cup formed by the receptacle. In a flower which has been cut in half it is easy to see that the carpels are distinct from one another, and stand on the inner surface of the cup. Each consists of a swollen ovary at the base, containing one ovule, a long style, and a slightly dilated stigma. The inner surface of the cup and the surface of the ovaries are clothed with long silky hairs, and similar but shorter hairs are borne on the style. The narrowing of the mouth of the cup is due to the presence of a swollen yellow rim, which has all the appearance of a nectary, though it secretes little or no nectar.

The flower is, however, visited by many insects (bees, beetles, and flies), which come to collect or feed off the pollen. The stamens and stigmas are mature at the same time, so that self- or cross-pollination may result from the visits of the insects. Since, however, the centre of the flower, where the group of stigmas

is situated, is the most convenient alighting place, an insect dusted with pollen coming from another flower is likely to effect cross-pollination. As the opening of the stamens proceeds pollen will fall on the stigmas of all flowers that do not stand erect. The pollination mechanism of this flower is thus a simple and little specialised one as compared with that of many of the flowers that have been described.

That pollination is successfully effected is shown by the large crop of fruits that almost every bush of the Dog Rose bears. The fruits are known as "Hips," and are derived from the hollow receptacle enclosing the fruitlets. Each fruit is surmounted by the remains of the calyx, stamens, and stigmas, the petals having fallen off. On cutting open the fruit we find that the floral receptacle has increased in size and thickness, while the separate carpels have developed into the fruitlets. The wall of the receptacle in the developing fruit is at first green and firm ; later it becomes bright red and softer. Each fruitlet is pale brown in colour and is clothed with hairs ; it bears the remains of the style. The wall of the fruitlet is hard and stony, and protects the thin-walled seed. The fruits often remain on the branches after the leaves have fallen, and are sought after by birds as food. They eat the succulent tissue, and either leave the fruitlets on the ground or swallow them. In either case the fruitlets are deposited at a distance from the parent plant, and the seeds thus dispersed.

The Ash (*Fraxinus excelsior*, L.)

The Ash, like any other tree, requires to be studied at different seasons of the year to gain a proper idea of its annual history and to obtain the flowers, buds, foliage, and fruits. The Ash is one of the most beautiful of our native trees, and is largely planted through the whole of Britain. Good specimens attain a height of over one hundred feet, and have a longer or shorter trunk and a loose crown of branches bearing the foliage. The root system extends deeply into the soil, from which it obtains the relatively large quantities of water that this tree requires. During the winter the branches are bare ; in early spring the flowers open, and flowering is over before the buds have expanded. The leaves unfold later than those of most other trees, and also fall early in

the autumn, often without changing colour. The fruits developed from some of the flowers remain on the branches in the autumn and winter and are gradually scattered by the wind.

The bark of the trunk of younger trees and of the branches is smooth and grey ; on old trunks it becomes furrowed but never scaly. The twigs in the winter condition are leafless, but marked with the large and prominent leaf-scars of former seasons. These stand in pairs at each node. The grey cork-covered surface of the internode is dotted over with small lenticels. Immediately above the leaf-scars we find the dark, almost black, lateral buds, and the tip of the shoot is occupied by a larger bud (Fig. 14, 1). The structure of the buds can be best studied when they are expanding. On the outside will be found some three pairs of bud-scales alternating with one another and increasing in size from without inwards. The inner surface of the scales is smooth, but the outer surface and margins bear short brown hairs. The portions of the outer surface exposed during the winter on the outside of the bud are deep velvety black, owing to the covering of short black hairs. Sometimes the scales of the innermost pair have small leaf-blades at their tips, and thus afford a transition to the foliage-leaves, but usually the change is an abrupt one.

The foliage-leaves are arranged in alternating pairs on the stem. Each has a thick base without stipules, narrowing into a strong leaf-stalk which bears some five pairs of leaflets and ends in a terminal leaflet. Each leaflet has a short stalk and a large leaf-blade, which tapers gradually from near the base to the point. The margin is toothed. Lateral veins run out from a well-marked midrib. The much lighter colour of the under as compared with the upper surface of the leaflets gives the characteristic appearance of Ash trees in the wind. The leaves are detached by the first frosts and fall early.

Before the leaves have unfolded in the spring some of the lateral buds on last year's shoots will be found to be developing not into leafy shoots but into inflorescences (Fig. 14, 1). These, though not brightly coloured, are conspicuous on the bare twigs. The inflorescence is repeatedly branched, the branches standing in the axils of minute scale-leaves, which, like the bud-scales enclosing the whole, are arranged in alternating pairs. The

ultimate branchlets end in the flowers, of which a very large number are borne on each inflorescence. The flowers themselves

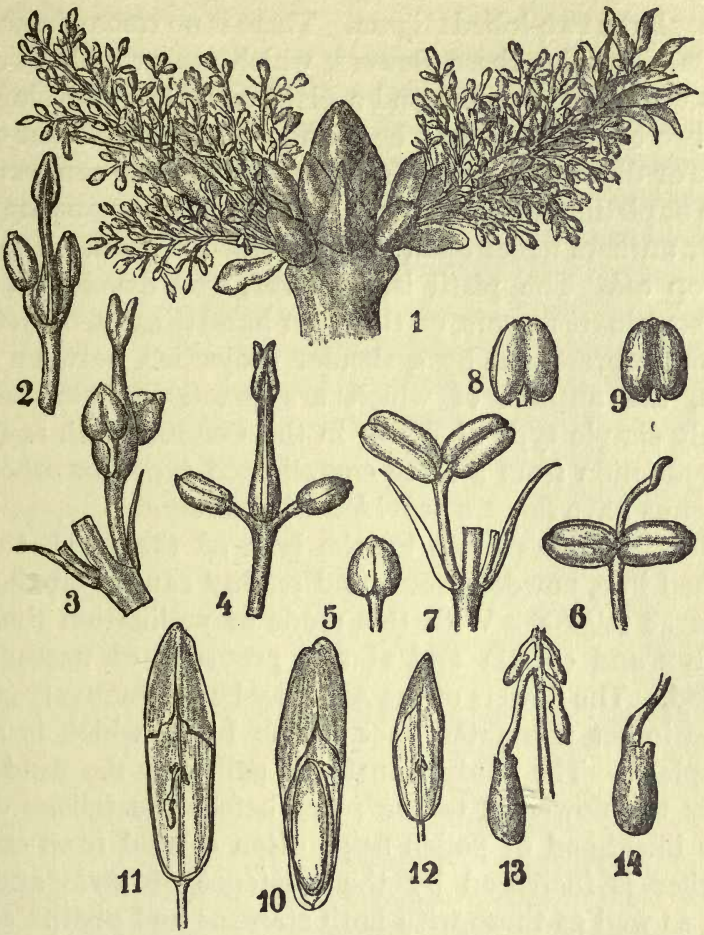


FIG. 14.—The Ash. 1, End of shoot in spring, showing the terminal bud and two inflorescences; 2, 3, flowers with both stamens and pistils; 4, pistillate flower with stamens which do not open; 5, one of these stamens; 6, staminate, or male flower, with rudiment of the pistil; 7, male flower with no trace of pistil; 8, 9, the anther seen from back and front; 10, ripe fruit opened to show the seed; 11, young fruit, showing the attachment of the ovule; 12, sterile fruit; 13, the four ovules from a young fruit, one of them is enlarging to form the seed; 14, the young seed. (After Schumann.)

are individually inconspicuous and of very simple construction. The most complete flowers consist of two stamens and a pistil

composed of two carpels (Fig. 14, 4). Each stamen has a short stalk and a purplish anther. The pistil consists of a somewhat flattened ovary, which narrows gradually into the style ; this ends in a rather large two-lobed stigma. There is no trace of either calyx or corolla. Besides these flowers, which are provided both with stamens which form pollen and a pistil capable of developing into a fruit, two other kinds may be found. These may occur either on the same or different trees. In one type which we can recognise as a female or pistillate flower (Fig. 14, 4) the two stamens are present, but their anthers never open and no pollen is shed. The anthers soon drop off. The pistil is, however, well developed. In the male or staminate flowers, on the other hand (Fig. 14, 6, 7), the pistil is at most represented by a slender projection between the two stamens, the anthers of which are practically stalkless. The extremely simple type of flower in the Common Ash is evidently due to reduction from a more complicated type, for other species of the genus have flowers provided with a calyx.

Pollination takes place by the help of the wind, the pollen being shed in a powdery form and readily caught on the surface of the large stigma. With this mode of pollination the absence of a calyx and corolla and of any provision of nectar may be associated. The flowers of the Ash may be instructively compared with the insect pollinated ones of the Lilac, which is a closely related plant. The ready transfer of pollen by the wind is facilitated by the flowering taking place before the foliage develops, and the likelihood of pollen being often carried from one flower to another is increased by the existence of male and female flowers, as well as those with both stamens and pistil.

The pistil is formed of two carpels, and the ovary is divided into two cavities. In each of these are two small hanging ovules. After flowering many of the flowers and often whole inflorescences fall off, but the ovaries of others increase in size and become the fruits. The hanging bunches of flat green fruits remain on the branches for months, and are commonly known as "keys." Some of the fruits are shorter and broader, and on dissection will be found to contain no perfect seeds (Fig. 14, 12). In the longer fruits, on the other hand, one of the ovules is developed into the single seed (Fig. 14, 11, 12, 13). This forms a swelling in the

lower part of the flattened green fruit. The upper portion of the latter is thin and flat, and has a slight spiral twist. The remains of the style may be found springing from the slight indentation at the free end.

The fruits ultimately turn brown and dry. They remain hanging for some time on the tree, but gradually become detached and flutter down. The thin wing formed by the upper part of the fruit offers a considerable surface to the wind, and the twist which this exhibits further retards the fall and increases the chance of the fruit being carried to some distance from the parent before it reaches the ground. Since only one seed is developed in the fruit there is no need for the latter to open, the wall of the fruit remaining to protect the seed until germination. The seed contains a considerable store of food material to enable the young plant to start its growth, and seedlings can usually be found in the neighbourhood of the tree, though the conditions rarely allow of their growing on into mature plants.

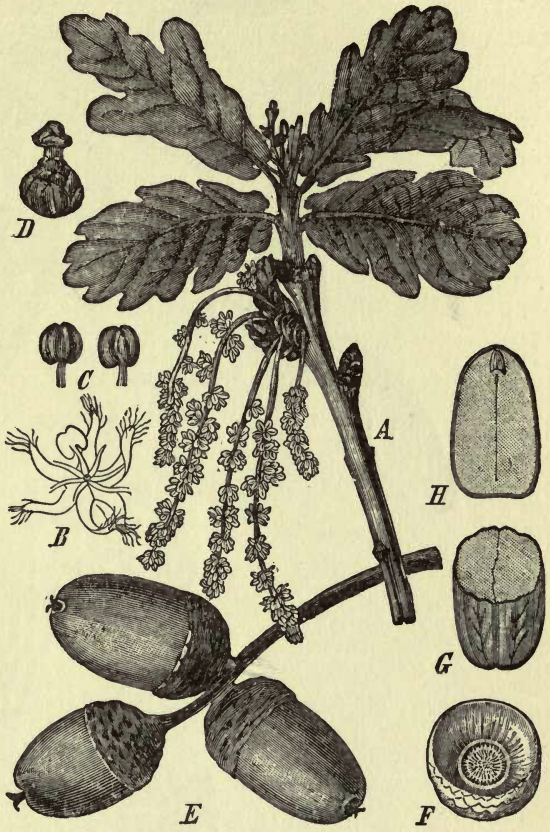


FIG. 15.—The Oak. A, Shoot in early summer, showing the foliage and the male and female inflorescences; B, male or staminate flower; C, stamens; D, pistillate flower; E, stalk of the inflorescence bearing the fruits (acorns); F, the cup surrounding the base of the fruit; G, seed removed from the fruit and cut across; H, seed cut lengthwise. (From Strasburger's *Lehrbuch der Botanik.*)

It may be added that with the help of a sharp knife and a pocket lens many of the features in the mode of growth of a woody plant can be made out on twigs and branches of various

ages of the Ash or other tree. The development of cork and bark, the position and structure of the lenticels, and the annual increase in thickness of the shoot due to the activity of a

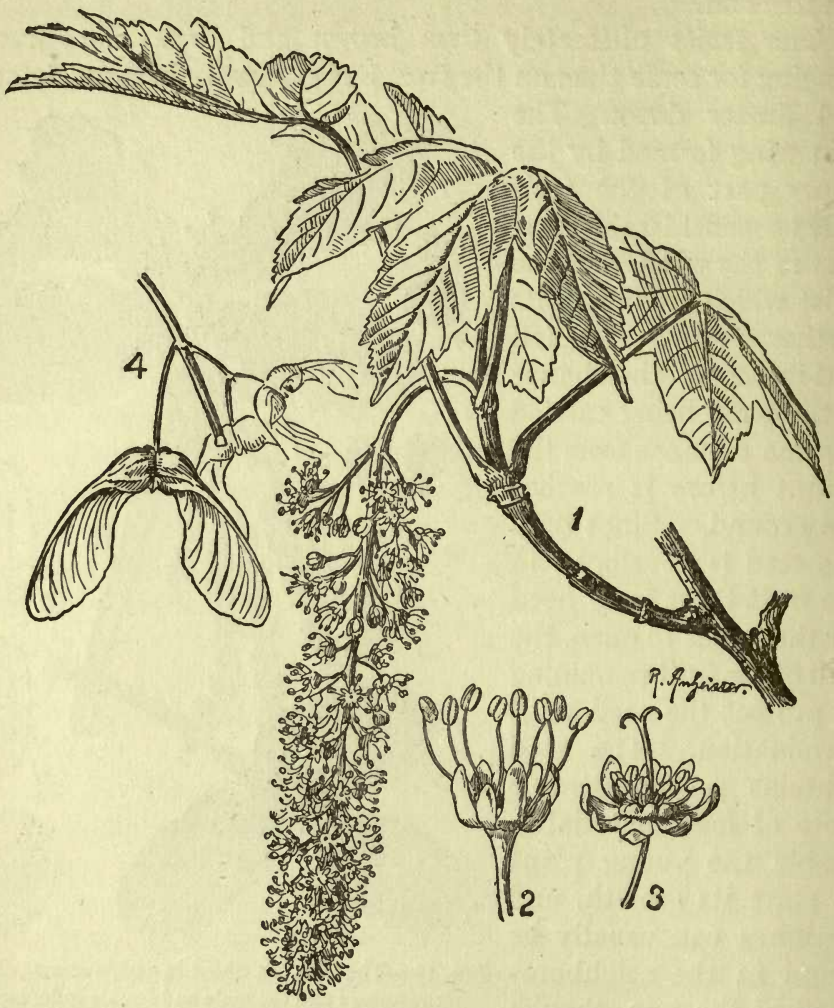


FIG. 16.—The Sycamore. 1, Shoot bearing foliage-leaves, and ending in the inflorescence; 2, male or staminate flower; 3, pistillate flower, with stamens which do not open; 4, winged fruits. (From Strasburger's *Lehrbuch der Botanik.*)

growing zone just outside the wood, can all be studied in this simple way.

Space prevents entering more fully into this aspect of the study of a tree, and also the description of other common trees. So many

interesting lines of nature study can, however, be based on trees, that figures are given of the flowering shoots, flowers, and fruits of two other common trees, the Oak and the Sycamore. The descriptions of these figures will assist the student in extending his studies from the Ash to other trees.

CHAPTER II

The Scots Pine (*Pinus sylvestris*)

All the plants which have been described in the preceding chapters belong to the great group of the Angiosperms, the flowering plants in the narrower sense of the word. The Pine and its relatives also bear flowers, but they differ in some very important respects from the flowers we have as yet studied. The Pines, Firs, Monkey-Puzzles, Cypresses, Yews, and a number of other plants belong to the group of the Gymnosperms, the second great group into which the vegetable kingdom is divided. This group, as compared with the Angiosperms, is represented by comparatively few genera and species at the present time. It is, however, the more ancient family of plants, and at a period in the earth's history a little before the chalk was deposited the bulk of the vegetation was composed of plants belonging to this group. The name Gymnosperm leads us to consider one great point of difference from the plants hitherto studied. It is derived from two Greek words, and means "naked-seeded." The ovules, and of course the seeds developed from them, are not enclosed in an ovary, as in the Angiosperms, but borne on the surface of certain leaves which do not compose a pistil. All the plants of the group are trees or shrubs, and in their general construction they resemble the trees we have just considered. They differ, however, in features of minute structure into which we need not enter.

There are only three Gymnosperms which are native British plants. These are the Pine, the Yew, and the Juniper. Many others, from all temperate parts of the world, are often planted as ornamental trees or shrubs. With these few remarks to explain why the Pine is treated apart from the other Flowering Plants, we may proceed to describe it as another example for detailed study.

The Scots Pine is one of our most beautiful trees, occurring wild or self sown in many places, though most of the examples met with will have been planted. When young the tree has the regular pyramidal form familiar in its relatives used as Christmas trees, but in old trees the lower branches have usually perished and the crown of branches borne on the stout tapering trunk is irregular and often very beautiful. The trunk and branches are clothed with a characteristic scaly bark and have a reddish tint. The foliage is confined to the younger twigs, but branches of from three to five years old are bare, having lost the evergreen foliage.

If a leafy shoot of the Pine is examined it will be found that the green leaves are not borne directly on the main stem. This bears only small pointed brown scale-leaves, which are spirally arranged and closely crowded. In the axil of each of these scale-leaves is a lateral shoot. This has a short cylindrical stem bearing the remains of a few scale-leaves and only two green foliage-leaves. Between these the little growing point of the shoot will be found, but it remains inactive and the shoot bears no more leaves and does not increase in length. These two-leaved shoots upon which all the foliage of the tree is borne are called "short shoots," in contrast to those to which the growth and branching of the plant is due. These "long shoots" bear, as has been seen, only brown scale-leaves. The foliage-leaves are the well-known "needles" of the Pine. Each is long, narrow, and pointed; convex on the lower surface, but flattened above. After living for several seasons, the short shoots with their leaves drop off, and the older parts of the branch system are bare except for the remains of the scale-leaves.

The tip of each long shoot ends in a large brown bud. This is covered with bud-scales which protect it through the winter. In the spring it grows into a shoot increasing the length of the branch, and in turn ending in a bud. The short shoots bearing the foliage-leaves are already developed upon the new growth and have only to attain their full size. Just beneath the terminal bud are several similar buds borne laterally. These, like the terminal bud, do not develop further until the following spring, when they grow out into long shoots. The branches thus stand,

several at the same level, at the upper limit of each annual addition in length to the main stem or branch. This position of the branches on the main trunk is best seen in a young tree, and leads to the regular conical outline of this.

The Pine bears two kinds of flowers, staminate or male, and the female cones; these occur on the same tree and often on the same branch. These flowers are borne on the new growth of the season, and are

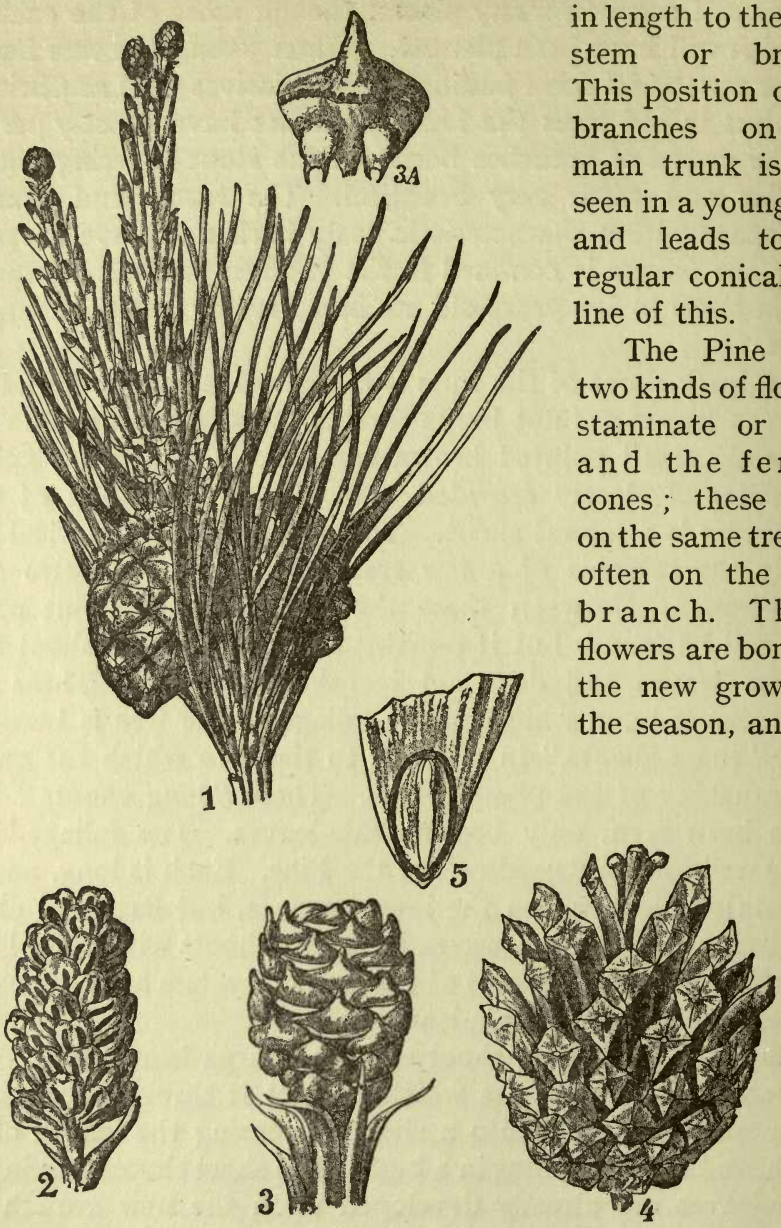


FIG. 17.—Scots Pine. 1, Branch showing the growth of last year and of the current season; the small cones at the tip are ready for pollination, those below were pollinated a year ago; 2, male flower enlarged; 3, female flower or cone at the time of pollination, enlarged; 3A, single ovuliferous scale showing the position of the two ovules; 4, mature cone opening to let the seeds escape; 5, seed, cut through to show the embryo plant. (After Schumann.)

thus apparent in the spring. They are best studied in material collected towards the end of May, at which time the stamens will be opening and the female cones be ready for pollination. The positions which the two kinds of flower respectively occupy on the long shoot bearing them is best defined with relation to the short shoots and lateral long shoots that have been seen above to occupy definite positions. The male flowers take the place of a number of the short shoots at the base of the current year's growth. Each male flower stands in the axil of a scale-leaf. The small cones or female flowers, on the other hand, occupy the place of the large lateral buds at the summit of the shoot; usually one to three cones are developed on the shoot. Their appearance is represented in Fig. 17, 1.

A single male flower is shown in Fig. 17, 2, on an enlarged scale. The slender stem bears a few scale-leaves below, and further up the numerous closely crowded stamens, which are arranged in a close and complicated spiral. Each stamen is a little leaf with a short stalk widening out into a thin oval blade. This extends almost horizontally from the stem of the flower, but the pointed tip bends upwards. Hanging down from the horizontal portion is a pair of pollen sacs. These when young are protected by the terminal portion of the stamen below. When the flower is mature its stem lengthens slightly, thus separating the stamens. Each pollen-sac then opens by a longitudinal split shown in the figure, and the yellow pollen readily escapes. On touching a branch with mature male flowers this comes out in a dusty yellow cloud. The pollen grains are peculiarly constructed to render them especially buoyant, but this can only be seen with a compound microscope. It will be clear, however, that abundant pollen is produced and that it is well suited for wind-pollination.

One of the young female cones or flowers is shown similarly enlarged in Fig. 17, 3. In colour it is usually pink or purplish red, sometimes greenish. At the base of the rather stout stem are a few scale-leaves, and above this come the structures bearing the ovules. These are most simply regarded as leaves, and compared with the carpels of the flowering plants we have studied. Each consists, however, of two parts, a small pointed scale-leaf

and, springing from the upper surface of this near its base, a wider and thicker structure which bears the ovules. These two parts are known as the bract-scale and the ovuliferous scale respectively. In Fig. 17, 3A, a single scale is seen from above, the ovuliferous scale completely hiding the smaller bract-scale. On the upper surface close to the stalk-like attachment of the scale to the main stem of the cone are two large ovules, not enclosed in an ovary, but freely exposed. When the little cone is ready for pollination the stem lengthens slightly, thus separating the scales. Some of the numerous pollen-grains in the air around will enter the clefts between the scales of the cone and reach the ovules. The pollen-grains in this case do not light on a stigma at some distance from the ovules, but on the tip of the ovule itself, which points towards the main stem of the cone.

After pollination, which happens about the end of May, the cone grows a little and the scales close tightly together again. The use of the male flowers is now over, and they fall off, leaving bare regions of the shoot. The pollinated cone, however, continues its development, which takes a long time. By June of the next season the cone has the appearance represented in the lower portion of Fig. 17, 2. If a cone of this age is dissected the bract-scales will no longer be distinguished, but the ovuliferous scales have enlarged greatly and the two ovules are now large bodies. These ovules are fertilised about this time, although pollination took place more than a year previously.

During the second summer the fertilised cone continues to grow, and as it matures the scales become dry and woody. In the autumn of this year or the following spring the scales separate and bend back, allowing the seeds to escape (Fig. 17, 4). Each seed is derived from an ovule, and carries with it when it separates from the surface of the scale a thin wing which offers resistance to the air and helps in the dispersion of the seeds by the wind. Fig. 17, 5, shows a seed and a portion of the wing. The seed is cut open, and the straight embryo-plant surrounded by a white mass containing reserve food can be seen enclosed in the thick hard seed-coat.

On germination the plant sends out a primary root, which penetrates the soil and grows into the main root of the tree.

The seed-leaves, of which there are usually six, remain for a time in the seed absorbing the food material, and later, when the seed-coat is thrown off, expand as a whorl of needle-shaped green leaves. In the centre of these is the terminal bud, which grows on to form the main shoot of the tree. The main shoot for a number of years bears green needle-shaped leaves, but in time the condition studied in the shoots of the mature tree is established and the long shoots bear only scale-leaves, in the axils of which bi-foliar short shoots stand. Each year the growth of the main shoot adds to the height of the tree, and since a number of branches, which grow in the same fashion, are formed after the first year or two at the upper end of each year's growth, the tree takes on a very regular shape. As it grows, however, the lower branches usually disappear, and the mature condition with a well-marked trunk and a crown of branches is attained. This increase in size and weight would not be possible did the stem and branches not increase in thickness and strength yearly. The yearly additions to the wood are well seen when a tree is cut down, and appear as the annual rings in the wood. By counting these the age of the tree can be ascertained. The root also has branched widely in the soil and fixes the tree firmly, and the main root and its branches, like the stems, grow in thickness. When the tree is from fifteen to thirty years old it begins to flower. The tree attains a height of from eighty to one hundred and twenty feet, and lives for several hundred years.

CHAPTER III

Arrangement of the Plants described in their Families or Natural Orders

This section of the Book of Nature Study has been devoted to the description of between forty and fifty common Flowering Plants. The student who has examined for himself a fair proportion of these plants will have met with many others which may be studied on the same lines. It was suggested at the beginning of this section that the work it dealt with would lead naturally to the naming and the classification of British flowering plants with the help of a Flora. The standard Floras will be found in the list of books at the end of this chapter, and it is not proposed to enter into the methods of their use here. It will, however, be of some value to the student who proceeds to further work on these lines, and will at the same time serve as an index, if the plants described above are grouped in their families or natural orders and arranged as they will be met with in any standard British Flora. The student will then see at a glance which are the families he has already studied in at least one example, and can proceed by the collection and examination of other plants of the same order to widen his idea of its characters. The natural orders below are arranged as in Hooker's *Student's Flora*.

ANGIOSPERMS

Class I.—Dicotyledons

Division I.—*Polypetalæ.*

Ranunculaceæ	Buttercup	vol. 3	page	89
	Lesser Celandine	,, 3	,,	115
Papaveraceæ	Red Poppy	,, 4	,,	21
Cruciferæ	Lady's Smock	,, 3	,,	120
	Charlock	,, 3	,,	209
	Shepherd's Purse	,, 3	,,	212

Violaceæ	Sweet Violet	vol. 3	page	124
Caryophylleæ	Cuckoo Flower	,, 3	,,	188
	Red Campion	,, 3	,,	190
Geraniaceæ	Herb-Robert	,, 3	,,	196
Leguminosæ	Bird's-Foot Trefoil	,, 3	,,	170
	Garden Pea	,, 4	,,	24
Rosaceæ	Wild Strawberry	,, 3	,,	166
	Common Avens	,, 3	,,	214
	Apple and Pear	,, 4	,,	48
	Dog-Rose	,, 4	,,	52
Saxifrageæ	White Meadow Saxifrage	,, 3	,,	192
	London Pride	,, 3	,,	194
Droseraceæ	Sundew	,, 4	,,	41
Onagrarieæ	Rose Bay Willow Herb	,, 4	,,	17
Umbelliferæ	Cow-Parsnip	,, 4	,,	1
Araliaceæ	Ivy	,, 4	,,	30
DIVISION II.—*Gamopetalæ.*				
Caprifoliaceæ	Honeysuckle	,, 4	,,	32
Compositæ	Dandelion	,, 3	,,	144
	Daisy	,, 3	,,	175
	Feverfew	,, 3	,,	177
Ericaceæ	Heather	,, 4	,,	13
Primulaceæ	Primrose	,, 3	,,	129
Oleaceæ	Ash	,, 4	,,	55
Apocynaceæ	Periwinkle	,, 3	,,	133
Convolvulaceæ	Dodder	,, 4	,,	36
Solanaceæ	Potato	,, 4	,,	6
Plantagineæ	Plantains	,, 3	,,	205
Scrophularineæ	Germander Speedwell	,, 3	,,	225
	Foxglove	,, 4	,,	10
Lentibularineæ	Butterwort	,, 4	,,	43
Labiatæ	Dead-Nettle	,, 3	,,	139
	Garden Sage	,, 3	,,	184
	Bugle	,, 3	,,	217
DIVISION III.—*Incompletæ.*				
Loranthaceæ	Mistletoe	,, 4	,,	38
Salicineæ	Willow	,, 4	,,	45

CLASS II.—MONOCOTYLEDONS

Orchideæ	Early Spotted Orchis	,, 3	,,	198
Irideæ	Crocus	,, 3	,,	161

	Yellow Iris	vol. 3	page	221
Amaryllideæ	Daffodil	„ 3	„	156
Liliaceæ	Tulip	„ 3	„	148
Junceæ	Woodrush	„ 3	„	152
Gramineæ	Rye-Grass	„ 3	„	180

GYMNOSPERMS

Coniferæ	Scots Pine	„ 4	„	62

Pollination of Flowers

It was pointed out in the introductory chapter (Vol. III. p. 101) that the construction of flowers had to be studied in the light of the need for transfer of pollen from the stamens to the stigma. This process of pollination is an essential preliminary to the development of seeds capable of reproducing the plant. Under each plant described above the method of pollination and the relation of this to the structure of the flower has been more or less fully considered. Such a study of individual cases forms the best way of approaching the subject. It may, however, be of use to place some general considerations before the student, although for any full treatment of the subject reference must be made to one or other of the works cited in the bibliography below. The flowers already described will provide us with examples of the general statements that can be made regarding pollination, and will save us entering into details of floral structure.

Many flowers contain both stamens and pistil, and the simplest method of pollination would be for the pollen to fall directly on the stigma of the same flower. This is known as *self-pollination*, and is found to occur in many instances. An extreme case has been seen in the small flowers of the Sweet Violet (Vol. III. p. 128), which never open, and in other flowers which are inconspicuous and have no efficient means for the transfer of pollen from flower to flower self-pollination is also the rule. The account of the flower of the Shepherd's Purse (Vol. III. p. 214) may be consulted as an example of this. In very many flowers self-pollination occurs as a last resort, and leads to good seed being formed. In most flowers, however, the arrangements are such as to lead either regularly or occasionally to the conveyance of pollen from one

flower to another. This is known as *cross-pollination*. In those plants in which the results of cross- and self-pollination have been compared, cross-pollination has usually been found to yield the more satisfactory results.

We might even without experiments infer this from the variety and complexity of the arrangements in flowers which on the one hand prevent self-pollination or render it difficult, and on the other lead to cross-pollination, often by very complicated relations between the plant and other living beings. The two great agencies by means of which pollen is conveyed from one flower to another are the wind and insects. We shall thus have to consider the general arrangements in relation to cross-pollination in *wind-pollinated* and *insect-pollinated* flowers. Some few plants have the pollen carried to the stigmas by means of water, and in others the transfer is effected by animals of other kinds, such as bats, humming-birds, or snails. These exceptional methods of pollination hardly come into consideration in studying British plants, and need not be dealt with further.

Whether a plant is wind- or insect-pollinated, we may find on studying it that self-pollination is rendered difficult or impossible. It is obvious, for instance, that when the staminate and pistillate flowers are borne on distinct male and female individuals, as in the Willow (Vol. IV. p. 45) and the Red Campion (Vol. III. p. 190), self-pollination is an impossibility. The existence of staminate and pistillate flowers on the same individual, as on the Pine (Vol. IV. p. 62), also makes self-fertilisation more difficult and cross-pollination more likely, and the same may be said of such cases as the Ash (Vol. IV. p. 55) and the Cow-Parsnip (Vol. IV. p. 1), where flowers of different kinds occur on the same plant. Even when all the flowers contain both stamens and pistil, self-pollination may be prevented, or at least rendered unlikely. Sometimes self-pollination can occur, but no result follows from it; the flower is self-sterile. In such a flower as the Orchid (Vol. III. p. 200, Fig. 92) the positions of the anther and stigma are such that pollen will not get upon the latter if the flower is left undisturbed. More commonly self-pollination is prevented in flowers with both stamens and pistil by these maturing at different times, so that the flower is at one time in a pollen-

shedding, at another in a pollen-receiving stage. The more common state of things is for the stamens to mature and shed their pollen before the stigma is receptive. The flowers of the Rose Bay Willow Herb (Vol. IV. p. 17) and of the Dandelion (Vol. III. p. 147) may be cited as examples of this, but many more of the examples described exhibit it to a greater or less degree. The development of the stigma first, so that it has ceased to be receptive when the flower sheds its pollen, is beautifully shown in the Field Woodrush (Vol. III. p. 153) and the Ribwort Plantain (Vol. III. p. 208). The flowers in which the pollen-shedding and pollen-receiving stages overlap are numerous, and these partially prevent self-pollination and favour cross-pollination.

The construction of the flower has reference to other things besides the actual pollination. One of these is the protection of the pollen from injury by wet. The mechanism of pollination may not be reconcilable with this, and the risk of wetting is then run, but the Dead-Nettle (Vol. III. p. 141) and many other flowers are examples of thorough protection of the stamens and stigma, in the case of the Dead-Nettle by the upper lip of the corolla. The variety in construction and in method of pollination cannot be fully treated here. We can only look at a few of the general features of wind-pollinated and insect-pollinated flowers.

In wind-pollinated flowers, of which the Pine, the Ash, the Woodrush, and the Plantains have been described in the preceding pages, we find a number of common features. These flowers lack the bright colouring, the conspicuous petals, and the provision of nectar which are all so important in insect-pollinated flowers. They also show a number of common characters which fit them for wind-pollination. The pollen is loose and powdery, and readily falls from the anthers, and the latter usually project clear of the flower to facilitate this. The stigma also, in the Angiosperms named, is large and prominent, and usually is rough and hairy to offer a good chance of catching the grains of pollen drifting by in the air. Such flowers may be said to economise in the development of petals and in the secretion of nectar, but have to form a large amount of pollen, since much is wasted, never coming near a stigma.

Insect-pollinated flowers exhibit much greater variety, and reference must be made to the descriptions of particular examples.

These will show how widely the pollination arrangements differ in complexity and in precision. The insects that are mainly responsible for the pollination of flowers visit them in search of either pollen or nectar, which they collect or feed upon. The most important visitors are bees, butterflies and moths, and flies, though beetles and other insects may also be of use. Of these the short-tongued flies are the least intelligent, and are also unable to reach deeply seated nectar. The long probosces of some of the flies, of the bees and of the moths and butterflies, enables them to feed on many flowers which exclude the shorter-tongued insects. Of all these insects the bees are the most intelligent and methodical visitors, and many of the most beautifully adapted flowers are bee-flowers. The study of the entrance to a beehive is a most instructive one, and it is often possible to form an opinion as to the flowers visited from the variously coloured masses of pollen carried in on the legs of the workers. The behaviour of bees and other insect visitors should be watched when they are visiting particular flowers and the insects caught, and the structure of their mouth-parts examined. Some particulars will be found in the portions of this work which deal with insects.

Without attempting any consistent classification, flowers may be grouped according to the presence or absence of nectar and the protection and concealment of the honey. Some flowers, such as the Poppy (Vol. IV. p. 21) and the Rose (Vol. IV. p. 52), offer only pollen to their visitors. These have as a rule little specialised methods of pollination. The simplest flowers with nectar have this freely exposed, so that it can be obtained by any insect visitor. The Cow-Parsnip (Vol. IV. p. 1) is a good example of such a flower. In other flowers the nectar is partly concealed, but still usually accessible to short-tongued insects. The Buttercup (Vol. III. p. 99, Fig. 53) and the Wild Strawberry (Vol. III. p. 168) are examples of this. More specialised flowers have the nectar concealed and often accessible only to long-tongued insects. Most of the more beautiful arrangements for pollination described above are in flowers of this class. These flowers may be regular, and approached indifferently from any side, as in the Periwinkle or the Red Campion ; but more usually in the highly specialised forms they are irregular, as in the Dead-Nettle or the

Orchid. This determines the approach of the insect in a definite way, so that particular portions of its body are dusted with pollen. The advantage of this greater precision in the pollination mechanism lies in the smaller amount of pollen that need be produced. While large amounts of this are formed by the numerous stamens of the Buttercup or the Poppy, only two stamens are fertile in the Sage (Vol. III. p. 185), and only one in the Orchid (Vol. III. p. 203). These are examples of highly specialised flowers. The Sage and the Dead-Nettle are specially suited to bees, the Foxglove (Vol. IV. p. 10) to humble-bees, the Red Campion (Vol. III. p. 191) to Butterflies, and the Honeysuckle (Vol. IV. p. 32) to moths.

The details of particular mechanisms cannot be entered into here, but it may be pointed out how frequently the stamens at one stage occupy the position which later is taken up by the stigma. The Rose-Bay Willow Herb is a good example of this, and another may be taken from the Wood Sage (*Teucrium scorodonia*), a plant which has not been described at length. The flower is constructed on the same general plan as that of the Bugle (Vol. III. p. 219), and Fig. 18 will show without further description how the stigma takes up the position occupied by the anthers at an earlier stage while these become bent out of the way. In the works mentioned below the student will find information to help him in extending his observations on the methods of pollination to other flowers.

The Dispersal of Fruits and Seeds

Another subject upon which a few remarks may be helpful is the dispersal of the fruits and seeds of plants. Here also attention has been drawn to points of interest in connection with the plants described, and all that can be done is to gather them together in a more general statement. The use of the seed is to reproduce the plant, and in order that this may be successfully effected not only must seeds be developed, but they must be given a chance of finding suitable spots to germinate in. Many of the seeds produced by a plant never germinate, many others germinate but the plant never gets beyond the seedling stage. Still the majority of plants produce so many seeds that, if a few find by

chance suitable positions and grow into mature individuals capable in turn of producing seeds, the success of the species is assured.

It is obvious that it will be advantageous to have the seeds dispersed so that they may grow at some distance and not compete with one another. This also increases the chance of some seeds finding suitable spots to grow in and thus spreading the plant. The competition of plant with plant is partly a direct competition for food, light, etc., but is largely a struggle as to which can reproduce itself most successfully under the conditions of life. We shall therefore be prepared to find that many plants show arrangements for the efficient scattering of their seeds, and that the structure of seeds and fruits must be studied in the light of this.

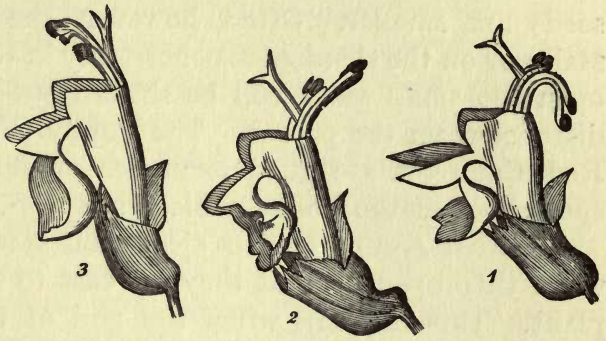


FIG. 18.—The Wood Sage. 3, Flower in the first (pollen-shedding) stage; 2, flower at the beginning of the second (pollen-receiving) stage; 1, flower at the end of the second stage. (From Müller's *Befruchtung der Blumen.*)

The seed consists of a seed-coat enclosing and protecting an embryo plant which is ready under suitable conditions to continue its growth. To enable growth to start, the seed contains a larger or smaller amount of food material, either stored in the embryo itself or placed beside or around this within the seed-coat. It is an advantage for the young plant to have a considerable amount of food material with it. It gives it a good start, and enables it quickly to become a self-supporting plant. A large store of food material involves, however, a large seed, and brings as a rule difficulties in the seed-dispersal. We have therefore two opposed needs, that of larger seeds which will carry a store of reserve food material and that of easy dispersal. In some plants the one, in others the other need is more fully met, but the existence of both must be borne in mind in studying the adaptations for seed-dispersal.

The seeds are contained in the fruit, which is developed from

the ovary, together with, in some cases, other parts of the flower. In most dry fruits which contain a number of seeds the fruit opens or splits in pieces to allow of their separate dispersal. But when a dry fruit contains only one seed this is unnecessary and such fruits do not as a rule open, but are dispersed entire, the wall of the fruit serving to protect the seed within. Succulent fruits, whether one- or many-seeded, do not usually open, but their seeds are separated and scattered in a different way.

Some plants show little or no special provision for the scattering of their seeds. The large seeds of the Pea, for instance, simply become detached and fall from the pod when it opens, and the same may be said of the Charlock and the Plantain, where the seeds are smaller. Often, however, the fruits, borne on long stalks or on the slender branches, sway in the wind, and when they open the small seeds will be shaken out and fall at some little distance from the parent. The Poppy (Vol. IV. p. 21) and the Red Campion are good examples of such a simple and little specialised method of seed-dispersal.

Another group of fruits eject their seeds more or less forcibly when they open, so that they are cast to some distance from the plant. This happens when the pod of the Bird's-Foot Trefoil splits open. The two halves coil spirally on the sudden opening, and the seeds are propelled away. The noise of the similar sudden opening of the pods of the Whin or Broom is familiar to every one who has stood among these plants on a warm summer day when their fruits are ripe. Other plants among those described which show arrangements of this kind to disperse their seed are the Herb-Robert (Vol. III. p. 198, Fig. 91) and the Wild Pansy (Vol. III. p. 128, Fig. 65).

Many plants are assisted in the spread of their fruits or seeds by the wind. This may happen even when these parts show no special modifications, but is much more efficient in seeds or fruits adapted for the purpose. The extreme lightness of the seeds of the Orchid fit them for wind-dispersal, but the minute seed can carry no store of reserve food material, and take a long time to produce a mature plant. In the Ash (Vol. IV. p. 55) and Sycamore (Vol. IV. p. 60, Fig. 16) the fruits are winged, and so offer a large surface to the wind. When they fall from the tree they will

probably be carried to some little distance before they reach the ground. The winged seeds of the Pine (Vol. IV. p. 66) serve the same purpose. The thin flat halves of the fruit of the Cow-Parsnip (Vol. IV. p. 6, Fig. 3) are also suited to be wind carried. The most beautiful arrangements for wind-dispersal are shown, however, by somewhat smaller fruits or seeds, which may often be carried long distances before they reach the ground. The parachute-like group of hairs on the seeds of the Willow Herb (Vol. IV. p. 20, Fig. 5) and Willow (Vol. IV. p. 48) and on the fruits of the Dandelion (Vol. III. p. 148) lead to the seeds or fruits being easily carried by even a gentle movement of the air. Every one knows the way in which Thistle-down is carried to a distance when the fruits are ripe and becoming detached from the inflorescence.

Another great agency for the dispersal of fruits is afforded by the power of movement possessed by birds and mammals. Animals are of use in dispersing fruits in two main ways. Many fruits have rough surfaces, recurved hairs or hooks which will catch readily in the fur or feathers, and not be loosened until the animal is some distance from the plant. No very good examples of this method of dispersal are among the plants described. The hooked style of the fruitlets of the Avens (Vol. III. p. 216) serve this purpose, however. Every one knows how, in walking over grassy land, fruits fasten on to the cloth of garments which brush against the plants. If such fruits are examined they will be found to be adapted for dispersal in this fashion.

The other method by which fruits and seeds are dispersed by animals, especially by birds, affords the explanation of the peculiarities of what are known as succulent fruits. In these, part of the fruit, usually of the wall of the ovary, but sometimes the receptacle of the flower or the leaves of the perianth, becomes swollen and when mature soft and succulent. The substance of this is often sweet tasted, and the fruits may also be attractive by their colour or scent. Within the fruit are one or more seeds enclosed in a hard covering ; this may either be the seed-coat or, as in the Plum or Cherry, an inner layer of the wall of the ovary. Space will not permit of a description of the different types of succulent fruits, and this is not necessary in order to understand their use to the plant. Such fruits are adapted to be eaten by birds.

Their conspicuousness against the foliage when ripe, their scent and pleasant flavour, attract the animals to eat them. In the intestines of the latter the softer parts are digested and serve as food, but the hard seed or stone withstands the action of the digestive juices, and is passed uninjured in the droppings. This will be at a considerable distance from the parent plant, so that we have in these arrangements a very efficient method of dispersal. The fruits of the Rose, Strawberry, Apple, Ivy, Honeysuckle, and Mistletoe among the plants described are of this nature

In concluding this brief summary of the way in which fruits and seeds are dispersed mention must be made of human traffic. Many of our common weeds have thus been spread not only locally, but to distant countries, where they have succeeded and spread widely. Such accidental spreading of a plant brings vividly before us the use of the natural arrangements for dispersal, to which the attention of the student should always be directed in examining a plant.

List of Books.—More or less full descriptions of single plants are given in many text-books of Botany. The following works are devoted to this, and will enable the student to extend his work on the lines followed above:—Church, *Types of Floral Mechanism*; Groom, *Trees and their Life Histories*; Schumann, *Praktikum für morphologische und systematische Botanik* (this work is not translated, but those who read German will find in it full descriptions of a large number of plants). For further information as to the life of an ordinary plant, and the relation between special conditions of life and the organisation of plants, pollination, seed-dispersal, etc., the student should consult Kerner and Oliver, *The Natural History of Plants*. The methods of pollination are described in detail in Müller, *The Fertilisation of Flowers*, and Knuth, *Handbook of Flower Pollination*. For identifying British flowering plants, and the study of their classification, one of the following may be used: Johns, *Flowers of the Field*; Hooker, *The Student's Flora of the British Islands*; Bentham and Hooker, *Handbook of the British Flora*.

FERNS, CLUBMOSSES, HORSETAILS, MOSSES, FUNGI, AND LICHENS

By Frank Cavers, D.Sc.
Professor of Biology, Hartley University College, Southampton

CHAPTER IV

Ferns and Their Relatives

We have rather few kinds of ferns in this country, since most ferns require a more thoroughly moist climate than that of Britain. Our native ferns are herbaceous plants, but in tropical and sub-tropical forests, and in moist climates like that of New Zealand, there grow, in addition to ferns like ours, the large tree-ferns, which can be seen in botanic gardens such as Kew. On the whole, the ferns now living represent a family which was formerly more widely distributed and formed a great part of the earth's vegetation, especially during the Coal Period. Many of the fern-like leaves found in the coal measures, however, probably belonged to a higher family, which bore seeds, and formed a connecting link between Ferns and Seed-plants.

Most of our ferns grow in moist and shaded places, but several kinds are adapted for existence in exposed and dry situations. Each kind has its own special home or habitat, and it would be useless, for instance, to look for the delicate shade-loving Lady Fern on a bleak wind-swept moor. For the same reason, if we would grow ferns successfully in gardens or greenhouses, we must give them as nearly as possible the sort of surroundings to which they are accustomed.

It is usually quite easy to tell whether or not a plant is a fern, though some flowering plants are (when without their flowers) liable to be mistaken for ferns. Asparagus is sometimes sold as a "fern," while the leaves of some umbellifers—

Fool's Parsley, etc.—look like those of ferns at first sight. Most people have seen the fern-like leaves produced by a carrot-top which has been cut off, scooped out, filled with water, and hung up by strings.

In studying ferns, do not root up every new kind you come across. Several of our rarer ferns have been almost exterminated by hawkers, fern-growers, botanists, and even by members of Nature Study classes, who ought to have had more sense! If you study ferns in their homes a single leaf is all that need be taken away for the purpose of preservation (between sheets of paper) and for identification. Besides, the very best way in which to study ferns is to *grow* them from their spores, and watch their development,—this is real Nature Study, but the tearing up of ferns and the spoiling of woodland banks is not.

As a first fern type we shall take the Common Bracken (*Pteris Aquilina*), which is so abundant that no harm can be done by pulling it up, or even digging out a plant, in order to examine its underground parts. The bracken covers large areas, especially on heaths and commons, but it also grows in woods and on high moors, having a much wider range than any other British fern, and being therefore adapted for growth in a greater variety of situations or habitats. It often grows to a height of four or five feet, while the bases of its large "fronds" may be buried a foot or more deep in the soil. Being a social or gregarious plant, it can grow in extensive patches in places, *e.g.* windy hillsides, where isolated plants could not flourish, though in such situations it is usually stunted and rough, whereas in more favourable homes—especially in woods that are not too densely shaded and have fairly deep leaf-mould—it grows as high as seven feet, and is a more tender and graceful plant.

The conspicuous "frond" is a single leaf, though its stalk resembles a stem at first sight. If the "frond" were a *shoot* we should expect to find buds on it, but comparison with other plants—especially with the bracken's cultivated relatives (the "ribbon-ferns") and other ferns—will show that the "frond" is a compound leaf, having a main stalk which bears secondary stalks right and left in pairs, while these again bear paired leaflets, which are deeply lobed or even cut into separate pieces. The

bracken leaf is technically described as "thrice pinnate." The uppermost part of the leaf is less cut up than the lower parts; note the different degrees of position or lobing at the base, middle, and top, sketching a part of each region. We shall return to the leaf presently.

Try to pull up a whole leaf; it is firmly fixed below, and the black basal part of the stalk that comes up has been wrenched off from—what? Dig up a whole plant; it will be necessary to use a trowel or a strong knife. The creeping stem, which grows in the soil, gives off thin wiry roots, besides sending up the leaves. It is dark brown or almost black, except at the rounded knob-like growing tips, and shows along each flank a lighter coloured line. You will notice also the withered bases of leaves of former years, which have died down; the rudiments of leaves which will grow up later—these, like the growing tips, are rounded and densely clad with brown chaffy hairs; and buds, resembling the young leaves, and arising from the leaf-stalks just above their bases—not from the stem itself, as in most plants. The stem does not branch much, and the leaves are well spaced out on it; each branch produces, as a rule, only one leaf each year. The leaves are in two rows on the flanks of the stem, each leaf bending up at the base so as to become vertical. If you cut across the stem at different places, and also slit it longitudinally (starting from the tip), you will see that, except at the soft growing ends, it is traversed by conspicuous dark-brown bands and cords and also by lighter-coloured cords, both lying in a whitish ground-mass. By examining slices with a lens and by scraping away the soft tissue you will see that the dark strands are hard and fibrous, while the lighter ones contain open tubes; also that there is an outer dark-brown hard layer, except at the light lines visible on the surface. These light lines, where the soft inner tissue is exposed at the surface, probably serve for aeration, having the same function as the lenticels on the stems of trees. Does the leaf-stalk contain both kinds of strands, or only the light-coloured tube-containing ones? You can trace the tube-containing strands right up the leaf-stalk and into the thin leaflets, where they branch and finally fork like a letter Y. Cut off a leaf, and set the end in

red ink ; trace the red-stained veins up the stalk into the leaflets. Dip a leaf into hot water and notice the air-bubbles given off by the lower surface, showing that this surface bears the stomates. Note the difference (1) in colour, (2) in hairiness, between the upper and lower sides of the leaf. Note the stickiness of the ground-tissue of stem and leaf-stalk, due to gum which, being retentive of water, prevents the tissue from drying up. Note the difference in colour between the ground-tissue of the stem (and the buried base of the leaf-stalk) and that of the leaf-stalk (the part above the soil). Does the whitish ground-tissue of the stem contain starch ? Test it with iodine solution.

Examine plants month by month. The stem, buried in the soil deeply enough to be safe from frost and drought, steadily grows forward at the hair-covered tip, which occasionally forks into two ; additional branches may arise from the buds on the leaf-bases. The young leaf, like the growing stem-tips, is thickly covered with hairs, which, besides acting as a protection against cold and rain, may attract ants, which keep off caterpillars and other destructive insects ; food material for new growth is stored in the stem, and excessive loss of water is hindered by the gummy sap of the soft tissue, which is very retentive of moisture. The young leaf, which emerges in early spring, is at first curved at the tip like a shepherd's crook, or like the young shoot of a bean or pea seedling, and is well adapted for pushing up through the soil. The coiled-up leaflets expand slowly, while the stalk hardens, so as to withstand the strain imposed on it by the spreading leaflets when they catch the wind. The expanding leaf is symmetrical throughout, the parts unrolling successively in pairs, so as to expose the leaflets to the air and light. When bracken grows thickly, other plants are more or less completely overshadowed and choked off.

The bracken, then, has roots, stems, and leaves like a flowering plant, but apparently no flowers or cones. Like other ferns, it has no seeds, yet we know that new plants are produced. In a fully grown plant, examined in late summer or in autumn, you will notice that the edge of each leaflet is turned in towards the underside, and is fringed with a scaly strip which covers a groove filled with brown grains. These are so abundant that the edges

of the leaflets appear as brown streaks, and in walking through a patch of bracken in autumn one gets covered with rusty powder. If you scrape some of these brown bodies on to a piece of white paper, or a moistened bit of glass, and examine them with a lens, you may be able to see that each has a slender stalk. Cut off a few " ripe " leaflets in autumn and lay them on a sheet of paper for some time, or shake a leaf over the paper, which will be covered with fine brown dust which has escaped from the stalked bodies. The dust-particles are the *spores*, the stalked bodies the *spore-cases*. It is easy to make a spore-case burst, by pressing or by warming it on a glass slip ; the case gapes open and lets the spores out. This naturally happens on a dry day, and the spores fall to the ground, or, being very light, are carried away by the wind. It is easy to see why the spore-cases are produced on the *lower* side of the leaf ; if they were on the upper side the sun might injure them, while rain would make the spores stick together so that they would fall out in a mass. As we shall see, the spore-bearing plants have adaptations for ensuring proper dispersal of their spores, just as the flowering plants show devices for scattering their seeds.

Why do botanists give the name *spores* to what many people call the " seeds " of ferns ? The best way to find out what the spores are is to grow them and see what they give rise to. If you have a microscope, you can tell at once on examining a fern spore that it is not a seed. A seed contains a young plant, with root and shoot, and usually a store of food (in cotyledons, or in a special part called the endosperm), whereas a spore does not contain a young plant, but is a *single cell*, so that it is an almost infinitely simpler structure than a seed.

What becomes of the spores after they are shed by the bursting open of the spore-cases ? You might search the soil among bracken plants for days without finding out, so the best plan is to sow the spores yourself and keep them under observation indoors. The spores of ferns should be collected by enclosing a ripe leaf, or part of the leaf, bearing the spore-masses, in an envelope on which you should write the name of the fern ; you should have a few envelopes with you when on a botanical excursion. Get some flower-pots or shallow seed-pans, some lumps

of peat or leaf-mould, and some glass sheets or bell-glasses. If you use flower-pots, half fill the pot with gravel and then put in enough peat to fill the pot to an inch from the top. If seed-pans are used, simply stand a lump of peat in the middle of the pan. In any case, the vessels and the soil must be, as far as possible, "sterilised," otherwise you will get fungi and other plants which will damage or destroy the germinating spores. Either bake the vessels and soil in a hot oven for a few hours, or steep them in boiling water. If you bake the soil, moisten it, and the pot or pan, and when it is again cold shake some spores over it, and cover with the glass. The latter keeps the soil moist, since the evaporated water condenses and runs back into the vessel, but it is as well to remove the glass now and then to renew the air. The ripe spores will retain their vitality for several months in most cases, but they usually germinate best if sown promptly, and the green spores of Royal Fern and a few others will perish if not sown at once. The pots or pans should be set out of direct sunlight, and the early germination of the spores is hastened by some warmth. The spores may be sown on previously heated or scalded bits of brick or tile sloping into water in a jar or dish, instead of using soil (peat or leaf-mould). In any case, do not sow the spores too thickly, and do not water them from above (for what reasons ?).

In a few weeks (a few days in the case of the Royal Fern) you will see greenish threads creeping over the soil, with here and there a small green disk. Each spore, on germinating, sends out a colourless thread, which becomes rooted in the soil, and then a thicker green thread which grows along the surface. The green outgrowth gradually broadens at the front, and finally grows into a thin green, heart-shaped plate bearing numerous rooting-hairs on its lower side. The green plate is called the *prothallus*. The germination of a fern-spore is obviously very different in its results from that of a *seed*.

The prothallus is usually more or less heart-shaped in outline, and has a thick opaque middle part (cushion) with thin transparent side parts. It is fixed to the soil by numerous fine rooting-hairs which grow chiefly from the cushion. The upper surface is quite even and smooth, but the underside shows, besides the

hairs, a number of small projecting bodies, which can be made out to some extent with a lens. At the front of the prothallus, just behind the notch of the "heart," there are several short finger-like organs on the cushion, which may be seen by washing the soil from the underside and holding the prothallus up to the light. These bodies—the egg-pockets or *archegonia*—are minute flasks, each with a swollen base embedded in the prothallus, and containing an *egg-cell*, and a curved neck which points towards the narrow hinder end of the prothallus. Behind these egg-containing organs there are more numerous smaller bodies, seen as round dots scattered over the prothallus; these produce the sperms, or male cells, and are called the sperm-pockets or *antheridia*.

After a month or two you will see a few small leaves appearing on each prothallus. The plants may then be dug out of the peat with the point of a knife and "pricked out," like seedlings, in pots of soil, to give them more room for growth. If the prothalli are too thickly crowded it is as well to thin them out. Finally, the plants may be removed to a rockery outdoors, after they have been "hardened" by removing the glass panes that had covered them.

You will notice that the young fern leaves grow from the notch at the front of the prothallus, and you can trace them to the underside, where the young roots also arise. The early development of the young fern-plant can only be followed out by using the microscope, but the following is an outline of the process. The egg is fertilised by a sperm, which swims into the neck of an egg-pocket, and grows into an embryo in which four parts can soon be made out:—(1) the young root which grows into the soil; (2) the first leaf, which grows forward and turns up into the air when it reaches the notch of the prothallus; (3) the young stem, which grows slowly at first; (4) a special absorbing organ which remains embedded in the prothallus and draws from it food to nourish the young plant. Before very long the prothallus dies and decays; the first root also dies and the later roots arise from the stem. The young fern is rather exceptional among green plants in being able to turn green even when kept in total darkness, though it does not live long unless it gets light; the same is true of pine and a few other seedlings,

also of the new growths produced by mosses and liverworts kept in darkness.

The rest of the ferns have the same general structure and life-history as the bracken, though varying greatly in the form of the leaf, arrangement of spore-masses, etc. They mostly grow in moist, shady places, having *as a rule* thin, soft leaves which can absorb moisture from the air, but are ill adapted to withstand exposure to sun, wind, or drought, and are divided up in a feather-like manner, so as to catch as much as possible of the feeble light falling on them.

The Common Polypody (*Polypodium vulgare*) resembles bracken in having a branching stem on which the leaves are spaced out. The polypody, however, grows on leaf-mould in hedge banks, or walls, or on the trunks and branches of trees, the stem, which is covered with golden-brown, pointed scales, creeping over the surface while the roots are inserted in the soil, or between the crevices of bark or old stone walls. It is the largest British plant, which regularly grows perched upon trees, sending its roots into the scanty soil composed of matter washed down by rain from the branches. It is not a parasite, like the mistletoe for instance, for it does not get its food from the tree it is growing upon. It is an *epiphytic* plant, like many mosses and lichens which inhabit the bark of trees, and obtains its food in a legitimate way from rain-water, dust, and the air. When growing on trees, it occurs chiefly in the forks from which the branches arise, but in damp woods it often clothes the horizontal branches, or even creeps vertically over the main trunk, sending its roots into the crevices of the bark. It is especially found on oaks and polled willows. The leaf is oval or oblong in general outline, from three inches to two feet long, and deeply divided into rather broad lobes on each side of the stalk. The edges of the lobes are usually even, though sometimes they are toothed. The leaf is smooth on both surfaces, evergreen, and leathery. Each lobe bears two rows of round spore-masses which have no protective scale ; at first the spore-cases are straw-coloured, but later they become orange.

The polypody is rather exceptional among ferns in that its leaves, which last for several years, are cut off when old,

like the leaves of trees, and do not simply wither down and leave their ragged stumps on the stem. It is obvious that the polypody differs a good deal from the bracken in its mode of life. One of the best methods of investigating the adaptations of a plant to its surroundings is to grow it under varying conditions, and see which suits it best. The bracken, as might be expected from its natural habitats, will grow quite well in almost any kind of soil, so long as it is dug up in its more or less dormant state in winter, and carefully transplanted. But to cultivate the polypody successfully we must imitate its natural environment as closely as possible. It must be planted where it can take undisturbed possession of the place selected, in soil consisting of leaf-mould mixed with some clay or garden-soil. The locality must be shaded, cool, and moist, but not too wet or stagnant, and the soil light and porous, not stiff and retentive. The stem should not be buried in the soil, but simply fastened down to it, with only the roots covered. When once established in such surroundings the growth of the branching stem is rapid, but it generally takes three or four years for the plants to become beautiful and flourishing. It is fairly easy to see that the polypody is adapted for the special habitats in which it grows. It requires a damp but well-drained soil, which need not be deep, since the branching stems run over the surface. The stem itself is green, hence it loves air and light, but the younger parts have to be well protected against the cold and drought to which they are exposed, hence its covering of scales. The leaves last for several years, hence they are leathery and able to withstand the cold of winter. On rocks, walls, and trees the polypody has but few competitors among higher plants, and its branching stems often overrun the mosses which grow along with it.

The Oak Fern or Three-branched Polypody (*P. Dryopteris*) resembles the common polypody in bearing its leaves singly on the branching stem, but the leaf is compound and feathery, and is divided into three branches—giving this fern a very characteristic appearance. The oak fern grows most luxuriantly in rocky, mountainous districts, but is very rare in Ireland. Its homes are shady woods and hedgerows, and though it occurs

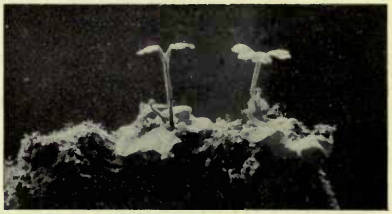
in damp places it prefers fairly dry and well-drained soil. The creeping stem is slender, dark-brown or blackish, and bears orange scales, which are continued a little way up the leaf-stalk. The latter is four to twelve inches long, while the upper leafy part is about the same length, and nearly as broad at the base. The leaf is divided into three branches which are stalked and triangular in outline, the two basal branches being smaller than the central one. The central division has its branches equal in size on each side, while in the lower pair of divisions the branches are larger on the lower side of the stalk. The leaf is smooth, soft, and bright green. The spore-masses are rounded, dark brown, small, and scattered over the whole under side of the leaf. The leaves lie down each year. The young leaf, when so far unrolled that the three branches are free, resembles three little green balls at the ends of three branches of a wire.

It is interesting to compare the habitats and adaptations of these two polypodies. The feathery leaves of the oak fern enable it to grow in deeply shaded places, often among other plants which tend to overshadow it. The leaves are thin and delicate, unable to withstand exposure to sun and wind, and they are annual, developing in spring and dying down in autumn. On the other hand, the common polypody, with its less divided, leathery, evergreen leaves, is able to grow in such exposed places as wall-tops and tree trunks, its leaves lasting during the winter so as to catch the light on bright spring and autumn days when the trees are bare. The oak fern is easily cultivated, if it be given shade and well-drained leaf-mould; like polypody, it is readily propagated by cutting the stem.

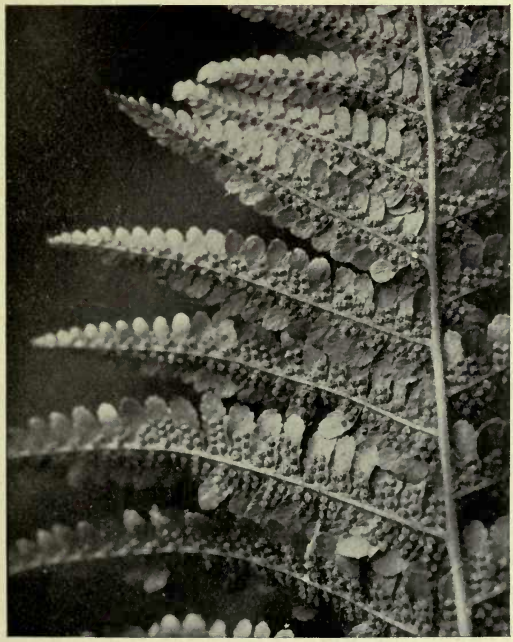
The commonest of our woodland ferns is the Male Fern (*Nephrodium Filix-mas*), which is very easily recognised by its robust habit, and above all by the peculiar kidney-shaped scales which cover the clusters of sporangia on the under side of the leaflets. The stem is thick and woody, covered with scales and the crowded bases of old leaves; the wiry black roots arise from the leaf-bases, not from the stem itself. The leaves are deciduous, dying down in autumn, but leaving their withered bases on the stem, and vary in length from six inches in stunted plants to four or five feet in especially robust ones. The stem grows at or just

THE LADY FERN

FERN PROTHALLI



TWO PROTHALLI WITH YOUNG PLANTS



BACK OF LEAF OF MALE FERN

YOUNG LEAF OF MALE FERN

Photos by Dr. O. V. Darbishire, Manchester University.

Photos by Chalkley Gould, Southampton.

ROYAL FERN (*Osmunda regalis*)

HARD FERN (*Lomaria spicant*)

COMMON POLYPODY

below the surface of the soil and lengthens very slowly, producing each year a rosette of leaves. It is at first conical, with the thin end downwards, since it grows thicker towards the top for a time, and then becomes uniform, and it does not branch. Branches are, however, formed from buds which arise on the bases of some of the leaves, and eventually become separated from the parent plant. The stem grows obliquely upwards, and often becomes eight or nine inches long and two or three inches thick, but the bulk of the thickness is due to the leaf-bases which remain attached to the stem. Within the expanded leaves are the young leaves which will unfold next year and the next again, for the leaves grow slowly, and are recognisable two years before they unfold. During the first year the leaf-stalk is formed, and in the second the blade. The young leaf is densely covered with brown scales, which persist along the stalk of the mature leaf, and is coiled up like a watch spring, each leaflet being similarly coiled. The coiling is due to the more rapid growth of the lower side of the leaf; when the leaf unfolds the upper side grows the more rapidly, and the curves are straightened out.

The mature leaf has a long stalk, traversed by two lateral ridges, and bearing two side rows of leaflets corresponding in position to these ridges. The leaflets begin rather abruptly at the base of the blade, become longer higher up, and gradually become shorter again towards the pointed tip of the leaf. Each leaflet is either deeply lobed or subdivided into smaller leaflets. The spore-masses, chiefly found in the upper part of the leaf, on the lower sides of the leaflets, and on the larger lobes or divisions, are arranged in two short rows, one on either side of the midrib, each mass lying over a vein. The cluster of spore-cases is covered by an umbrella-like scale, differing from an umbrella in being slit inwards as far as the short "handle" on one side, so as to have a kidney-shape as seen in surface view. This scale protects the young spore-cases against rain, sun, and wind; when the spores are ripe it withers.

The male fern grows in various habitats—dry woods, wet woods, hedgerows, beside streams, among rocks—though rarely occurring in very open and exposed places. It is more easily

transplanted and cultivated in gardens than any other fern, and will grow quite well in any kind of soil. Its hardiness is due largely to its very effective protection of the young leaves, by the scaly covering, and to the food stored in the fleshy stem.

The Lady Fern (*Asplenium Filix-fœmina*) has the same general form as the male fern, but is a more delicate plant, and grows most luxuriantly in damp and shady woods. Like the male fern, it is very easily grown both outdoors and in pots. The scales covering the young parts of the stem, the young leaves, and the bases of the mature leaves are dark brown ; the spore-masses are small, black when ripe, and covered by a scale which is curved like that of male fern, but attached at one side of the spore-mass instead of in the middle. The leaf is thin and brittle ; each primary leaflet has numerous closely-set toothed divisions.

The lady fern belongs to the Spleenworts, which vary greatly in the form of the leaves and in their habitats, but are distinguished by having the protective scale inserted along one side of the spore-mass. The spleenworts grow chiefly on rocks and walls, their long wiry roots penetrating narrow crevices and minute crannies in such a way as to make it difficult to root the plant whole out of its place. As might be expected from this mode of life, the spleenworts are hardy plants with firm leathery, evergreen leaves, agreeing in these respects with other ferns (*e.g.*, polypody) which grow on walls and rocks, and are exposed to sun and wind and a precarious supply of moisture. The commoner spleenworts are easily recognised. The form of the leaf corresponds roughly with the habitat of the species ; at one end we have the scaly spleenwort, which has its leaves very slightly divided, and is the most thoroughly *xerophilous* species, *i.e.* the one best adapted to live in dry places, and at the other the delicate lady fern with its much-divided feathery leaves.

The Scaly Spleenwort or " Stone Fern " (*Asplenium Ceterach*) is easily known by the dense covering of reddish-brown scales on the under side of the frond, which has a short stalk and numerous oval lobes on either side, the divisions not reaching to the midrib. The upper side is deep green, but in dry weather the lobes curl over and the whole leaf rolls up, so that the plant

looks dead and withered. When moistened, however, the leaf expands and again presents its green upper side to the light. This fern grows on walls and ruins, up to about six hundred feet above sea-level, usually on the south side of the wall. The stem is short, stout, scaly, and tufted, the leaf-stalk blackish and scaly, and the frond 4 to 6 inches long and leathery, the lobes about half an inch long. The spore-masses are in lines, hidden by the scales on the under side of the lobes, and the protecting scale is small or absent—being rendered unnecessary by the abundant small scales which cover the lobe below.

The Maiden-hair Spleenwort (*A. Trichomanes*), on walls and rocks up to 2000 feet, has a crowded rosette of rigid narrow leaves, about six inches long, arising from the short stout creeping stem. The frond consists of paired dark-green rounded or oblong leaflets, with a wiry black stalk representing about half the length of the whole leaf. The leaflets are evergreen; when they fall off they leave the black stalks bare. This fern is not very easy to grow; it does best in a mixture of porous loamy soil, bits of sandstone, and lime from old walls, and the soil must be well drained, since the plant cannot endure excess of moisture.

The little Wall Rue (*A. Ruta-muraria*) has a short scaleless stem, and grows chiefly on the northern side of walls, mounting up the wall as high as possible. In dry situations it dwells alone, but in moister parts has for companions the maiden-hair and scaly spleenworts. It is a difficult fern to cultivate, requiring a very stony soil and a dry atmosphere. The leaf is very variable in length, being over 6 inches long in sheltered positions, but reduced to an inch in high exposed places, and equally so in amount of lobing. The leaf-stalk is purple, and the leaflets are usually divided into two or three fan-shaped stalked segments. The spore-masses are in lines at first, but later form broad patches.

The Black Spleenwort (*A. Adiantum-nigrum*) resembles wall rue in general habit, but the leaf is larger and more divided, deep shining green above and paler below; the ultimate leaflets are notched and toothed. It is usually very difficult to remove this fern from a wall, for its stem is deeply embedded in the crevices. The leaf is often nearly a foot long, and has a rather long stalk which passes out through the wall crevice, so that the weight of

the broad triangular frond is chiefly supported by the ledge of the crevice. When one does manage to extract the plant from its crevice the slender dark-brown or black stalk is found to be too weak and brittle to support the weight of the frond, so that the leaf either snaps across or sprawls in a manner very different from its graceful drooping appearance when left undisturbed. However, this fern is easily cultivated in well-drained sandy soil in a rockery, where we can more or less closely imitate its peculiar mode of growth—hanging out of a deep crevice in a vertical wall or steep rock-face.

The Hard Fern (*Lomaria Spicant*) grows in woods and beside streams, and is easily recognised by having the fertile (spore-bearing) leaves quite distinct from the ordinary leaves. The latter are usually about 8 inches long, and spread out, or lie nearly flat ; the leaflets are in two rows, as in common polypody, and are crowded together on the leaf-stalk. The fertile leaves are brown, stand erect in the centre of the rosette, and are about twice as long as the barren leaves ; the leaflets are narrow and spaced out, and their edges are curled over the spore-masses on the under side. The barren leaves are evergreen, thick, and leathery, but the fertile leaves die down as soon as the spores have been scattered.

The Hartstongue (*Scolopendrium vulgare*) has strap-shaped leaves arising from a short and more or less erect stem. It looks, at first sight, more like a dock than a fern, but is at once recognised as being a fern by the spore-masses, which are arranged in lines on the under side of the leaf. The leaf varies in length from a few inches when growing on dry walls, to a yard when on moist and shaded banks. Though not evergreen, the hartstongue always shows some green leaves, because the old leaves do not die down until the young ones have expanded. The spores are very easily grown, the prothalli and young fern plants being obtained more certainly and quickly than in most other ferns. The young leaves are covered with silvery scales, and are at first erect, though later they usually hang downwards, especially when the plant is growing in its favourite habitat—on a wall or sloping bank. The long strap-shaped leaves are well adapted to this mode of growth, hanging out from the wall or bank, and catching the

light, while their narrow form enables them to insinuate themselves among other vegetation which may compete with the hartstongue for light and air.

The Royal Fern (*Osmunda regalis*) excels the bracken in regard to size, its large but graceful leaves being sometimes ten feet high and a yard broad. About half of this length is represented by the stout bare leaf-stalk. This fine fern is becoming scarcer every year in many districts, and has been practically exterminated in some places, though it still flourishes abundantly in remote and boggy localities where greedy and stupid persons cannot get at it. It grows in low-lying parts of the country, rarely over 300 feet above the sea, occurring in bogs, beside streams, and in swampy woods. In a few places it has been exterminated by drainage operations, showing that it requires a thoroughly moist habitat. It is equally unable to withstand cold, for the first frosts kill the leaves. The leaf is twice-divided, the leaflets being oblong and bright yellowish-green. The upper leaflets resemble the fertile leaves of the hard fern, having no green tissue, and bearing crowded masses of brown spore-cases which are larger than in most other ferns, and open by a vertical slit.

The Moonwort (*Botrychium Lunaria*) and the Adderstongue (*Ophioglossum vulgatum*) are sharply distinguished from our other ferns in having the leaf divided into two parts, one part being a frond and the other bearing the spore-cases. In both plants only one leaf comes up from the stem each year, each leaf taking several years to develop, and not showing the coiled form so characteristic of other ferns. The adderstongue grows in moist meadows, and is widely distributed in Britain, and often abundant but easily overlooked. The leaf is from 3 to 12 inches long, and is divided into a broad thin frond and a cylindrical-stalked spike. The frond is rather like a plantain leaf; the spike shows two rows of spore-cases embedded in its tissue, and each spore-case opens by a transverse slit. The moonwort grows in dry pastures up to 3000 feet, and is usually smaller than the adderstongue. The frond is divided into paired leaflets, roughly half-moon shaped, while the spike is also divided, and bears grape-like clusters of spore-cases. Both these plants are difficult to cultivate, and their spores do not germinate readily.

From their habit it is obvious that both plants are but poorly adapted, as compared with other ferns, for successful competition with other plants living in the same habitats. This is especially the case with adderstongue, whose erect leaves are so scantily produced, but this plant sends up its leaves in early spring, so as to catch the light before there are too many competing plants, and part of the food they make is stored in the fleshy stem and roots; in May or June the spores ripen, and soon after the leaf dies down. But if the plant is carefully dug up, with plenty of the soil about its roots, and put in a cool greenhouse, it will remain fresh and green until late in autumn, showing that the early death of the leaves is due largely to the keen competition for light and air which takes place in the adderstongue's habitat in summer, when larger plants have grown up around and over it.

Horsetails and Clubmosses (Lycopods), are allied to ferns, but belong to distinct groups. Each is comparatively poorly represented on the earth nowadays, the modern horsetails and clubmosses being the puny descendants of once great families of large and stately plants which flourished during the Coal Period, and have left their remains in still more ancient rocks. The ancestors of the horsetails (the Calamites) and of the club-mosses (the Lepidodendrons and Sigillarias) were tall trees forming a large part of the Coal Period forests, and their remains can be seen in almost every museum of natural history.

The Field Horsetail (*Equisetum arvense*), the commonest of our British horsetails, will serve as a type for study. It grows chiefly in damp sandy soil, in meadows, by roadsides, on railway embankments, margins of woods, and in cultivated fields and neglected gardens. Like bracken, it has a stem which burrows deeply in the soil, but the parts which come above ground are in this case shoots and not merely leaves. In summer the plant shows green jointed shoots, each consisting of a cylindrical stem bearing at intervals circles of outgrowths which are often branched again. At the upper end of each joint there is a collar-like sheath with pointed teeth on its edge. This sheath consists of a series of *leaves* joined by their bases. The branches grow out of the lower part of the collar—a rather peculiar mode of origin for branches. If you look at the nodes of a youngish plant you

will see that the collars are formed first, and that the branches arise inside, just above the attachment of the leaf-collar to the stem, and push their way out, each bursting from the collar after bulging it out. The horsetail, then, has no green leaves, only scaly ones joined at their bases which protect the buds of the branches. On examining a stem you will find that it is ridged, and that the ridges run from the stem into the teeth of the next leaf-sheath above, also that the ridges of each joint alternate with those of the joints above and below. Each branch has four ridges, though the main stem may have a dozen or more. The stem is hollow, except at the ends of the joints (where the leaf-sheath and branches come off), which have a solid partition to strengthen the stem. A cross-section of the stem shows, besides the large central cavity, a series of outer canals, one corresponding to each groove on the outer surface. The stem is very hard at the outside, owing to the presence of flinty matter in the skin.

If you mark the position of a patch of field horsetail before the green shoots die down in autumn you will notice, on visiting it in early spring (April), a number of shoots of a very different kind growing up. These are the fertile shoots, which bear the spore-cases. The fertile shoot is softer, thicker, and shorter than an ordinary or barren shoot, and is pale-coloured (having little or no chlorophyll) and usually unbranched. It has, however, the characteristic leaf-collars. The club-like end of the fertile shoot is at first compact, and shows on its surface lines marking it out into hexagonal areas. As the club, or *cone*, enlarges we see that each hexagonal area is a mushroom-like structure or stalked scale. The scales are arranged in circles on the stem of the cone, and each bears a number of spore-cases attached to the flat part, and lying around and parallel with the stalk. Lay a ripe cone on paper; after a time you will see numerous brown spores which have escaped by the bursting open of the spore-cases. Each spore has four threads attached to it. If you shake a ripe cone over a sheet of paper or a glass slide you will probably, while examining the spores with a lens, see these threads moving about in a curious way. When you breathe on the spores the threads suddenly become coiled up around the

spore, and as the spores dry the threads straighten out with a jerky and wriggling movement. In this way the threads cause the mass of spores to be spread out and more easily blown away by the wind.

As soon as the spores are shed the fertile shoot dies down, its work being done, and meanwhile the ordinary sterile shoots come up from the soil. The fertile and sterile shoots arise independently from the underground stem, which is jointed and bears sheath-collars like the erect shoots. The creeping stem bears, besides the collars, (1) roots, (2) erect fertile and sterile shoots which come above ground, and (3) short swollen branches —tubers—which contain starch and are able to produce new plants.

The spores are green, and will only germinate if sown immediately when ripe. The growth of the prothalli, however, is very slow, except just at first. Small male prothalli, bearing sperm pockets, are obtained within a month, but it is rather difficult to prevent "damping off" (due to fungi), and to get the larger female prothalli which eventually bear the young horsetail plants.

There are several other horsetails in Britain which resemble our type in all essential points, but differ in details. The Wood Horsetail (*E. sylvaticum*), which grows in damp woods and shaded places, is the most graceful kind. Its slender stem, about a foot high, bears collars with *broad* teeth, and the drooping branches (about a dozen in each circle) bear secondary branches, usually in pairs, which, with the drooping of the primary branches, give the plant an elegant tufted appearance. The profuse branching, as compared with other horsetails, is evidently connected with the different habitat,—the wood horsetail in this way presents a large amount of green surface, to catch as much as possible of the scanty light falling upon it in its shaded home. The Giant Horsetail (*E. maximum*) resembles the field horsetail pretty closely, but is much larger, its barren stems being sometimes six feet high, and bearing crowded circles of long branches—about thirty in each circle. The stem is white and feels quite smooth, the ridges and furrows being only slightly developed, and is about half an inch in diameter. It grows chiefly in bogs,

marshes, and ditches, so that on the whole it prefers a wetter habitat than the field and wood horsetails, but it also occurs in gravelly places and (at least in the south of England) on dry exposed hills, especially on chalk downs near the sea. The fertile shoots, which appear in spring and are short-lived, are shorter but stouter than the barren shoots, and have large overlapping brown sheaths, each with thirty to forty long pointed teeth. Sometimes the later shoots bear a small cone at the top above the branches. The Marsh and Smooth Horsetails (*E. palustre*, *E. limosum*) are confined to marshes and ponds, and often grow in dense masses. Both kinds are very common; in *E. palustre* the stem is fluted and feels rough, in *E. limosum* it is quite smooth and even. It will be noticed that, on the whole, the more distinctly water-loving horsetails are less branched, and have fewer ridges and furrows (or none at all) than those which grow in drier places. The marsh kinds grow in crowded masses, hence the few and short branches, as compared with the less gregarious roadside and woodland kinds (*e.g.* field and wood horsetails). The stomates on the stem are found in the furrows, hence the stems are more deeply furrowed, and the furrows more numerous in the kinds growing in dry places (*e.g.*, field horsetail) than in the water-loving kinds.

The horsetails show a curious mixture of adaptations. The leaves are reduced to scales, and the work ordinarily carried on by leaves is done by the green stem and branches, while the area from which water is lost (by transpiration) is further reduced by the restriction of the stomates to the parts of the skin (epidermis), which line the grooves on the stem. In correspondence with this the water-conducting bundles, or veins, are feebly developed. Adaptations of this kind, for preventing excessive loss of moisture, are characteristic of plants growing in dry places. On the other hand, the horsetails also show a great development of air-spaces, characteristic of water-inhabiting plants. This combination of characters has been explained as follows. The horsetails live chiefly in mud or stagnant water, so that the roots are badly supplied with air, therefore fresh air must be taken in by the upper parts of the plant, and conveyed to the creeping stem and the roots along the air-passages. At

the same time the presence of acids and other products of decaying vegetable matter in the mud makes it difficult for the roots to absorb water, hence it becomes necessary to limit the rate at which water vapour is given off by the upper parts of the plant. This explanation is not, however, quite satisfactory; the horsetails and other bog and marsh plants offer interesting problems in plant adaptations.

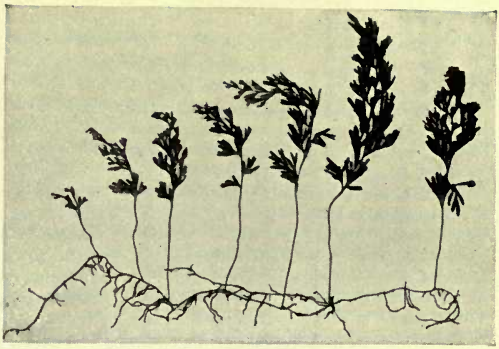
The Lycopods or Club-Mosses are very different from the true mosses. The Common Club-Moss (*Lycopodium clavatum*) grows chiefly on high hills and moors. In Hampshire another species (*L. inundatum*) occurs on low-lying heaths a hundred feet or so above sea level. The stem of the common club-moss runs along the ground, sometimes for a length of several feet, and gives off numerous branches, some of which are stout and prostrate like the main stem, while others grow erect and give off slender shoots ending in club-shaped thickenings or cones. The creeping stems are densely covered with stiff, narrow, curved, and pointed leaves, and give off roots chiefly at the points where branching occurs. The erect cone-bearing branches have fewer leaves, more closely pressed against the stem, but the leaves on the cone itself are larger and overlap each other.

The cone bears kidney-shaped spore-cases, one within the base of each leaf. The spore-case opens by a cross-slit, to let out the dust-like yellow spores—the "lycopodium powder" or "vegetable brimstone," used for coating pills, for fireworks, and stage lightning, etc.

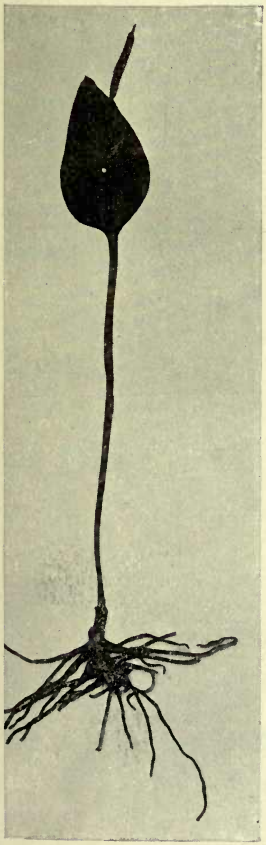
The common club-moss is well adapted for existence on exposed and bleak hills. Its wiry but pliable stems run along the surface among the other plants which form the moorland carpet—heath bedstraw, tormentil, tough grasses, etc.—sending a root here and there into the soil, while the closely overlapping leaves curve inwards in dry weather and prevent undue loss of moisture.

The only other club-moss at all common in Britain is the Fir Club-Moss (*L. Selago*), which is confined to hills and moors. It differs greatly in habit from the common club-moss, for the stem branches repeatedly as it rises from the ground, and the plant, which may be eight inches high, thus acquires a tufted

WALL-RUE (*Asplenium ruta-muraria*)



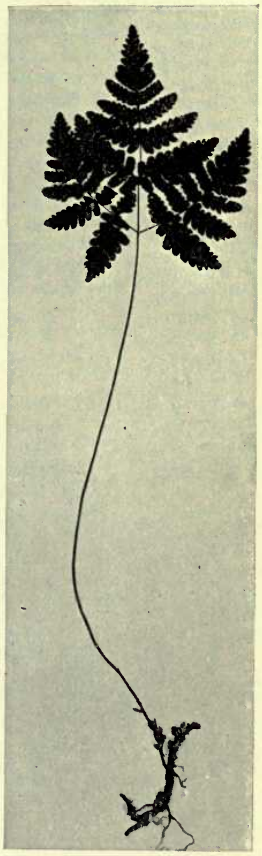
FILMY FERN



ADDER'S-TONGUE

MOONWORT

Photos by Chalkley Gould, Southampton.



THREE-BRANCHED POLYPODY

"LITTLE CLUB-MOSS" (*Selaginella*)

"FIR CLUB-MOSS" (*Lycopodium selago*)

"WATER CLUB-MOSS" (*Isoëtes*)

COMMON CLUB-MOSS (*Lycopodium clavatum*)

Photos by Chalkley Gould, Southampton.

fan-like form. The leaves are narrow and pointed, and all except the youngest ones spread out from the stem. There is no distinct "club" or cone, but the upper leaves of the branches, which are broader than the lower ones, and yellowish instead of dark-green, bear the spore-cases. Very often the spore-cases are replaced by buds or "bulbils," which fall off and give rise to new plants. These bodies are easily recognised by their pale green colour.

The "Little Club-Mosses" (*Selaginella*) have more delicate leaves than the true club-mosses. One species grows in bogs and marshes in various parts of Britain, except in southern England, but many are cultivated in greenhouses for ornament. The stem is usually slender and creeping, and sends down a root at each point where it branches, this root only branching when it grows into the soil. In most kinds there are two sets of leaves on the stem—larger leaves in a row at each side, and much smaller ones forming two rows on the upper surface of the stem.

The cones are on short, special branches, with all the leaves alike, and usually in four rows. The upper spore-cases contain large numbers of small spores, but the lowest ones are larger, and contain each only four large spores.

The germination of the spores is not easy to follow, the prothalli being extremely small. But if you sow both kinds of spore together on damp soil you may get young Selaginella plants, each coming from one of the large spores.

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CHAPTER V

Mosses and Liverworts

The term " Moss " is popularly applied to all sorts of small plants, and even to large ones, such as the " Club-Mosses " (Lycopodium). Mosses grow chiefly on damp soil, but many are adapted for living on walls, rocks, trees, and various dry and exposed places, while a few grow submerged in fresh water. Their adaptations vary as widely as their habitats; mosses which grow on dry wall-tops or mountain rocks may become thoroughly dried up without losing their vitality, while the aquatic kinds quickly die on being taken out of the water. Some mosses have peculiar habitats. The cord-mosses (*Funaria*) are regularly found on charred soil where a fire has been made, while some mosses grow only on dung in hilly districts. Mosses play an important part as pioneers in the process of soil-formation in rocky places, while others help the fungi to convert fallen leaves in woods into leaf-mould. In moist woods many of the elegant creeping feather-mosses form a soft green carpet, this being their favourite habitat. Other feather mosses grow in large patches on the bases of tree-trunks, while the erect mosses, which generally form tufts or cushions, grow chiefly on walls and rocks, and also on soil in more open situations.

The most conspicuous and familiar mosses are the various kinds of Peat-Moss (*Sphagnum*), which differ considerably from all other mosses. They grow in dense masses in bogs, especially on heaths and moors, and in some places play a large part in the formation of peat deposits. The most notable feature of the peat-mosses is their great capacity for absorbing water, which makes them useful in various ways, *e.g.*, in the cultivation of orchids. Pull up a handful of Sphagnum and note the long stems, which are individually limp and weak, but gain support

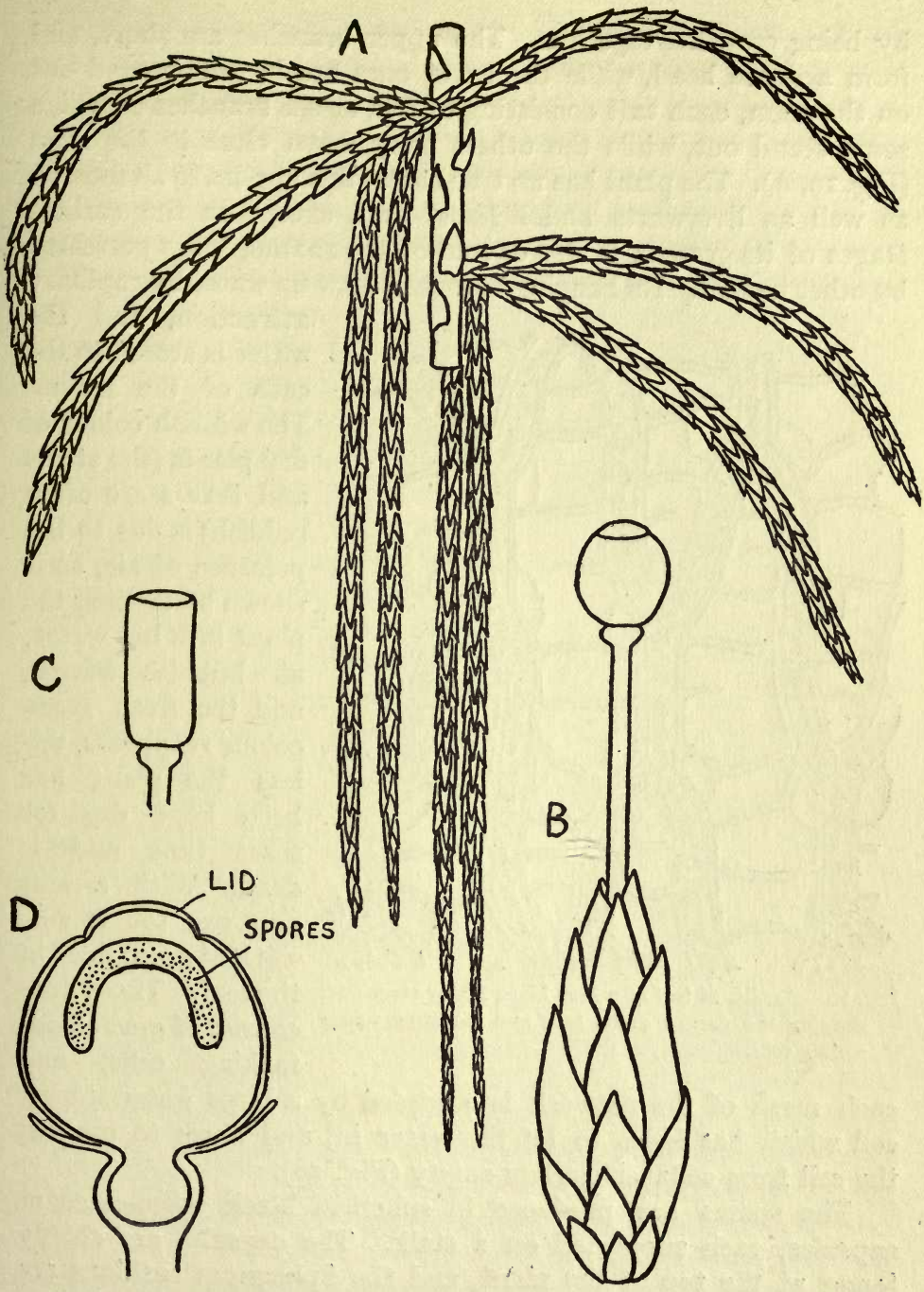


FIG. 19.—Bog-Moss (*Sphagnum*). A, part of a stem with two branch-tufts; B, a female branch with fruit; C, capsule after the lid has been thrown off; D, longitudinal section of an unripe capsule.

by being crowded together. The upper branches are short, and form a dense head, while the lower ones are in tufts spaced out on the stem, each tuft consisting of five or six branches of which some stand out, while the others hang down close to the stem (Fig. 19, A). The plant has no true roots (this applies to all mosses, as well as liverworts and lichens) and, except in the earliest stages of its growth, is also devoid of the rooting hairs possessed by other mosses. Its hanging branches draw up water by capillary attraction, and the water is stored in the cells of the leaves. The whitish colour of dry plants (the stems and leaves are often reddish) is due to the presence of air, as is shown by dipping the plant into hot water; air-bubbles escape, and the fresh green colour reappears, unless the plant has been kept dry for some time and is dead. With a lens you can see a network of green lines in the leaf. These lines consist of green food-making cells, and each mesh of the network is occupied by a large water-storing cell which has holes to let the water in, and fibres to prevent the cell from collapsing when empty (Fig. 20).

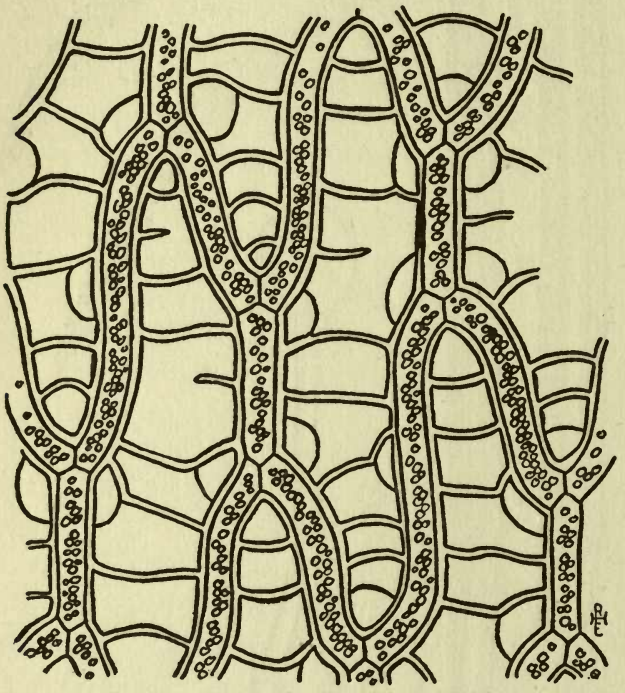


FIG. 20.—Portion of leaf of a Bog Moss, highly magnified, showing the narrow green cells and the large water-storing cells.

The spores are produced in spherical black spore-cases or capsules, each supported on a stalk. The capsules are chiefly found at the top of the plant, and the Sphagnum cushions are often seen studded with the pin-like fruits. The capsule opens by throwing off a small circular lid at the top, to let the spores escape.

If you put some fruiting plants in a jar or deep saucer, covered with a sheet of glass, you will probably see, in a day or two, loose lids on the under side of the glass.

The rest of the mosses may be roughly divided into two sets, which we may study separately, choosing a few of the commonest kinds only—for there are more than five hundred distinct kinds (species) of mosses in this country.

In the first set the stem is erect, and usually not much branched, and the fruit is produced at the top. The tendency to upward growth results in the formation of tufts or cushions, while the "top-fruiting" prevents further growth of the main stem itself, and therefore new branches are formed below the fruit. Brownish threads arise from the base of the stem, and fix the plant to the soil, but most of the water which a moss needs is absorbed by the leaves as rain or dew, and we find among mosses various adaptations for holding water by capillary attraction between the leaves, and in other ways.

The common Cord-Moss (*Funaria*) is a good type to study, because it produces its fruits all the year round. It grows on walls, heaths, and banks, and you are almost sure to find it wherever the soil has been burnt, also on old cinder-heaps and paths, forming bright yellowish-green patches. The stems are only about half an inch high; the lower ends give off a felted mass of brown rooting-hairs, the pointed leaves (thin, but with a distinct central vein) are scattered over the lower part of the stem, but at the top they form a swollen tuft or bud. The fruit, when ripe or nearly so, consists of a reddish stalk (1 to 2½ inches long), bearing at its bent upper end a pear-shaped and lopsided capsule. The capsule is green at first, and bears a scaly cap with a long point, but later it turns brown and the cap falls off. Look for very young fruits; they are long and tapering, and the scaly cap is swollen out below, the swelling containing water which keeps the young capsule (at this stage a rod-like body) from drying. As the young fruit grows the envelope breaks across, part of it being carried up to form the cap, while the lower part remains as a cup round the base of the stalk. At the free end of the ripe capsule there is a round lid, placed obliquely, which falls off eventually, but the mouth of the capsule, instead of being a

clear opening, as in Sphagnum, is closed by a series of reddish teeth; with the lens you can see sixteen of these teeth, with their tips meeting at the centre of the mouth, and giving the latter the appearance of an "iris diaphragm" (Fig. 21, B). When the air is dry the teeth move apart, leaving slits between them through which the spores escape as brown dust; when the air is damp the teeth become more curved until they meet and close the slits. The stalk of the

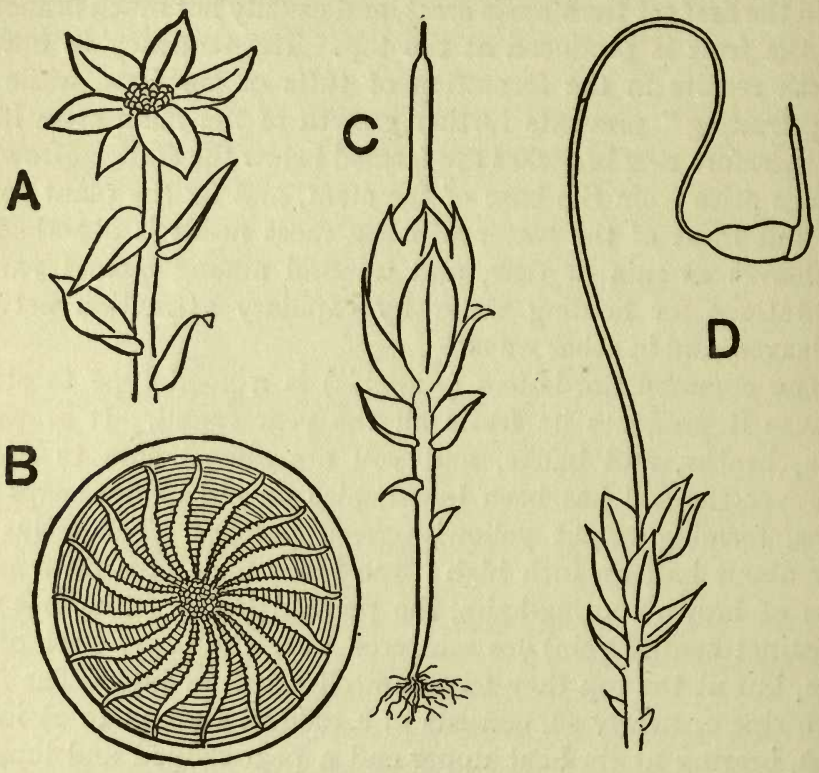


FIG. 21.—Cord-Moss (*Funaria*). A, upper part of a male shoot; B, peristome seen from above; C, female shoot with young fruit; D, same with older fruit.

cord-moss shows peculiar movements when wetted and dried, whence the name Funaria hygrometrica. You will notice that the dry brown stalk is curved, wavy, or spirally coiled. Dip it into water or moisten it with the tongue; the stalk untwists itself, swinging the capsule round from right to left (seen from above); you can easily tell the cord-moss from other mosses by this peculiarity.

Open up ripe capsules, and sow the spores as you did the fern spores. In a few days notice the branching green threads, which soon form a felt on the soil. This felt is called the protonema. Put some of it on a slide with a drop of water, and look

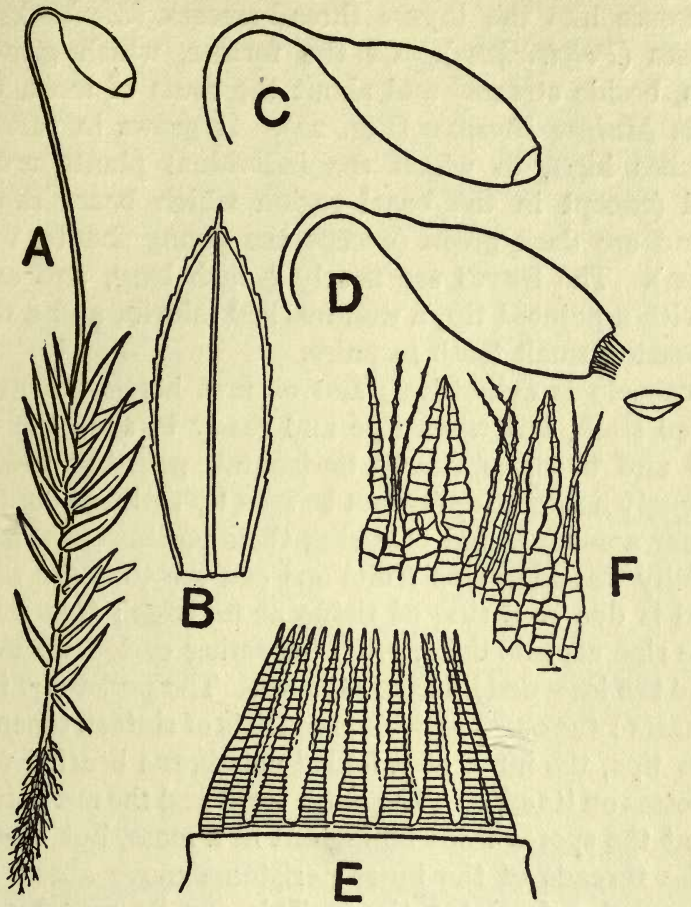


FIG. 22.—Thyme Thread Moss (*Mnium Hornum*). A, female plant with fruit; B, a leaf magnified; C, ripe capsule, before opening; D, capsule throwing off its lid and showing the peristome; E, outer peristome; F, inner peristome.

for the *buds*, which eventually grow into new moss plants. Keep cultures of protonema going, and watch the growth of the buds; a single protonema (formed by germination of one spore) can give rise to many plants. You can also get protonema cultures at any time of year by simply cutting out sods of Funaria and growing them upside down, covered with a bell-glass and kept

moist, or by cultivating isolated leaves or bits of stem. Any part of the plant—rooting-hairs, leaves, stems—can produce the green threads and thus give rise to new plants.

Some points not easily made out in Funaria can be seen in larger mosses like the thyme thread-mosses (*Mnium*) and the hair-mosses (*Polytrichum*). Of the former, which grow chiefly in woods, beside streams and about the roots of trees, the commonest is *Mnium Hornum* (Fig. 22). It grows in tufts two or three inches high, in which the individual plants are seldom branched (except in the basal region which bears the rooting hairs), and are dark green (except the young shoots, which are pale green). The leaves are nearly ¼ inch long, and are lance-shaped with a pointed tip, a well-marked midrib, and a thickened border bearing small teeth in pairs.

The capsule is cylindrical, and at first hangs downwards on the curved stalk, but when ripe and ready to shed the spores it is raised and becomes nearly horizontal, pointing towards the more strongly lighted side (as can be seen by setting young fruiting plants near a window and changing their position now and then). By carefully watching ripe fruits one can see that the separation of the lid is due to a ring of tissue at its edge ; this ring comes off as the ripe capsule dries, often becoming curled up in a single piece, and the loosened lid then falls off. The peristome is double, as in Funaria ; the outer peristome consists of sixteen tapering teeth with free tips, the inner of a folded membrane bearing numerous fine processes on its edge. The outer teeth and the membrane serve to prevent the spores from falling out in a mass, but when the air is dry the threads of the inner peristome move about and jerk the spores out a few at a time. This can be seen by laying a ripe capsule on white paper and breathing on it, watching what happens as it is alternately moistened and dried.

The sperm- and egg-pockets are easily found in Mnium, especially the former, which are carried on special male shoots whose lower leaves are small, while the upper ones spread out like a flower. The centre of the male " flower " is a brown mass, which, on being teased out in a drop of water on a slide, is seen to consist of short-stalked cylindrical bodies, the sperm-pockets (*antheridia*), mixed with numerous hairs. Slice a male " flower "

longitudinally with a razor, and notice the dense packing of the sperm-pockets and hairs. Squeeze a sperm-pocket on a slide; the liquid which oozes out contains the sperms or male cells. The female "flowers" are more like the barren shoots, but they,

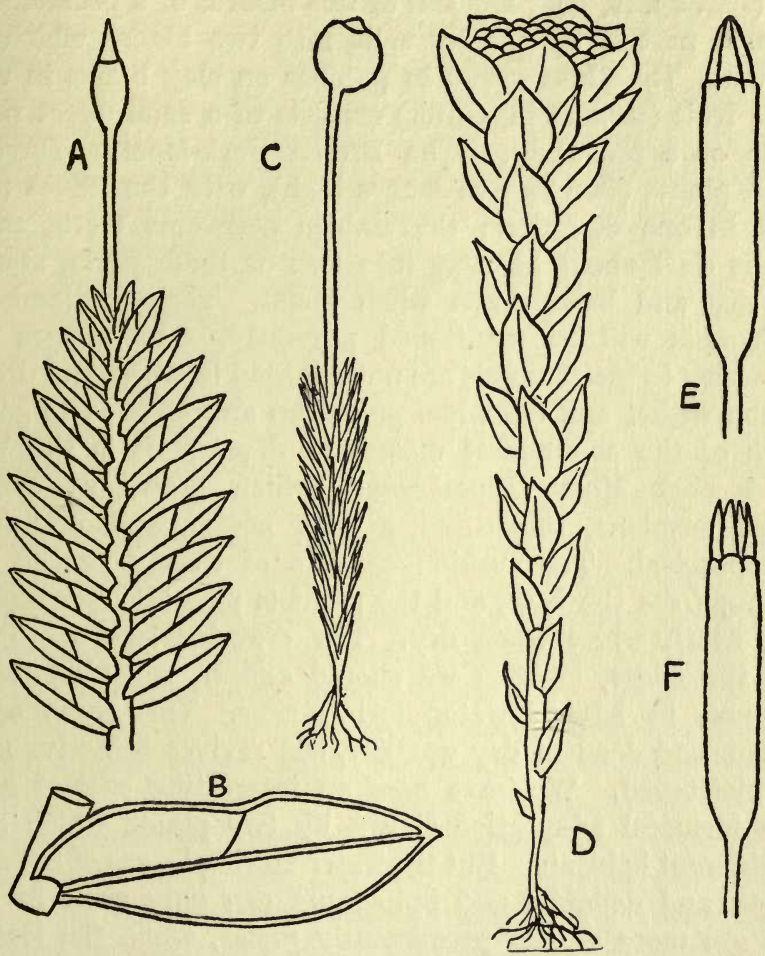


FIG. 23.—A, shoot of Flat Fork Moss (*Fissidens*) with fruit; B, leaf of same, magnified; C, Apple Moss (*Bartramia*); D, shoot of Four-toothed Moss (*Tetraphis*) with cup containing brood-bodies; E, capsule of same closed; F, ditto, open.

like the male shoots, have small leaves below and larger upper ones, in the centre of which lie the egg-pockets, long-necked flask-like bodies easily seen on teasing out the "flower."

Several other top-fruiting mosses are common in woods and

other damp, shaded places. Beside streams we get another kind of thyme thread-moss, *Mnium punctatum*, easily recognised by its large, round or oval, dark-green leaves. The Flat Fork-Moss (*Fissidens*) has its leaves in two rows lying in the same plane (Fig. 23, A, B). The leaf of this moss is of a peculiar form; the basal part is apparently split into two blades which clasp the stem. The plant grows in patches on clay banks in woods, and its fruit (formed in winter) consists of a small erect pointed capsule on a red stalk. The Broom Fork-Mosses (*Dicranum*) are tall plants (two to five inches high), with the leaves mostly turned in one direction; the sixteen peristome teeth, each of which is cleft about halfway into two or three parts, stand up when dry and bend down when moist. The woodland kinds of hair-moss will be mentioned presently. The mosses which are confined to moist woods are not adapted to withstand drought, but soon wither and die when pulled up and allowed to get dry.

One of the commonest mosses in dry woods is the White-Leaved Fork-Moss (*Leucobryum*), which grows in compact, rounded cushions, sometimes a foot across, and occasionally quite spherical. The cushion consists of closely packed stems radiating from the base, and the plant is pale bluish-green when moist, nearly white when dry. The crowded leaves are rolled up at the edges, and, as we should expect, resemble those of Sphagnum in having water-storing cells. This moss appears withered and dead in dry weather, but revives to active growth when moistened. We have here an interesting case of a practically identical adaptation shown by two plants which live in very different habitats. But the water-storing leaves of Sphagnum are thin and delicate, and Sphagnum can only grow in places which are more or less permanently moist, while the leaves of Leucobryum are thick and robust, so that the plant is able to endure a long period of drought. Sphagnum occurs only in bogs and very wet woods, Leucobryum in dry woods and also on heaths.

The following are common on roadsides and on walls. Apple-Moss (*Bartramia*), on sandy banks, forms yellowish-green tufts, the crowded narrow spreading leaves giving the plants a star-like appearance as seen from above. The young capsules in spring are nearly globular and pale-green, resembling miniature

apples. The Hairy and Silvery Thread Mosses (*Bryum capillare*, *B. argenteum*) have pear-shaped capsules like those of the Mniums, but they hang vertically downwards on the stalk. The former, common on walls, rocks, and often on tree trunks, is a tufted plant with bristle-tipped leaves; the latter, on dry roadsides and walls, is smaller (about half an inch high), and is pale green when moist, but white and silvery when dry, with blunt-tipped leaves. These, like the other wall-inhabiting mosses, are able to endure complete drying up for a fairly long time. The Small Fringe-Mosses (*Grimmia*) form neat, grey, rounded cushions on stone walls almost everywhere, the grey appearance being due to the leaf-bristles (one at the tip of each leaf). One kind has a very short fruit-stalk hardly projecting from the leaves, but in the commonest kind the stalk is long. The peristome teeth are dull red and notched at the top; they spread out when dry. It is interesting to compare the fruits of the two common Grimmias. In the very common grey-cushioned kind (*G. pulvinata*) the stalk is at first strongly curved, so that the young capsule is buried in the leaves and protected by them until it is ripe, when it becomes erect. The mouth of the capsule is small, so that the spores can only be shaken out gradually by the wind, an important thing (to avoid waste of spores) for a plant growing on an exposed wall top. In the rather less common "sessile-fruited" kind (*G. apocarpa*), whose tufts are less dense and brownish, the capsule has a wider mouth, since it is less exposed to the risk of having all the spores blown away at once in a high wind. The Large Fringe-Mosses (*Rhacomitrium*) grow on rocks more commonly than on walls, and one kind (Woolly Fringe-moss) grows on moors in large cushions a foot or more across. The leaf has a white hair at the tip, which is often as long as the leaf itself, or longer. The Purple Fork-Moss (*Ceratodon*), one of the commonest wall mosses, is easily known by its purple fruit-stalk. The peristome is very pretty, each tooth being nearly cleft to the base into two equal parts. The Screw-Mosses (*Tortula*) have hair points on their leaves, but are distinguished from other mosses by their curious peristome. This consists of thirty-two long threads, which are spirally coiled. On drying, the teeth become partly uncoiled,

leaving narrow spaces through which the spores escape, the whole peristome becoming shorter (Fig. 24). When moistened the peristome expands again and the threads are tightly rolled

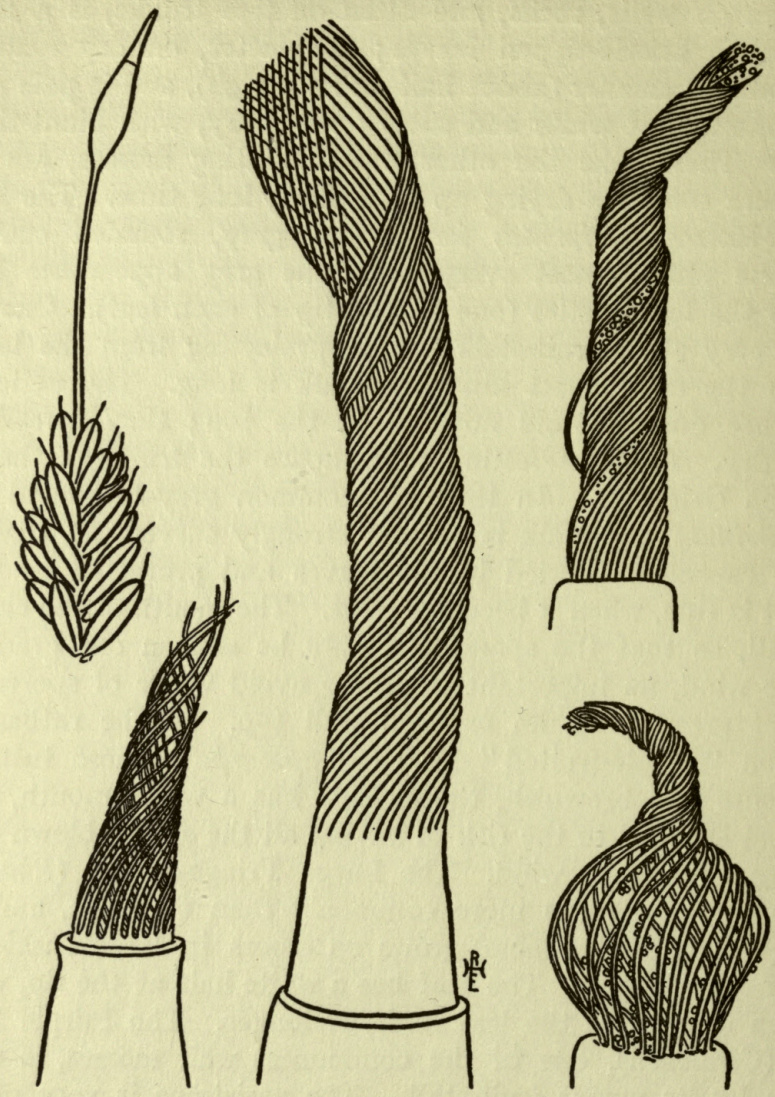


FIG. 24.—Peristomes of Screw Mosses.

up. In some kinds the threads start from the edge of the capsule mouth (where the lid fell off), but in others there is a tube or collar below the teeth, so that the escape of the spores in dry weather is still further limited.

Some of the top-fruiting mosses grow on trees. The curious Four-Toothed Moss (*Tetraphis*), which grows chiefly on old stumps and decaying wood, is well worth studying. It forms bright green tufts, about an inch high, and many of the stems end in a neat cup which contains a number of small buds or brood bodies, each carried on a short, slender stalk (Fig. 23, D). On being set free these bodies produce new plants. The fruits, which are formed all summer, but are often rather sparingly produced, have a peristome of four teeth, which move inwards and meet when moist but stand erect when dry (Fig. 23, E, F). The Bristle-Mosses (*Orthotrichum*) grow in neat tufts on trees, and are short, erect plants with short-stalked capsules, usually showing eight ribs on the surface (one kind has a smooth capsule), and having a very elegant peristome. In the commonest kinds (Fig. 25, A, D) there are sixteen outer teeth, in eight pairs, which when dry bend out widely and hang over the edge of the mouth, and eight or sixteen slender inner teeth which behave in just the opposite way, bending up when moist and closing down when dry. Hence in damp weather the capsule mouth is closed, while on drying the outer teeth bend right, but the spores can

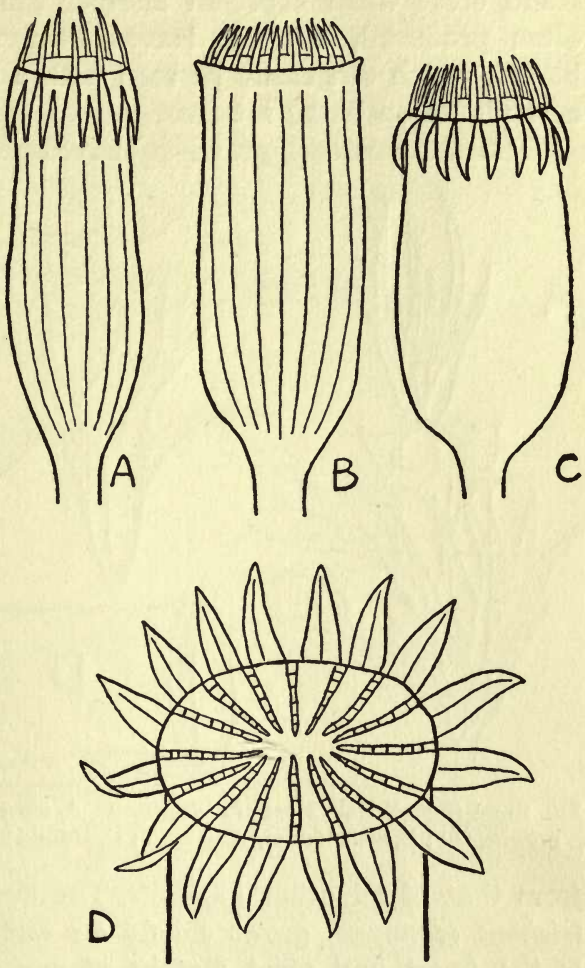


FIG. 25.—Capsules of Bristle Mosses (*Orthotrichum*).

only be shaken out gradually through the spaces between the inner teeth. The smooth-fruited kind (Fig. 25, C) has sixteen inner teeth. Another kind (Fig. 25, B) has no inner teeth, and in this case the outer teeth do not curve outwards, but simply stand erect when dry. In another kind still capsules are not often produced, but the leaves bear numerous brown brood bodies, which can easily be seen with a lens, and which produce new plants on being set free.

The hair mosses (Figs. 26–29) have a peculiar peristome differing

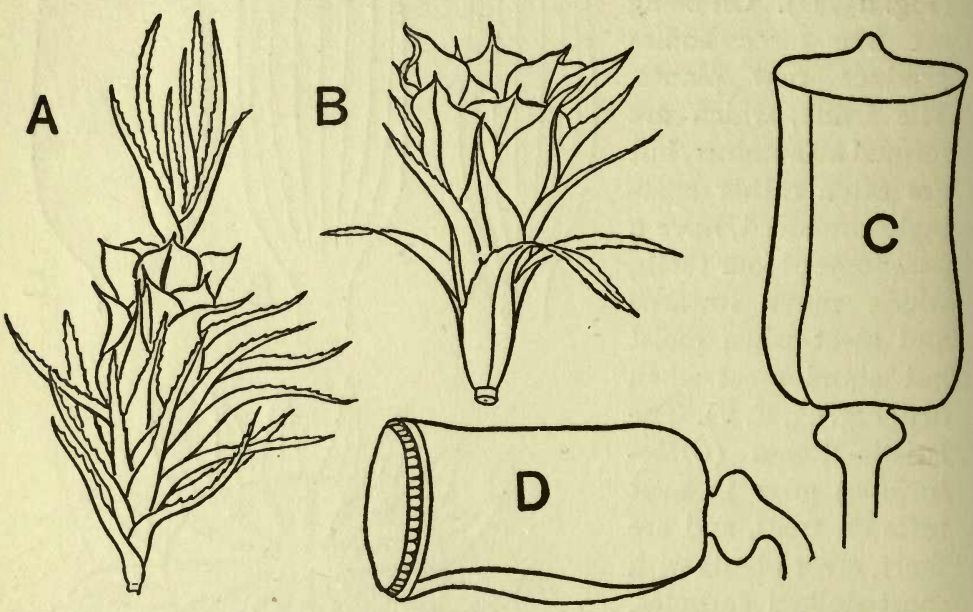


FIG. 26.—Common Hair Moss (*Polytrichum*). A, top of a male-shoot, with a fresh shoot growing out; B, male 'flower,' magnified; C, capsule before opening; D, open capsule.

from that of all other mosses. The Common Hair Moss (*Polytrichum commune*) grows chiefly on wet heaths and moors, and is the finest and most stately of our mosses. It often forms huge cushions—on Dartmoor I have seen them several yards across and several feet deep—and the stems have a star-like appearance as seen from above. It is used for making light brooms and for stuffing mattresses. Pull up a handful of the moss, wash the soil off the lower part, and notice (1) the brown "root-stock" which is covered with hairs and gives off the erect, leafy shoots; (2) the crowded dark green leaves, narrow and tapering.

Pull down a leaf and note the colourless sheath at its base clasping the stem. In plants that have been allowed to get dry you will notice that the leaves close up so as to lie against the stem, but on dipping the plant into water they spread out again. In addition, some of the hair-mosses have a thin wing along each side of the leaf, and when the plant gets dry these wings roll inwards and cover the green middle part of the leaf. The hair-mosses are therefore beautifully adapted for life in places where they are liable to undergo periods of drought,

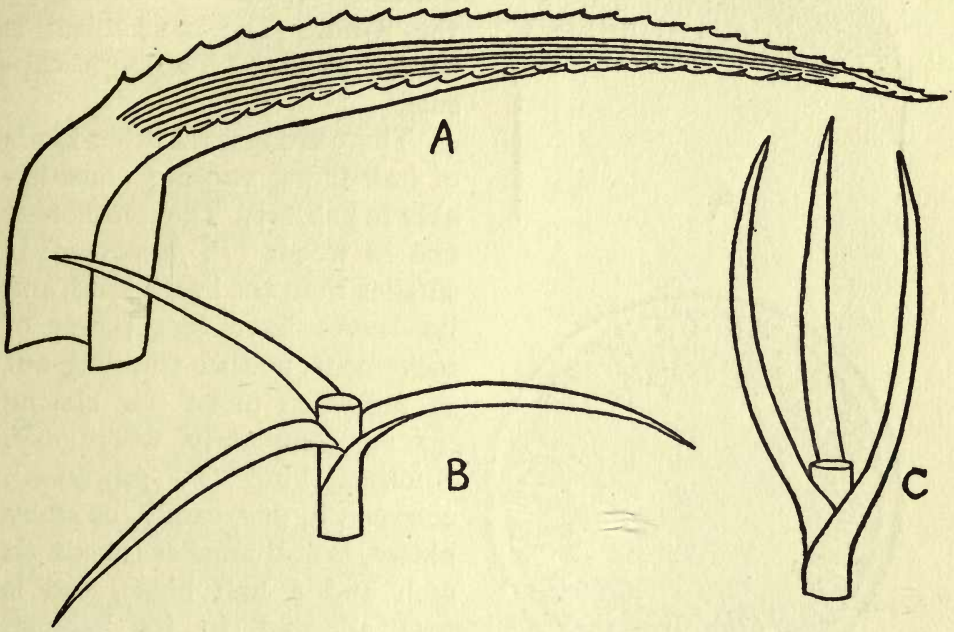


FIG. 27.—Common Hair Moss. A, a leaf, magnified; B, a piece of stem with three leaves spread out (moist condition); C, same with leaves closed up (dry condition).

and have excellent means of protecting themselves against drying up.

The male "flower" is cup-like, and is peculiar in that the stem after a time (when the sperms have been discharged) grows out of the cup, and produces another cup and so on (Fig. 26, A, B). The capsule grows on a long, firm stalk (2 to 5 inches), and is at first erect and covered with a conical, fibrous hood which is easily picked off, but eventually the capsule becomes horizontal by the bending of the stalk. It is sharply divided

into three parts—(1) the peaked lid, (2) the square spore case, (3) a swelling separated from the spore case by a groove; the swelling, however, strictly forms part of the stalk. When the lid falls off, or is picked off, one sees a flat membrane across the mouth of the capsule, and below this a ring of small pores (usually sixty-four) separated by short bars; these bars are the peristome teeth, across whose tips the membrane is stretched. It is easy to see how this mechanism causes the spores to be dusted out gradually when the nodding capsule is shaken by the wind. The mechanism is similar to that of a poppy capsule.

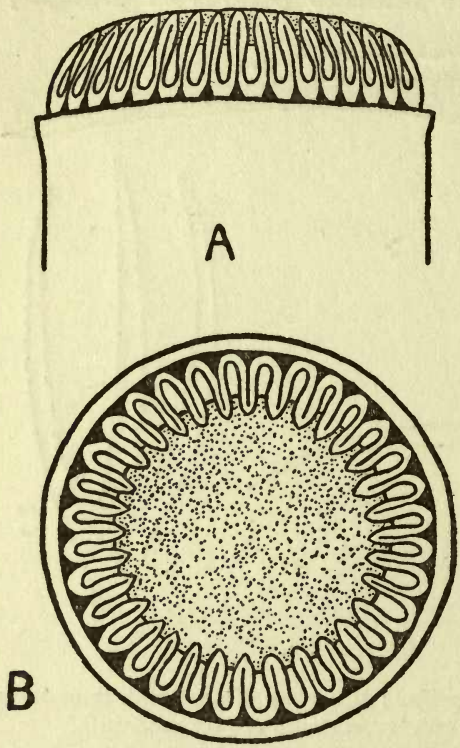


FIG. 28.—Peristome of Hair Moss, magnified. A, side view; B, view from above.

There are several other kinds of hair-moss, varying considerably in habitat. The commonest one in woods (*P. formosum*) is smaller than the heath kind, and its leaves have less power of movement, neither standing out so far when moist nor closing up so completely when dry. Another kind (*P. piliferum*), common in dry, sandy, or stony places, is still smaller (about an inch and a half high), and is well adapted to its habitat. The rolling up of the leaf is very marked, the scaly wing-like margin of the leaf being easily seen in this species, which is rendered conspicuous by its bright orange or scarlet male flowers, and the golden hood over the capsule.

The Wavy Hair Moss (*Catherinea undulata*, Fig. 29), very common on sandy or clayey soil in woods, fruits in late autumn and winter. The capsule is slender and strongly curved, though the stalk is straight, and its lid has a curved beak (often nearly as long as the capsule itself), while the hood is thin and

smooth—not hairy as in the Polytrichums. The leaf has no sheath base.

In the second set of mosses, the Side-Fruiting Mosses, the stem, which is usually much branched, bears the fruits on special short branches. Hence the stems keep on growing after producing the fruits, and may reach a great length. These mosses are rarely erect, but form loose straggling patches, and the branching is usually feathery, like that of a fern leaf. The stems are fixed to the soil here and there by tufts of brown rooting threads. These threads penetrate decaying leaves and twigs lying on the wood floor, and help, along with the threads of fungi, in the work of breaking up the dead vegetable matter and its conversion into leaf-mould. Besides forming the greater part of the soft mossy carpet of woods, the side-fruiting or feathery mosses grow among grass in damp fields and lawns, while many occur on tree trunks, walls, stones, and rocks, and a few in running streams.

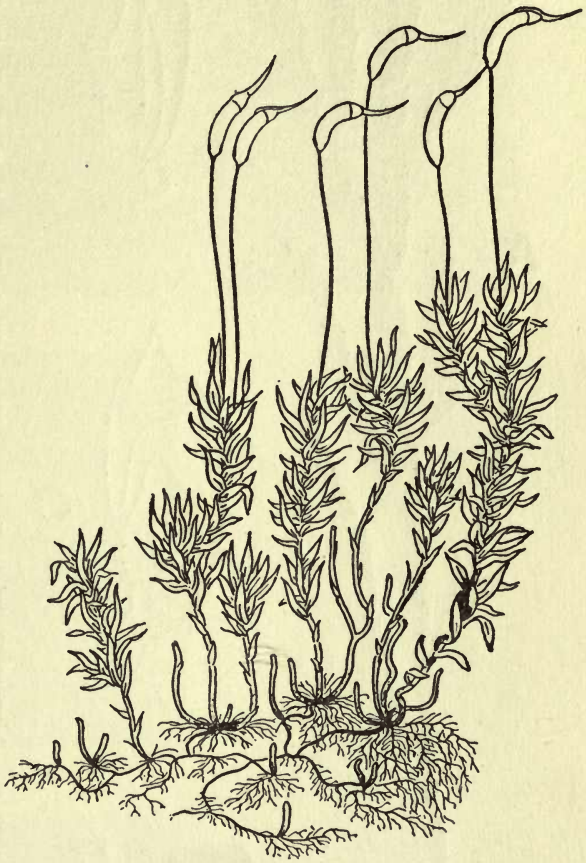


FIG. 29.—Wavy Hair Moss (*Catherinea*).

The Great Water-Moss (*Fontinalis*) is sharply separated from all the other side-fruiting mosses. Its shoots are attached to stones in streams, and may be several feet long (Fig. 30). The dark-green leaves are in three rows, each leaf sharply folded inwards along the middle line. When the plant is submerged it rarely fruits, but in summer it is often

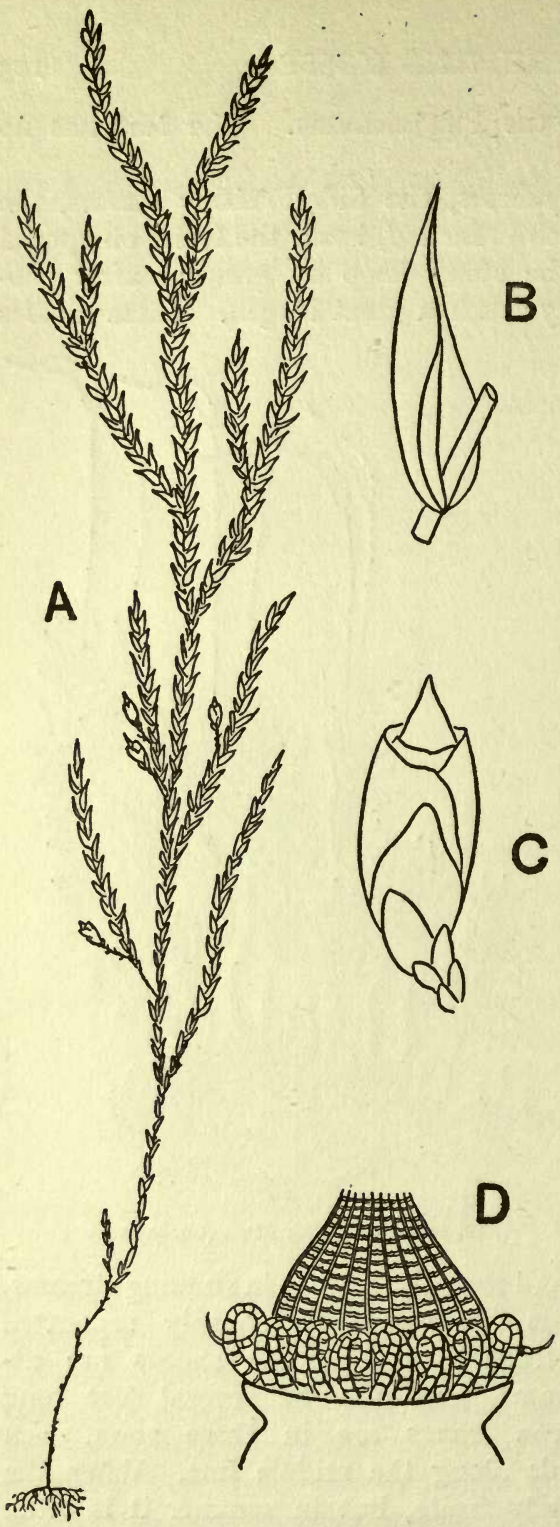


FIG. 30.—Great Water Moss (*Fontinalis*). A, entire small plant, reduced; B, a leaf; C, female branch with fruit; D. peristome.

left high and dry, and then produces abundant capsules. The capsule is almost sessile, and has a most beautiful peristome, bright red in colour, and consisting of sixteen outer teeth which are separate and curved inwards when dry, and sixteen inner teeth which are joined by cross bars so as to form a cone-shaped lattice or sieve. The spores are thus held in a sort of basket, and gradually shaken out of the openings.

The other side-fruiting mosses are very much alike in general appearance. The peristome is like that of Mnium, consisting of sixteen outer teeth and sixteen branched inner ones. The outer peristome serves to open or close the mouth of the capsule after the lid has fallen off. The spores, when moist, stick to the branches of the inner peristome, which, by their wriggling movements during drying, flick the spores out in dry weather.

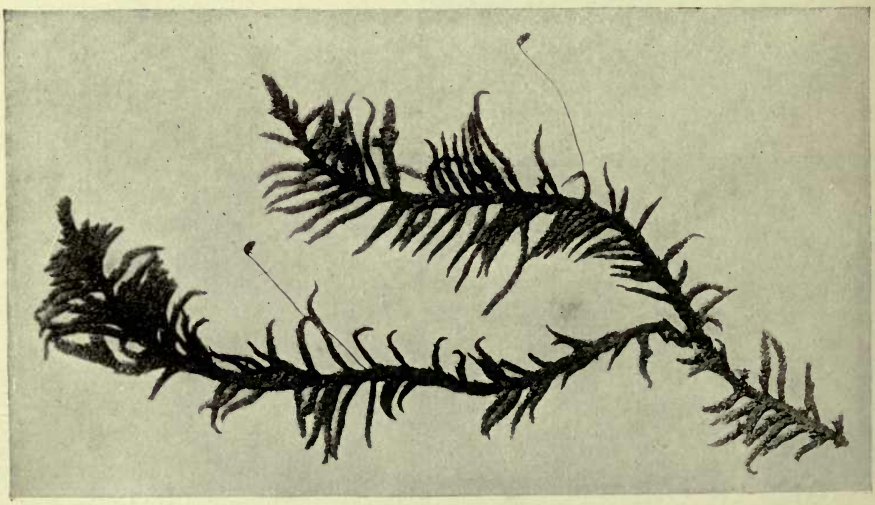
PELLIA, IN FRUIT (*Photo by Dr. O. V. Darbishire*)

MARCHANTIA, WITH GEMMA-CUPS

EGG-POCKETS OF A MOSS, MAGNIFIED

MARCHANTIA, WITH FRUITS

HAIR-MOSS, IN FRUIT



FEATHER-MOSSES

Photos by Chalkley Gould.

Several of the commonest feather-mosses are shown in our plates, made from photographs.

The Liverworts grow in the same kinds of habitats as the mosses, but on the whole are more decidedly moisture-loving plants.

The commonest and most easily recognised of our liverworts is *Pellia epiphylla*, which grows chiefly beside streams. Almost any stream will yield abundant material, and *Pellia* is an extremely interesting plant on which to make continuous observations throughout the year. It can easily be grown indoors, kept moist in flat dishes. It forms patches, sometimes a foot or more across, in which the plants overlap each other, the new branches growing over the old ones so as to form a felted mass. The plant consists of a branching green ribbon or *thallus*, which has a thick middle part or "midrib," and is covered below with brownish rooting-hairs given off by the midrib. In early spring the growing ends of the thallus have a crisp parsley-like appearance, due to the young branches, which have a bright fresh green colour. Later, these grow out and form the new ribbon-like lobes. About this time (April or May) the plants often show the fruits. These are stalked capsules, the stalk being long, slender, and delicate in texture, while the capsule is spherical and black. Since each branch may produce a fruit, the appearance of a fruiting patch of *Pellia* is very striking, the plants appearing to be studded with long black-headed pins. If you pull up a patch before the fruits have grown up, and keep it under observation indoors, you will find that the stalk is at first very short, and that the fruit lies inside, or just projects from, a cavity in the thallus. The fruits can be found during the winter months, each sheltered in its pocket-like cavity, which has a little flap over the opening. In spring the stalk grows in length, carrying the capsule upwards. This growth is usually very rapid, and the stalk may reach a length of four inches (*i.e.* forty or fifty times its original length) in three days after it has begun to elongate. The capsule then splits into four pieces, exposing a mop-like mass of spores mingled with threads (*elaters*). The elaters wriggle about with every change in the moistness and dryness of the air, and thus loosen the spores, which are dispersed

by the wind. When this has happened the stalk has become weak and limp, and soon it falls over and perishes. It is a fragile and temporary structure, serving only to hold the capsule well up in the air, above the thallus, until the spores have been shed. This is true of liverworts generally, the delicate and short-lived fruit contrasting strongly with the stiff stalk and more highly organised capsule of the mosses. If you do not happen to examine a patch of *Pellia* at the right time (during the first few months of the year) you will see nothing of its fruits. The sperm pockets are produced in small cavities on the upper side of the thallus, which are often very conspicuous through being raised and wart-like.

Another very conspicuous liverwort, which you are almost certain to find in the same habitats as *Pellia*, and often growing mixed with it on stream banks, is *Fegatella conica*, a large plant for a liverwort. The thallus is brighter green than that of *Pellia*, and may be six inches or more in length, and over half an inch broad. It branches in the same way as *Pellia*—by repeated forking at the growing ends, but differs markedly in that the upper surface shows a network of fine lines. At the centre of each of the diamond-shaped areas thus marked out there is a white spot. Each of these spots is an opening in the roof of an air-chamber, as is easily proved by dipping the plant into hot water ; an air-bubble escapes from each pore. The air-chambers are arranged in a layer, their side walls corresponding to the lines seen on the thallus. In autumn and winter the plants often bear, at the front of each branch, conical bodies resembling small pointed toadstools, and in spring each of these bodies is raised to a height of two or three inches by the rapid elongation of its stalk. These bodies are not single fruits like those of *Pellia*, however. Each has six lobes at its edge, and from each lobe a small black capsule projects a little distance, hanging downwards. The whole structure is a special branch of the thallus, which grows up into the air and carries with it six fruits. The individual fruits have, of course, no need for long stalks ; they have stalks, but these are short—just long enough to push the capsule down beyond the lower surface of the cone, and so expose the spores to the wind. The sperm pockets are also collected into groups,

each group being produced on a rounded or oval cushion seated at the front of the thallus.

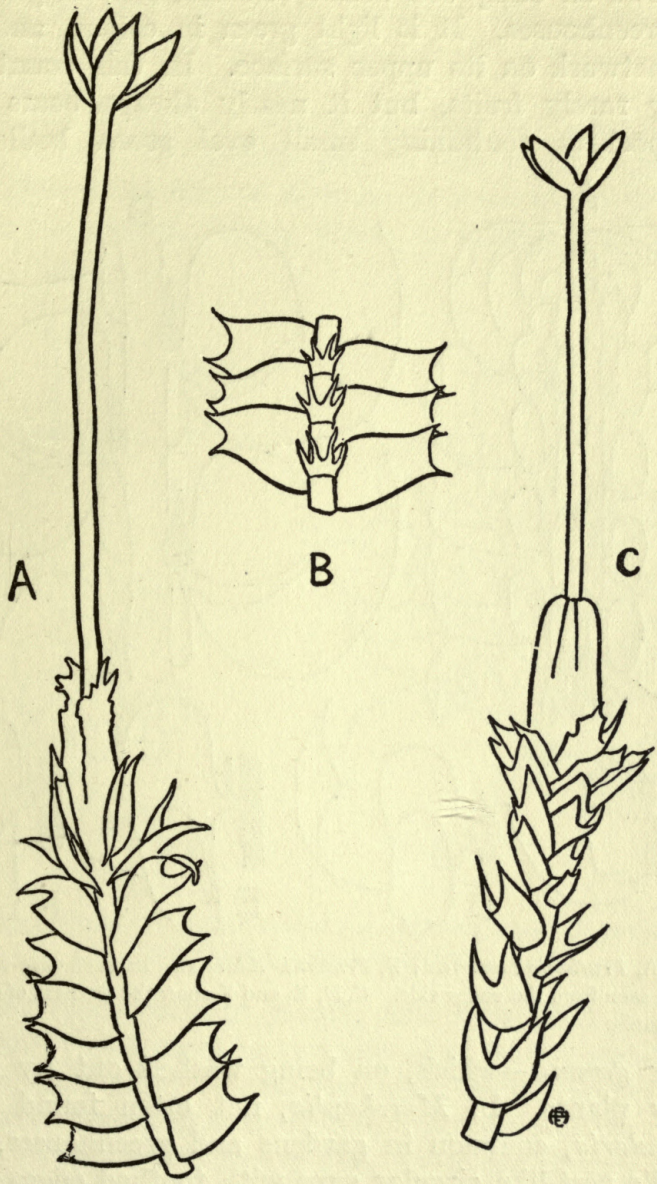


FIG. 31.—Leafy Liverworts. A and B, *Lophocolea bidentata*, very common on damp soil and rotten tree stumps (A shows upper side; B, lower side); C, *Cephalozia bicuspidata*, very common on damp soil in shaded places.

Three other plants which resemble *Fegatella* in general appearance are commonly found. The commonest is *Lunularia*, which grows on damp soil beside streams, also on garden paths and in greenhouses. It is light green in colour, and shows a distinct network on its upper surface. In this country *Lunularia* very rarely fruits, but it nearly always bears crescent-shaped pockets containing small oval green bodies—brood

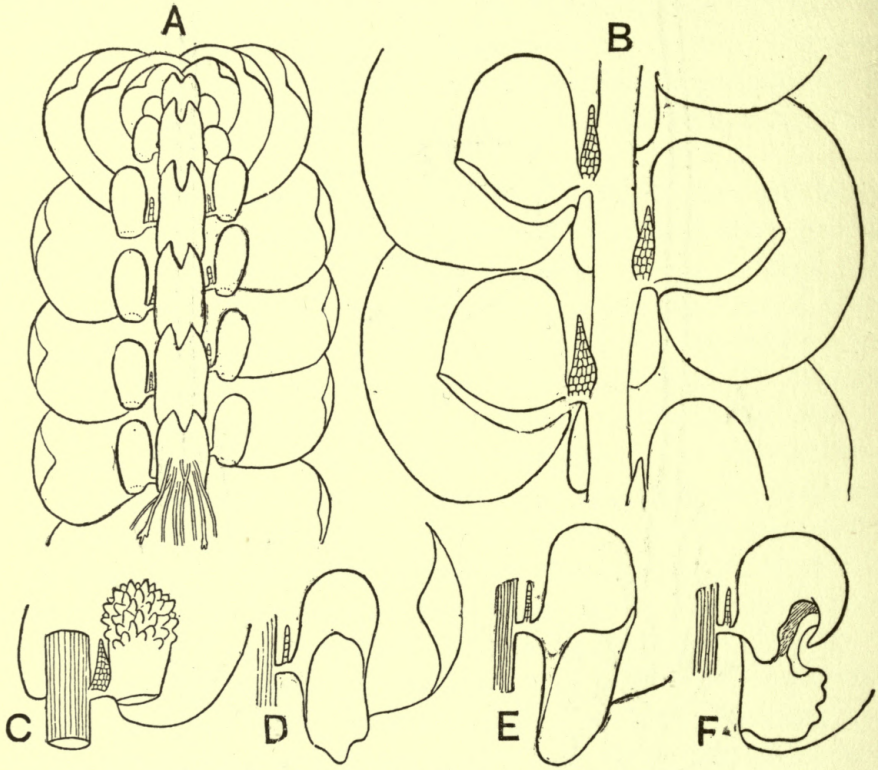


FIG. 32.—A, *Frullania tamarisci*; B, *Frullania dilatata*.. In each case a part of the plant is seen from the under side. C, D, E, and F show the pitchers of other species of Frullania.

bodies or *gemmæ*—which, on being washed out by rain, grow into new plants. In *Marchantia*, not often found wild, but, like *Lunularia*, common in gardens and greenhouses, there are neat bird's nest-like circular cups with toothed edges containing gemmæ. The male and female branches are on separate plants, and in both cases are on stalks. In the female branch the fruits are produced in groups on the lower side of the umbrella-

like head, between the radiating ribs. *Reboulia*, common on road banks, resembles the three preceding plants in general appearance, but the thallus is narrower and thicker and the network of lines on the upper surface is less distinct. Its fruit-head is hemispherical in form.

Besides the ribbon-like liverworts, there are *leafy* liverworts, —forming, in fact, the greater part of this group of plants. It is a little difficult at first to distinguish some of the leafy liverworts from the mosses, among which they often grow, but they

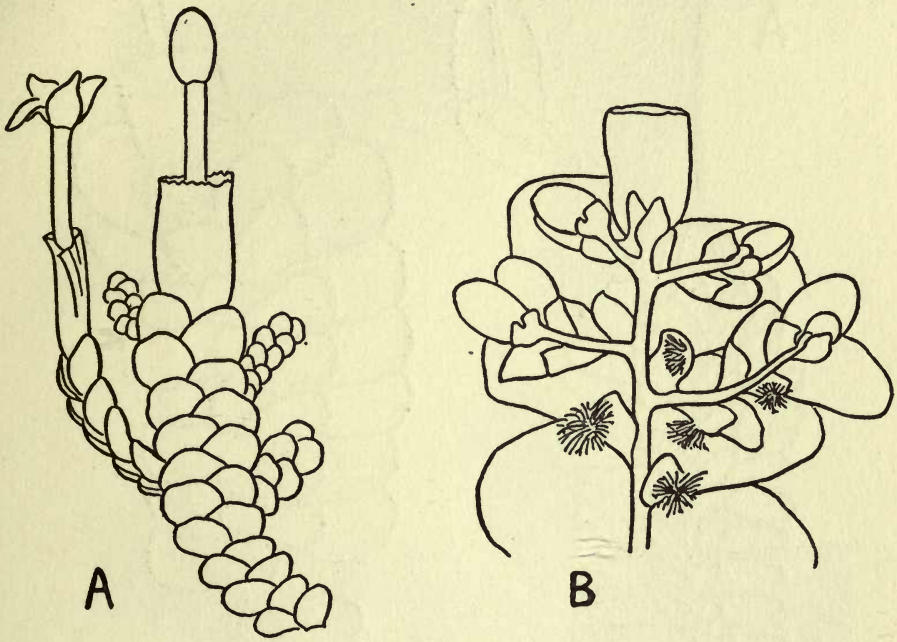


FIG. 33.—*Radula.* A, upper side of plant with two fruits; B, part of under side of a plant, magnified.

are generally more delicate plants, and their thin transparent leaves are always arranged in two side rows on the slender stem, sometimes with a third row on the under side. Some of them have the leaves divided into two lobes, which is never the case with the mosses. The kinds shown in Figs. 32–36 are all very common, and occur in most places, especially beside streams. It will be noticed that their fruits resemble that of *Pellia*, the capsule opening by four valves.

Very few of the leafy liverworts are able to endure drought,

but some show interesting adaptations for retaining and storing up water. The closely set leaves hold water by capillarity attraction in the narrow spaces between them, the leaves over-

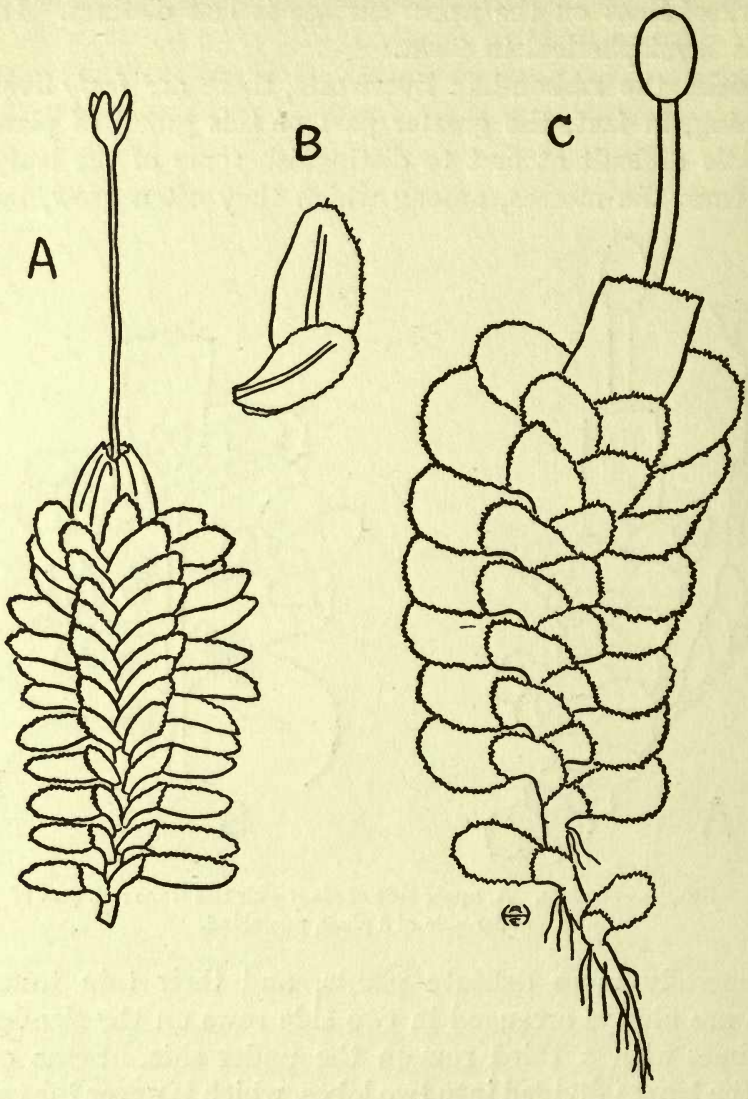
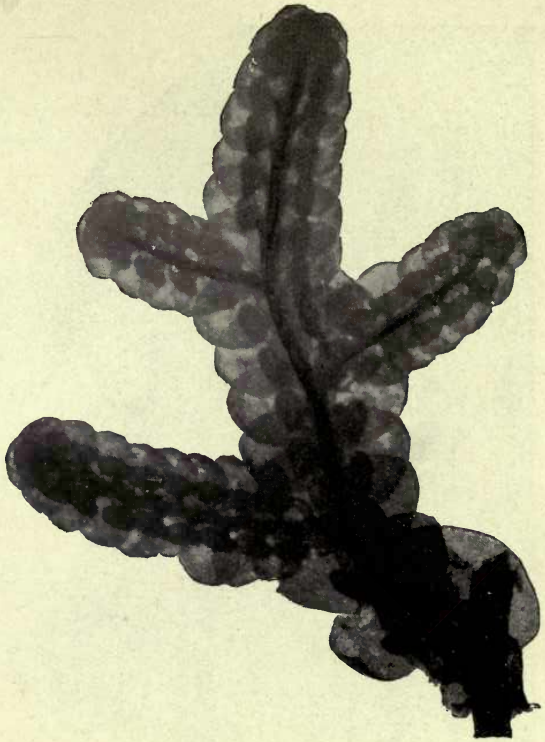


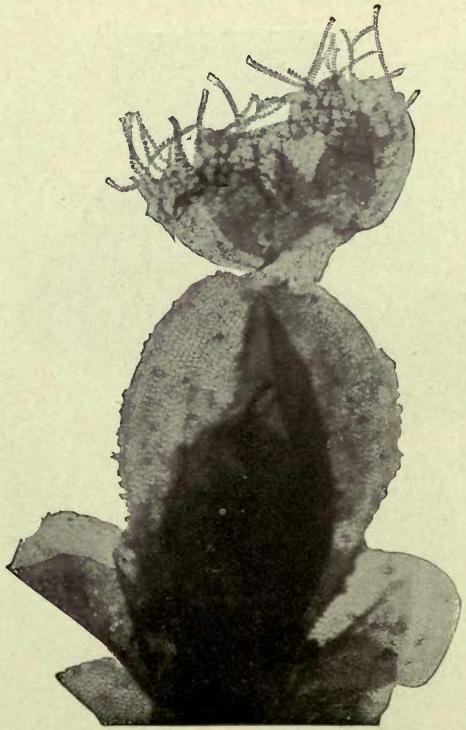
FIG. 34.—Leafy Liverworts. A, *Diplophyllum*, upper side; B, a leaf of same; C, *Scapania*.

lapping each other like the slates on a roof. In some cases, however, the leaves bear water pitchers. This is beautifully shown in the Frullanias—the most elegant of our liverworts.

FRULLANIA DILATATA



FRULLANIA TAMARISCI



FRULLANIA DILATATA

End of a female branch, showing the capsule with its elaters

POLYOTUS MAGELLANICUS

A foreign liverwort bearing numerous water-pitchers

The commonest species, *F. dilatata* (Fig. 32 and Plate), grows on tree trunks, especially smooth-barked ones like beech and holly, forming patches which are usually purplish in colour. Each side-leaf is deeply divided into two lobes, the large upper lobe being large and roughly circular, while the lower forms a neat little cup or pitcher. The pitchers are closely pressed to the tree trunk, and besides storing water often contain small animals (wheel animalcules, insect larvæ, etc.) which have come in for shelter. It has been supposed that these organisms are captured and digested by the liverwort, but this is doubtful. Another kind, *Radula complanata* (Fig. 33), also found on tree trunks, has the lower leaf-lobe folded upon the larger upper lobe, forming a kind of water pocket, and also bearing the rooting hairs. In a few cases the lower lobe of the leaf is *larger* than the upper (*Diplophyllum*, Fig. 34, A; *Scapania*, Fig. 34, B), the two lobes being folded on each other. In others still, the

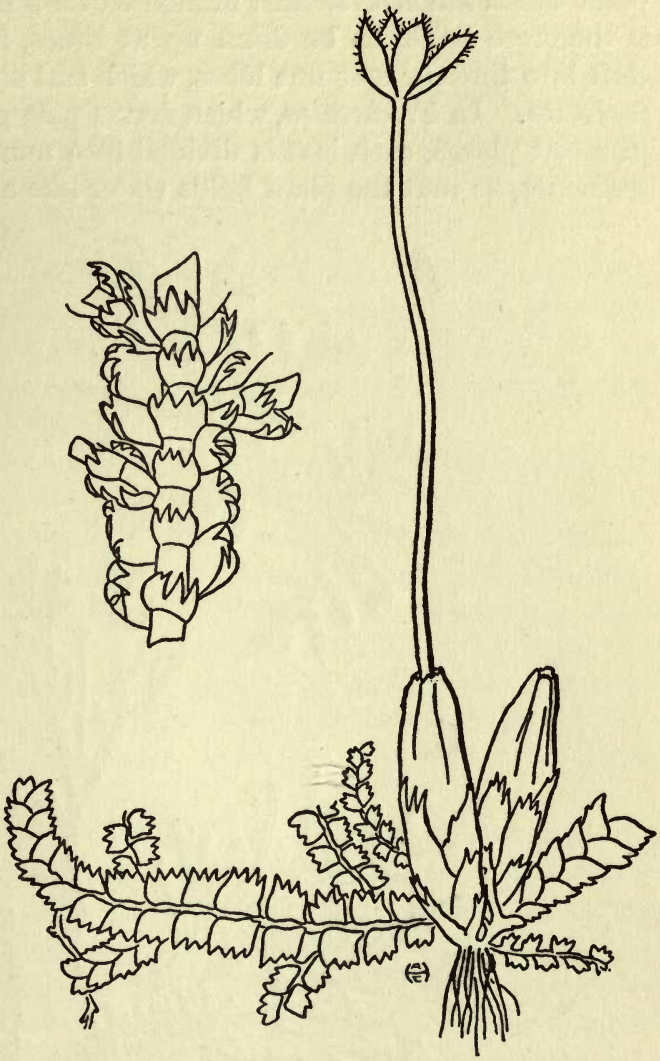


FIG. 35.—*Lepidozia*, a leafy liverwort. The larger drawing shows the upper side, the smaller one the under side.

leaves are deeply divided into several lobes or teeth, which readily absorb water and retain it by capillarity. *Lepidozia reptans* (Fig. 35), very common in shaded places on soil and tree stumps, a small plant which sends its slender branches over and among mosses, and is therefore liable to be dried up at times, has its leaves deeply cleft into three or four fine lobes, which curl inwards and thus hold moisture. In *Trichocolea*, which forms pale green woolly patches in moist places, each leaf is divided into numerous long hair-like segments, so that the plant holds water like a sponge (Fig. 36).

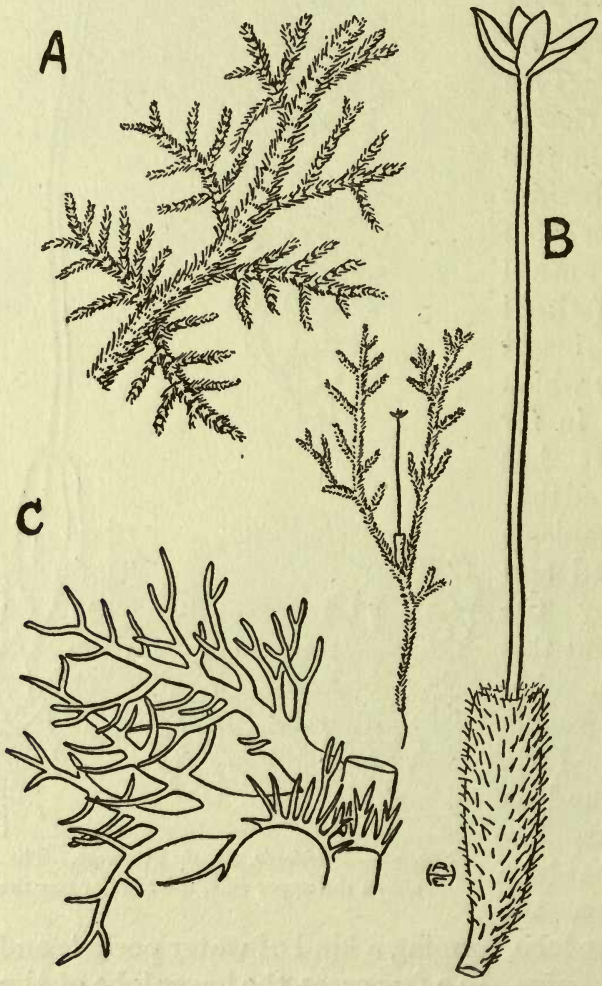


FIG. 36.—*Trichocolea*, a curious leafy liverwort common in wet places beside streams. The smaller sketch shows part of a plant, with fruit, about natural size. A, part of plant, magnified; B, a fruit; C, a leaf, highly magnified.

CHAPTER VI

The Higher Fungi

The Mushrooms, Toadstools, Moulds, Rusts, Mildews, Yeasts, and Bacteria ("germs") all belong to the large group of plants known as Fungi. In this chapter we shall study some of the higher Fungi, including the Mushrooms and Toadstools and other conspicuous kinds.

Fungi have none of the green colouring matter found in ferns, mosses, liverworts, and most of the flowering plants, so that they cannot make food for themselves from the air and the soil water. They require ready-made food, and this they obtain either from decaying matter previously formed by other plants or by animals—*e.g.*, leaf-mould and dung—or from the actual living bodies of other plants or animals. A fungus cannot live when supplied only with mineral matter, *e.g.*, the inorganic salts used in making a "culture solution," in which a green plant thrives quite well.

The conspicuous part of a mushroom or a toadstool is simply the spore-producing body or fruit. The rest of the plant is buried in the leaf-mould, and consists of a fluffy mass of branching threads which run in all directions, resembling a mass of cotton wool. This part of the fungus is readily seen in the moulds which grow on stale bread, jam, damaged fruit or vegetables, old boots, and all sorts of dead vegetable and animal substances.

Get some mushroom "spawn" from a dealer in bulbs and seeds. The "spawn," which is sold in cakes or blocks, is a brittle fibrous mass consisting of richly manured soil permeated with the fungus threads. Break bits off and plant them in soil, or set them in dishes and put in a warm damp place. After a time you will see the little "buttons," or young mushrooms,

growing up as white rounded bodies. When a "button" gets fairly large it swells up and becomes somewhat pear-shaped, then it splits right round, and the upper part is carried up to form the cap, the lower part forming the stalk. The under side of the cap shows the radiating gills—thin plates which are at first white, but later turn pink and finally purple-brown. Where the cap has split away from the stalk you will notice a ring, or collar-like fringe, round the stalk.

While the "spawn" is growing you should go out and find various kinds of mushrooms and toadstools. The commonest kinds of toadstools have gills like those of the mushroom itself. In many cases you will find the same sort of toadstool coming up again and again in successive crops on the same patch of soil, for the buried part of the toadstool lasts year after year. In some cases the toadstools are arranged in circles, the so-called "fairy-rings," which keep on widening as the buried part uses up the food in the soil and spreads out in search of more.

The spores, which are produced by the gills, are very small and light, so that they are easily blown away by the wind as they fall from the cap. The use of the stalk is, of course, to hold the cap up, so that the spores may have a good chance of catching the wind. If you cut across the top of the stalk, just below the cap, and lay the cap, gills downward, on a sheet of white paper, the spores will of course fall out in their usual way and collect in heaps, forming lines each of which corresponds to the space between two adjoining gills. If the paper has been moistened with weak gum—a little gum mixed with water—the "spore-print" thus obtained can be kept as a permanent specimen. You should make spore-prints of all the toadstools you come across.

The Common Mushroom is not, as a rule, difficult to distinguish from other fungi, but there are a few unwholesome fungi which might possibly be mistaken for it. We have not space enough to describe all the edible fungi, or to give complete rules enabling one to decide whether or not a fungus is good to eat. The common mushroom grows in open fields, from June to the end of September; its stalk is white, short, and solid; its cap is dry and cottony on the upper surface; its gills are

Mycena ammoniaca

Mycena galopoda

Boletus edulis

Amanitopsis vaginata

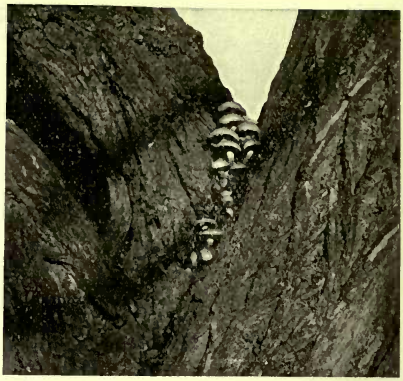
Panæolus phalænarum

Russula depallens

SOME COMMON TOADSTOOLS

Photos by Dr. O. V. Darbishire, Manchester University.

CUP FUNGUS (*Peziza*)



TOADSTOOL GROWING ON A TREE-TRUNK

Photos by British Botanical Association, York.

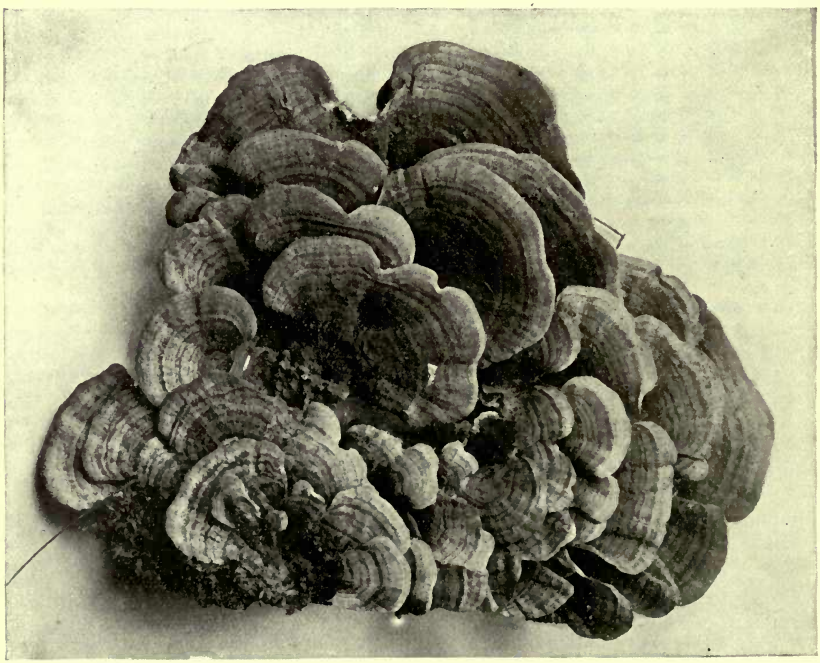


Photo by Chalkley Gould.

A BRACKET FUNGUS (*Stereum*), GROWING ON A TREE STUMP, SEEN FROM ABOVE

closely set, and do not run on to the stalk; the flesh is white, but turns reddish-brown on exposure to the air when cut or broken. It is well to avoid fungi which are either pure white or brightly coloured, as well as those which contain milky juice, or have a bad smell, or have a biting or bitter taste. Several fungi besides the mushroom are edible, and the rest are mostly harmless or only slightly injurious, but some are very poisonous.

Some of the mushroom-like toadstools (gill toadstools) are very common. The Ink-Caps (*Coprinus*) give a very neat spore-print, and when ripe they turn to a black fluid which can, after filtering, be used instead of ink. One of the commonest is the "lawyer's wig" toadstool (*C. comatus*, see Coloured Plate), which grows in fields and lawns during spring, summer, and autumn, forming clusters. The young fruits are egg-shaped, white, and smooth, but later they become bell-shaped and brown, the gills changing from white to pink. In a few more hours the edge of the cap splits at various points into narrow strips, the gills turn black, the tall stem falls over, and soon all that remains of the fruit is a black stain on the ground. A small ink toadstool often occurs on dirty dish-cloths in sculleries; another nearly always appears on horse-dung kept under a bell-jar for a few weeks.

Few fungi are so short-lived as the ink toadstools, but many show great rapidity of growth. As is well known, scores of mushrooms may be gathered in the morning in a field which, the evening before, showed no apparent signs of them, and some of the bigger pore toadstools attain a great size in a short time. One of these huge fungi is recorded, on good authority, as having become over seven feet in circumference and thirty-two pounds in weight after growing for four weeks. The remarkable growth of fungi in all such cases is easily explained. The fruit, though a solid body, has essentially the same structure as the underground part. It consists of branching threads, closely interwoven, and each thread grows in length independently of the others, while at the same time the general shape of the plant is preserved. As might be expected, the greater part of the increase in weight of rapidly growing fungi is due to the taking up of water. As everyone knows, fungi spring up most abundantly

after a spell of wet weather, and they are easily killed both by drought and by frost, owing to the large amount of water they contain. In growing, fungi exert considerable force, as is easily seen from the ease with which they can push up the paving-stones in a yard or stable. Some years ago the main streets of Basingstoke were paved with large stones, and a few months later the pavement showed an unevenness which could not easily be accounted for at first. The mystery was soon explained, for some of the heaviest stones, one weighing over eighty pounds, were completely lifted out of their bed of cement by the growth of large toadstools below them, and it became necessary to re-pave the town.

There are many small gill toadstools besides the "ink-caps." One of these (*Marasmius*) forms very distinct "fairy rings," and has a small cap with thick gills and a stiff tough stalk. Other small kinds, called *Mycena*, are found in woods towards the end of autumn, after rain; they are elegant and fragile plants with thin gills.

Of the larger gill toadstools, two of the most conspicuous are the "Fly Agaric" and its relative the "Poisoner." They differ from most other toadstools in having a sheath which at first covers the cap and stalk, but later is burst and mostly left behind as a cup at the swollen base of the stalk, part of this sheath being carried up in pieces on top of the cap. The fly agaric has a scarlet cap dotted with the scaly whitish remains of the sheath, of which consequently little is left at the swollen lower end of the stalk. The poisoner, which is responsible for nearly all the fatalities caused by eating fungi incautiously, shows the swollen base and sheath—the danger signals—very plainly, in addition to the ring or collar just below the cap; the cap is yellowish or greenish, the stalk and gills pure white.

The Hedgehog Toadstools have spiny projections, bearing the spores, on the under side of the cap. The common kind grows in woods and has a pink or brown cap, bearing long brittle spines below.

The Pore Toadstools have, instead of gills, closely packed tubes covering the lower side of the cap. The Edible Boletus, which grows chiefly in oak and pine woods, is easily recognised.

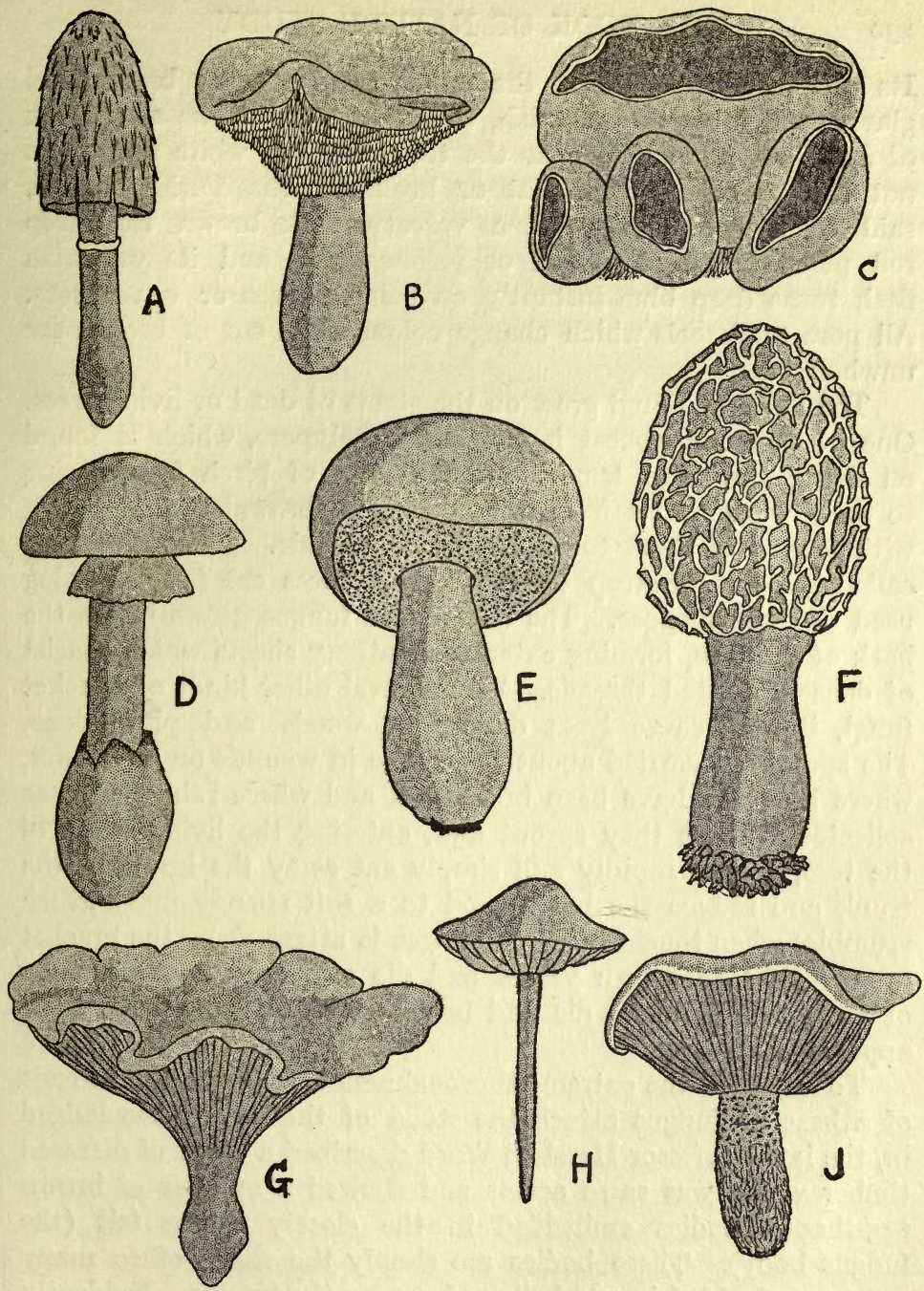


FIG. 37.—Common Fungi. A, "Lawyer's wig" (*Coprinus comatus*); B, Hedgehog Toadstool (*Hydnum*); C, Cup Fungus (*Peziza*); D, the Deadly White Amanita; E, Edible Boletus; F, Edible Morel (*Morchella*); G, Plum Mushroom (*Agaricus prunulus*); H, Fairy-ring Toadstool (*Marasmius oreades*); J, False Mushroom (*Hebeloma fastibile*).

Its cap resembles a bun, the upper surface being brown and glazed, the tubes are greenish, the stout stalk shows a network of fine lines (especially near the top), and the white flesh does not change colour when cut or broken. The Lurid Boletus, said to be poisonous, has a velvety dark brown cap, deep red pore surface, and red or yellow stalk, and its yellowish flesh turns deep blue instantly on being broken or cut across. All pore toadstools which change colour when cut or broken are unwholesome.

The Bracket Fungi grow on the stems of dead or living trees. One of the commonest is the Birch Polypore, which is found on living and dead trunks and branches of birch from spring to early winter. Its fruit is hoof-shaped, brownish, and corky, with a layer of short tubes on the under side. It is sometimes called the "razor-strop fungus," thick slices cut from it being used for this purpose. The rest of the fungus grows inside the bark of the tree, forming extensive leathery sheets which consist of densely matted threads. Like several other kinds of bracket fungi, it may cause great damage in woods and plantations. The spores are carried about and settle in wounds on the trunk, where branches have been broken off and where rain-water has collected. There they sprout and, entering the living wood of the tree, spread rapidly and simply eat away the inside of the trunk and reduce the hard wood to a soft spongy mass which crumbles when touched. When a tree is attacked by the bracket fungus its leaves turn yellow and die off, then the lower part of the stem begins to die and becomes rotten, though the bark appears unaffected.

To illustrate the extreme thoroughness with which the threads of a bracket fungus attack the wood of the tree it has lodged in, the late Professor Marshall Ward described a block of diseased timber which was sawn across and showed a number of brown egg-shaped bodies embedded in the closely woven felt (the fungus body). These bodies are simply the shells of so many acorns, embedded in and hollowed out by the fungus. Evidently a squirrel had stored up the acorns in a hollow in the tree and had not returned to them,—what tragedy intervenes must be left to the imagination. The polypore had then invaded the

hollow and destroyed the contents of the acorns, leaving only the hard shells looking exactly like fossil eggs in the matrix.

The higher fungi include many other interesting plants. The Puff-Balls have a spherical or pear-shaped fruit, which opens by a small hole at the top. The whole fruit, when ripe, consists of a thin skin containing a powdery mass of spores, and these are thrown out in " puffs " as the fruit dries and contracts.

BIBLIOGRAPHY.—*Guide to Sowerby's Models of British Fungi*, published at the Natural History Museum, South Kensington, 4d.

CHAPTER VII

Lichens

Lichens are plants which show great diversity in form, but never have distinct stems and leaves like the mosses and leafy liverworts. They are found in various habitats, but are especially abundant on heathy soil, on tree trunks, and on rocks and walls, while a few grow in moist places among mosses and liverworts.

Lichens form a quite exceptional group of plants with many peculiar features. A lichen is a compound organism, consisting of a fungus individual and numerous alga individuals. The fungus, composed of branching and interlacing threads, has grown around the algæ, and enclosed them in a sort of nest. The result is that the lichen can grow in places which would be quite unsuitable for the independent existence of either the fungus or the algæ of which it is composed. Algæ grow in water or in moist places, and very few can live without a regular and abundant supply of water, while (apart from the leathery and cakey bracket fungi) fungi are, beyond most other plants, sensitive to cold and drought. Yet lichens can thrive in the bleakest positions and in the most severe climates, as on bare mountain rocks, where at different times they may get no water for weeks on end, or may be soaked with rain and mist for equally long periods, and where they are exposed to the greatest extremes of heat and of cold. In a typical lichen, like, for instance, *Peltigera canina*, the fungus provides the organs of fixation; protects the alga cells, especially from drought, and causes them to be spread out so as to catch the light; absorbs water, with dissolved salts, and air containing carbon dioxide; and it alone produces the spore fruits. The alga absorbs sunlight, and from the carbon

BRACKET FUNGUS (*Polyporus*) ON A TREE-TRUNK

Photo by Frith & Co., Reigate.

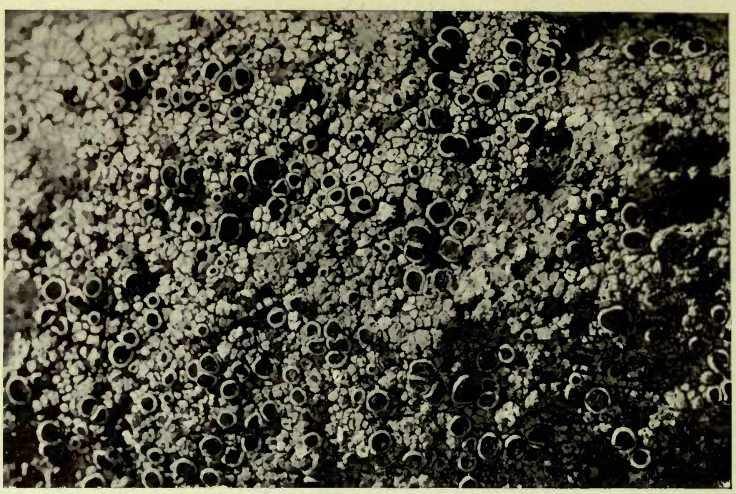


Photo by Dr. O. V. Darbishire.

CUP-LICHENS ON BARK

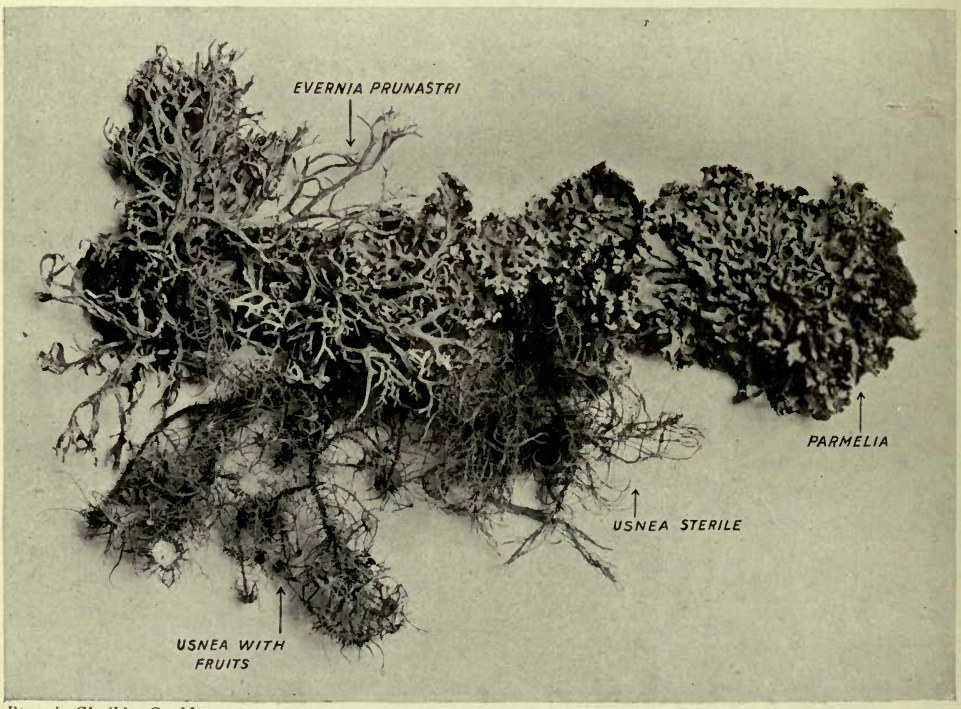


Photo by Chalkley Gould.

LICHENS ON AN OAK TWIG

dioxide, water and salts, manufactures organic food for the benefit of both organisms ; it also shares with the fungus in the work of producing the brood bodies or buds (soredes). Both the fungus and the algæ which make up a fungus can, under suitable conditions, be induced to grow independently, though in the lichen itself they are very dependent upon each other. The isolated alga cells grow and multiply when supplied with water, a few simple inorganic salts, and air (containing carbon dioxide). The lichen spores will germinate in a culture solution containing organic substances (sugar, etc.), and produce a small thallus which of course contains no alga cells. In the lichen thallus the fungus has discarded the usual fungus method of nutrition, which is either saprophytic (*i.e.* using dead organic matter) or parasitic (*i.e.* using the living substance of another organism), so that it can flourish on bare rocks. An ordinary fungus, *e.g.* a mushroom, has its vegetative part (mycelium or " spawn ") buried in the substratum, and growing away from the light and towards moisture, since it cannot utilise sunlight for food making, and at the same time is protected from cold and drought ; only the spore fruits grow into the air, that the spores may be dispersed. The behaviour of a lichen is very different, as may easily be observed by noticing the habitats in which the plants grow.

The reproduction of a lichen is somewhat complicated, for we have to consider the processes of multiplication carried on by (1) the alga cells, (2) the lichen fungus, (3) the lichen as a whole. (1) The alga cells increase in number by simply growing and dividing as if they were living independently, but do not bring about the reproduction of the lichen as a whole, which is effected by the second and third methods. (2) In spore production the fungus alone is concerned ; the spores are usually formed in open cup-like fruits, though sometimes the fruits are flask-shaped with a small opening, or long and then sometimes branched (*Graphis*). The spores are carried away by the wind, and on reaching a suitable place begin to germinate. Unless, however, the threads put out by the spore meet with the proper alga cells they cannot develop further. If the right algæ are present the fungus threads surround them, and a lichen thallus is gradually woven. By sowing lichen spores on glass plates

or tiles on which minute algæ are growing we can readily observe the production of a lichen. In nature, the algæ which are present in lichens are very widespread, so that the formation of a young lichen thallus depends largely upon the existence of suitable external conditions. (3) Many lichens are largely propagated by means of small brood bodies (soredes) budded off by the thallus at the surface. Each sorede consists of a few alga cells, or only one, surrounded by a web of fungus threads. In some cases the soredes are produced in definite clumps, but more often they form a powdery layer sprinkled over the thallus. They are readily carried by the wind, and on reaching a suitable place can at once produce a lichen thallus. This is well shown in the "trumpet" or "cup" lichens (Cladonias), the numerous young plants seen in spring being produced from the soredes.

Lichens do important pioneer work in nature. They help to break up or "weather" the surfaces of hard rocks, and prepare soil on which other plants can grow. In woods they contribute to the formation of humus ("leaf-mould"), when lichen-covered twigs break off and decay in the soil. Many lichens are the hardiest and longest lived of all living creatures. As is well known, the vital activities of all plants are absolutely dependent on the presence of water, which is the most important factor in their environment. Many plants, however, are able to endure a prolonged period of drought and retain their vitality in a dried-up condition, the processes of assimilation, respiration, and growth being suspended. This capacity is especially marked in lichens, which have an unusually strong hold on life, and can withstand drought and extremes of temperature for practically any length of time. Lichens are very long lived, and once established they grow very slowly, as a rule; plants have been observed to increase very little in size during half a century. They are, however, very sensitive with regard to the composition of the air, and cannot grow in the impure atmosphere of towns and their neighbourhood.

In some lichens the plant body (thallus) is rather like that of a liverwort (*e.g. Pellia*) at first glance, while others might be mistaken for fungi—especially as the spore fruits of lichens are similar in structure to those of the cup fungi.

The common Ground Lichen (*Peltigera canina*) has a large green thallus with broad spreading lobes, resembling a large *Pellia*. When growing on shaded banks among damp mosses—its favourite habitat—the upper side of the plant is deep green, but when dry or growing in more exposed places it is grey or brown. The under side, however, is always white, with pale brown veins from which arise, here and there, rooting processes (rhizines) firmly attached to the substratum (mosses or soil). This handsome plant is the best species in which to study, by means of sections, the inner structure of a typical "leafy" lichen. The spore fruits, chestnut-brown or brick-red in colour, are curved around the lobes, on which they are carried at the edge of the thallus. In some of the leafy lichens the thallus spreads out as a flat and more or less circular rosette, with rhizines all over the under side except at the edges. The commonest kinds belong to the genus *Parmelia*, of which several species are very abundant. *P. physodes*, perhaps the commonest British lichen, grows chiefly on trees, forming large and often circular patches several inches (sometimes a foot) across, and is whitish or light bluish-green above, glossy and brown below, and quite smooth, with rounded and turned-up lobes. *P. caperata*, nearly as common, is yellowish-grey above, rough and blackish below; it also grows mostly on tree trunks. *P. saxatilis* is the lichen which so often forms hundreds of large flat grey patches on walls and rocks, though sometimes also found on trees. The thallus lobes branch by repeated forking; the under side is blackish, but brown near the tips of the lobes. It is rarely fertile except in mountain regions, where the thallus is often brown like the fruit cups. The next two species are distinguished by having very narrow lobes and by practically always bearing abundant fruits. *P. pulverulenta*, on trees chiefly, is olive-green when moist but whitish when dry, with brown or nearly black under side and fruit cups. It is often covered with a frosty greyish-green powder consisting of minute buds or *soredes*, which on being blown away give rise to new plants. Finally, *P. parietina* is the most conspicuous of our lichens, growing on roofs, walls, rocks (especially near the sea), palings, and roadside trees; the thallus is yellow or orange above, and whitish below, while the abundant bright

orange cups make this lichen distinguishable from a great distance.

Next, we have a large number of lichens whose thin, flat thallus is attached to, and often actually embedded in, rocks and the stones or bricks of walls, or clinging to the bark of trees, and attached so firmly that one has to chip off bits of the stone or bark in order to remove the lichen itself. These crust-lichens form very thin films or scales, or appear to be mere stains on the stone or bark. More than three-fourths of the total number of British lichens belong to this class, which provides a delightful study for those who will take the trouble to examine with a lens the surface of old walls and tree trunks. On walls these crust-lichens have varied and beautiful tints, though the wall itself looks dull and monotonous from a distance owing to the blending of the colours.

The most interesting bark-inhabiting kind of crust-lichen is *Graphis scripta*, the "letter-wort" or "scripture-wort." The thallus forms a thin grey or whitish film on smooth-barked trees, while the spore fruits form black or brown lines, either straight, curved, or branched, having a strange resemblance to ancient hieroglyphics. In *Graphis* itself these fruit lines are sunk in the thallus, but in some allied kinds they project from the surface. The commonest crust-lichens on rocks and walls are species of *Lecanora* and *Lecidea*; some Lecanoras and Lecideas also grow on trees, however. The Lecanoras, in which the fruit cup has a distinct rim of the same colour and texture as the thallus, are generally grey or whitish. In *L. atra*, on stones, the thallus is white above and black below, and the fruits are jet black. In *L. subfusca*, chiefly on trees, the thallus is whitish on both sides and the fruits brown. In other species the fruits are white, yellow, orange, or red. The Lecideas, which form the great majority of rock-encrusting lichens, have a dark coloured thallus, usually black and charcoal-like, and often sunk into the actual substance of the rock. They have very small but neat fruit cups which have no distinct rim.

In the higher lichens the thallus is either shrub-like and tufted, attached at only one point to the substratum, or bears erect branches in addition to a flat, creeping portion. To the

first of these types belong two very common lichens found almost everywhere on tree trunks. The "Beard-Moss" (*Usnea barbata*) consists of tufts of greyish-green branching threads. When

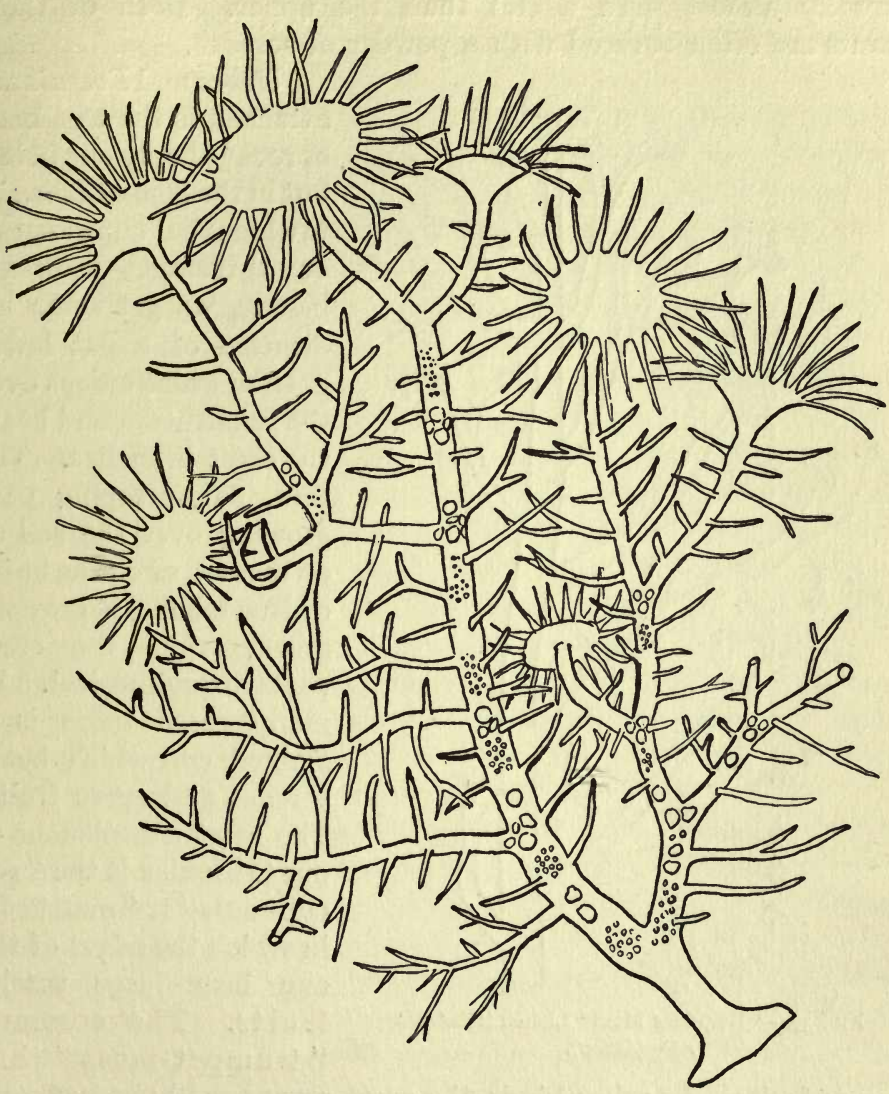


FIG. 38.—"Beard-Moss" Lichen (*Usnea*), with fruits.

young the tufts are rigid and shrubby, but later they droop and become looser. The plant is more often found without spore fruits than with them; the fruits are saucer-like, rather large, and fringed with threads at the edges (Fig. 38).

Evernia prunastri forms drooping tufts of strap-like branches, and rarely produces fruits. The thin branches show a network of wrinkles, and the under side is much lighter in colour (usually almost pure white) than the upper. Both of these plants are often covered with a powder of soredes.

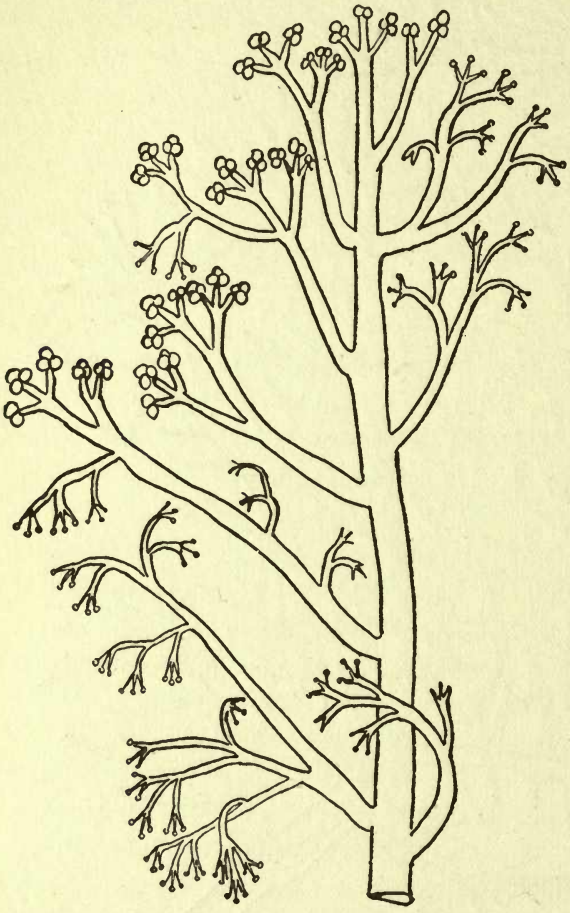


FIG. 39.—"Reindeer Moss" Lichen (*Cladonia rangiferina*).

Usnea and *Evernia* are attached to the tree bark or rocks at only one point, but in the genus *Cladonia*, to which the "cup mosses" or "trumpet-mosses" belong, we get some indication of a flat lower portion which creeps over the substratum and bears the erect branches. The thin, flat, creeping part growing over the soil or on mosses, or on the bases of tree trunks, is greyish-green, while the erect parts are cylindrical. In many cases there is a stalked cup which bears soredes and spore fruits. The most conspicuous of our Cladonias is the "red cup-moss" or "matches," in which the edges of the cup bear large scarlet fruits. The common "trumpet-moss" has brown fruits. In other kinds the erect organs are branched, and in some cases there are no cups at all. This is shown in the "reindeer-moss," which is very common on our heaths and hills. In Norway and the northern parts of Russia and Siberia it grows in great abundance, often covering vast tracts, and giving the landscape a yellowish-grey tint. It forms the chief food of

reindeer, which in winter clear away the snow with their horns to browse on the lichen, and is not despised by mankind when other food is scarce. In Britain the "reindeer-moss" (Fig. 39) is seldom over three inches high, the mealy stalks growing in branching tufts with fine drooping tips on which the fruits are produced.

The adaptations of lichens to their habitats offer an attractive and little-explored field for observational work. Apart from heaths, which are characterised by Cladonias and similar forms with erect assimilating branches, there are three chief lichen habitats—tree-bark, rocks, and moist and mossy places. On trees the encrusting lichens follow the surface of the bark, growing to keep pace with its extension and its cracking as the trunk thickens year by year. On stones the lichens often have the thallus sunk below the surface; if growing on the surface, it often shows furrows in which water can collect, and as it grows it becomes raised into ridges or wart-like projections.

Dry periods appear to be absolutely essential to the well-being of most lichens, especially to those which grow on trees and stones. These soon die and decay when kept moist artificially; the alga cells grow and divide rapidly, but the fungus tissue becomes waterlogged, and the lichen becomes deformed and perishes. Lichens, like *Peltigera*, which grow in moist places, can be cultivated when kept damp, though they also retain the power to resist drought.

It is obvious that the dryness of lichen habitats is due to the nature of the substratum rather than to actual lack of rain. Tree trunks, rocks, stones, and heathy soil, on which lichens grow most luxuriantly, are not well adapted for retaining rain-water, which either runs off quickly (tree trunks, rocks), or is rapidly absorbed and sinks downwards (peaty or sandy soil). Water is absorbed over the whole surface of the thallus; the rhizines, which are often poorly developed, serve mainly for fixation, and, as we have seen (*Usnea*, etc.), the plant may be attached at one point only. A dried-up and dead-looking lichen can in a few minutes become saturated with falling rain or dew—the lichen's only sources of water—and the surface layers become transparent when wet, so that the underlying green alga cells can

absorb light and at once begin to make food. A heavy fall of rain after long drought also enables the plant to produce its spore fruits, which can often be obtained simply by moistening a lichen which has remained dry for some time. A few lichens swell up and become slimy or jelly-like when moist, thus retaining water for a long time, but most lichens have not this power and soon dry up again after having absorbed water, especially when exposed to sun and wind. Like other evergreen plants subject to extremes of temperature and the ever-present danger of desiccation, lichens are tough and resistant, and very few of them can thrive in the moist places which suit other plants.

It is interesting to compare the "bark flora" on different parts of a tree. As every observant person knows, a tree, when not growing in a crowded wood, has a distinct rain-side exposed to the prevailing wet wind, and the wettest part of the tree is on the rain-side at the base of the trunk, where rain-water trickles downwards. This is especially marked in rough-barked trees, like oaks. On the rain-side we find chiefly mosses and liverworts, with here and there a tufted or foliose lichen, while the drier opposite side has few mosses and is often entirely covered with crust-lichens. Higher up the trunk the bark becomes drier, partly because rain-water runs off and partly because of the stronger wind which causes drying, so that the conditions become more favourable to lichens, which here grow all round the trunk. In many cases, too, one can observe a fairly regular zonal arrangement of the different lichen species at different heights on a trunk.

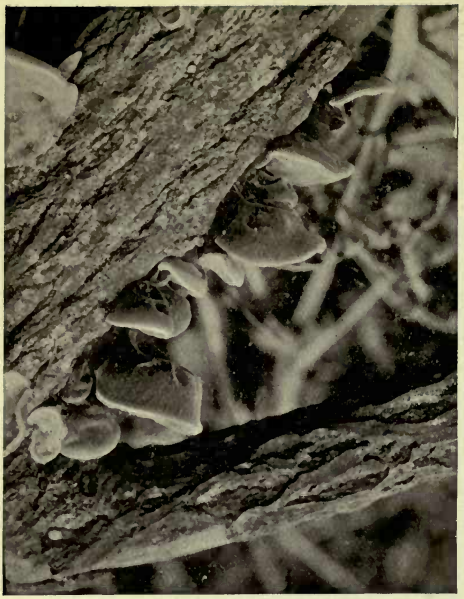
On trees with smooth bark, like beeches, very little water collects and very few mosses grow, though some liverworts (*e.g. Frullania, Metzgeria, Radula*) grow in profusion, but this dry substratum suits *Graphis* and the other crust-lichens which often entirely cover the bark.

Photo by Dr. O. V. Darbishire.

"CUP-MOSS" LICHEN (*Cladonia pyxidata*), GROWING ON A HEDGE-BANK

Photo by Blampey & Co., Ashburton.

GRANITE ROCKS ON DARTMOOR, WITH VARIOUS CRUST LICHENS



Bracket Fungus (*Polyporus*), on a tree-trunk

A Puff-ball (*Lycoperdon*)

"False Truffle" (*Scleroderma*)

Fungus (*Empusa*) growing on a dead fly, magnified

A Mould (*Mucor*), with two fruits, magnified

FUNGI

Photos by Dr. O. V. Darbishire.

CHAPTER VIII

Moulds, Yeast, Bacteria

Moulds occur on all sorts of organic substances—bread, jam, cheese, fruits, leather, blacking, horse-dung, etc. If you put a slice of stale bread in a dish, cover it with a glass, and keep it moist, various moulds will appear, three of which are easily distinguished. One of the first of these, seen about the fourth day, is the Black Mould (*Mucor*), consisting of a white, fluffy mass of fine threads which branch copiously on and in the bread. From this mass there arise upright, stouter branches, each of which ends in a round head, white at first, but soon turning black. The head is a kind of spore case; on dipping one into water on a glass slide the spores are seen to escape by the bursting of the case. Green and blue moulds and many other fungi can be obtained by simply keeping soaked bread under a bell-jar, but ultimately they are destroyed by bacteria, some of which form slimy masses of various colours—blood-red, purple, etc. A host of fungi of all sorts can be obtained on dung treated in this way—moulds, other moulds growing as parasites on the first ones, cup fungi, toadstools, etc.

Mould-like fungi also grow on various living plants and animals as parasites, often causing disease and death. In autumn dead flies are often seen surrounded by a fluffy mass of fungus threads, at the edges of which one can see, with a lens, the spores which spread the fungus to other flies. A similar growth of fungus threads is sometimes seen on goldfish which have been neglected, and a fungus of the same kind attacks salmon and does a great deal of damage. Almost every cultivated plant is subject to one or more of the many destructive fungus enemies of agriculture and gardening. Many of these fungi—rusts, smuts, mildews, etc.—are too small to be studied

without the microscope, but the naked-eye appearances are usually characteristic of each kind and are easily distinguished.

You have probably noticed that a pot of jam sometimes has an alcoholic smell when opened, the jam itself having a frothy appearance. The jam has "fermented." All kinds of fermentation in sugary substances are due to the action of minute plants called yeasts. The most familiar kind of yeast is beer yeast or brewer's yeast, used in brewing and in bread-baking. In brewing, the grain (usually barley) is allowed to germinate until the starch (stored in the endosperm) is largely converted into sugar, then the sprouting barley is killed by heat, and the sugar extracted by water and yeast added to the extract.

If some yeast is rubbed up in water to form a paste, and a little of this is added to a solution of sugar, the liquid soon becomes turbid, bubbles of gas (carbon dioxide) rise to the surface and form a froth, and the liquid loses its sweetness and smells of alcohol. The turbid sugar solution is found to contain an enormous number of yeast cells, some floating singly, while others are connected in chains. Test the gas given off by sugar solution in which yeast is growing by lowering a lighted match or taper, or a glass rod with a drop of lime-water on its end, into a jar; or place some yeast containing sugar solution in a flask fitted with a cork and bent tube dipping into lime-water. The alcohol produced may be recognised by smelling and tasting the fermenting sugar solution from time to time, or by warming the liquid in a test-tube or flask fitted with a straight piece of glass-tubing until the alcohol vapour given off can be ignited with a match. Yeast, like bacteria, produces spores, especially when the food supply runs short; these spores remain alive for a long time, even when dried up, are blown about in the air, and develop into active yeast cells as soon as they reach a suitable medium—as is shown by simply exposing a sugar solution to the air.

In baking, yeast is used simply for the sake of the gas (carbon dioxide) given off, which forms bubbles and makes the bread light; the alcohol produced is, of course, driven off by the heat in baking.

Bacteria are minute plants, whose structure is extremely

simple and can only be seen with the high powers of a microscope. A good deal, however, can be made out regarding their mode of life by simple experiments. Most bacteria can only live when supplied with organic substances, in which they set up decay (putrefaction). During this process gases are formed which cause offensive smells—ammonia, sulphuretted hydrogen (from rotten eggs, cabbages, etc.), phosphoretted hydrogen (from rotten fish, etc.) Other examples of bacterial action are the souring of milk and the conversion of alcohol into acetic acid (as in the souring of wine and cider). Bacteria are also concerned in such processes as cheese-making and tobacco-" curing."

If you put a few peas into a tumbler of water and set it aside, the water soon becomes cloudy, then a scum appears on the surface, and after a time the water gets a nasty smell. The spores, or " germs," of bacteria are present everywhere in the air, ready to grow in any suitable material they may fall into. New spores are formed in the scum on the water, and when the water had all evaporated they would be blown about in the air, in which they would remain suspended for a very long time, since they are extremely small and light. The cloudy appearance of the water is due to the presence of countless millions of bacteria, for they multiply with great rapidity, and have minute whip-like organs by means of which they swim about. We can tell that they must have some power of movement, from the fact that the cloudiness spreads through the whole of the water, which would not be the case if the bacteria were motionless and simply settled down in the water.

As all know, some bacteria are of unpleasant importance on account of the diseases they set up in mankind and in various warm-blooded animals—hardly a single *plant*-disease is due to bacteria. But *most* bacteria are not merely harmless, but of great use to mankind. The great work of bacteria is that of breaking up the organic matter (remains of dead plants and animals) in the soil. In this they are assisted to some extent by moulds and other fungi, as well as such animals as earthworms and various insects, which, with the bacteria, make up nature's army of scavengers. The ultimate products of decay are largely used over again by plants as food.

WOODLAND VEGETATION

By Charlotte L. Laurie, *Ladies' College, Cheltenham*

CHAPTER IX

There is abundant evidence that at one time Great Britain was far more extensively wooded than it is now. Roman historians speak of the forests in which the ancient Britons took refuge. Tacitus, for instance, states that in A.D. 59 Agricola himself reconnoitred the forests and the estuaries, and it is recorded that the Emperor Severus traversed the greater part of Caledonia, hewing down forests and throwing causeways across marshes.

Besides historical, there is geological, evidence of the fact. It is now generally accepted that the presence of peat moors is an indication of the existence of former forests. The peat moors of the Pennine range contain much buried timber, and there is little doubt that primitive forests extended over almost the whole of the Pennine slopes and over a considerable part of their summits, the oak being the dominant tree up to a height of 1250 ft., and the birch from 1250 up to 1750 ft. The peat bed near Sharpness on the Severn has a thickness of nearly fourteen feet, and is composed mainly of oak, alder, beech, and hazel; some of the oaks found in it are of considerable size, one measuring 80 ft. The geological period immediately following the Great Ice Age is sometimes characterised as an age of forests, the growth of which must have gone on for a considerable time to accumulate the depth of peat found at the mouths of rivers, such as the Severn, the Tay, and the Earn. It must be remembered that in that prehistoric age the elevation of the land was far higher than it is at present, and the sea much farther out; in fact, it is probable that part of what is now the North Sea was forest

land connecting Britain with the Continent, and geologists tell us that the whole of the coast line of Great Britain is more or less fringed with submerged forests. It is believed that all of our inland and mountainous regions up to the level of 1500 feet were once covered with dense primeval forest, which has in course of time been cleared away to make room for pasture and agriculture.

In the days of primeval forest the two most marked trees were the oak and the Scots pine; the former characteristic of temperate regions, the latter of sub-alpine. These two trees must often have been in keen competition with each other for the possession of a given area. Supposing the climatic conditions of the area to have been exactly suitable to both, the oak would have encroached on the domains of the pine, for it has stronger branches and a deeper root-system. But if unsuitable conditions were introduced, such as the grazing of animals or the thinning of the oak forest, the pines would have tended to oust the oak.

In the present day there is very little primitive forest left, and in order to understand our woodland vegetation as it is at present, it is important at the outset to realise the influence of man and of animals. The planting of trees—unfortunately not always scientifically—combined with disforesting, has completely changed the character of our woodlands. Old oak woods have been constantly replaced by coniferous trees, such as the pine and the larch. This latter was not known in Scotland till 1738, and two of the first trees then planted still stand beside the cathedral at Dunkeld. Between the years 1774 and 1826 the Duke of Atholl planted as many as fourteen million larch trees. At the present time the Scots pine has practically ceased to grow spontaneously, and is now extensively planted. That it is an indigenous species is certain for two reasons: first, because occasional pine remains are found in peat; and secondly, certain herbaceous plants occurring in woods are known from observation of primeval forests in other countries to be characteristic of primitive pine woods; amongst these may be mentioned *Linnæa borealis, Pyrola minor, P. media, P. rotundifolia, P. secunda, Trientalis europæa, Listera cordata.*

Trees are often prevented from growing spontaneously where animals are allowed to graze. The Scots pine will flourish on sand-dunes; seedlings will spring up naturally, and will grow into young trees, provided they are protected from animals. When, however, cattle and sheep are allowed to roam at will over the dune the seedlings are destroyed, and the pine has to be planted and enclosed until the young trees have reached a certain height. Foresters are all agreed that animals—roedeer, squirrels, above all rabbits—do incalculable harm to woodlands and plantations. Not only do rabbits destroy young trees, but they eat the bark off the bottom of the young trunks, and thus affect the formation of sound wood, so that even after a lapse of fifty years or more the wood may be found in a state of decay. It is lamented by woodmen that rabbits are getting more "wood keen" than they used to be. Wire netting is now placed 4 feet high, instead of 3, and with an outward slope to prevent the rabbits getting into the wood. Mice, too, do a great deal of harm, especially since hawks, weasels, and stoats have been destroyed. Those animals used to eat the mice, which now exist in large numbers, and devour millions of bushels of acorns.

Methods of Observation on Woods

In studying woodland vegetation it will be best to begin with the woods nearest to the home or school. In many parts of the country, particularly in the west, farm houses have small belts of woodland around them. This is so usual that there must be some reason for it. Trees not only shelter the pastures and the houses from the force of the wind, but they improve the land in several ways. Their decaying leaves enrich the soil; they prevent too rapid evaporation from its surface, and thus help to retain a certain amount of moisture in it. If such a wood is on a slope it effectually prevents the denudation of the soil, which may be considerable on an exposed hillside owing to the action of water, particularly in heavy rains. Belts of woodland also afford breeding places for birds, which are very useful in destroying insects that might otherwise become a pest to the farmer.

Of late years the municipalities of large towns, in order to

ensure the purity of the water supply, have tried to obtain wooded areas in which to form their reservoirs. Glasgow is supplied by Loch Katrine, Manchester by Thirlmere, and Liverpool has created an artificial lake in Montgomeryshire, Lake Vyrnwy. This is five miles long, and drains some 18,000 acres. Portions of this are being systematically planted with trees, primarily to ensure the purity of the water supply, although it is hoped in the future to get valuable timber from the plantations.

The larger number of our existing woodlands are, however, maintained for the sake of game, and there is no reason why foresters should not manage woods so as to have covert for game without reducing the yield of timber. This is especially easy in the case of pheasants. The essential thing is to have an under-wood worked as coppice, and an over-wood for the produce of timber. The under-wood must be dense, therefore the trees planted in the coppice must give a great deal of shade; ash and hazel are perhaps the best for this purpose. The under-wood should be cut periodically, but how often depends on circumstances. As far as the trees of the over-wood are concerned, it is better not to cut the coppice too frequently. In some cases every ten years is the time fixed, but every twenty years would be better; for if the under-wood is cut more frequently the trees forming the over-wood will make branches low down, and the wood will be knotty. On the other hand, if the under-wood is allowed to grow too old it becomes thin below, and, when cut down, does not form vigorous young shoots, and is of course useless as covert for game. The selection of the tree forming the over-wood is a very important matter. It must not be a species with thick foliage, but one with an open canopy, allowing plenty of light to get through to the coppice. Ash, oak, larch, birch, poplar are all suitable; but beech, sycamore, elm would not answer, for these trees have thick foliage and cast a deep shade.

It would be interesting to make observations on the woods within reach of a school, and to note which were shelter belts; which served the double purpose of game preserves and production of timber. In these latter, the trees forming the coppice and those of the over-wood should be noted, especially the character of the foliage and the height above the ground of the lowest

branches. In those woods where there is a regular rotation in the cutting of the coppice, the under-wood will show areas with trees in varying stages of growth; where the trees have been lately cut, vigorous young shoots ought to be seen; in other parts the trees will be forming thick covert; whilst others will be ready to be cut down. The direction in which the under-wood is cut is important. It should proceed against the prevailing wind, so as to leave a shelter belt against strong winds. Hazel is very commonly planted as coppice, with oak as the dominant tree of the over-wood, thus forming an oak-hazel wood. The hazel is one of the earliest shrubs to flower; the staminate catkins, or "lambs' tails," may be seen hanging in many a hedgerow or copse about the middle of January. The pistillate flowers have the appearance of mere leaf-buds, and are often unnoticed; they may be recognised by the red styles which protrude from their tips, the whole inflorescence pointing upwards ready to receive the pollen from the pendulous catkins. As the pollen is carried by the wind the supply is abundant. The catkins bear numerous flowers arranged spirally, each in the axil of a bract. The flower itself consists of eight stamens, or, strictly speaking, of four stamens, divided almost to the base, so as to appear eight in number. The way in which they fit against each other and under the bract is shown in Fig. 40.

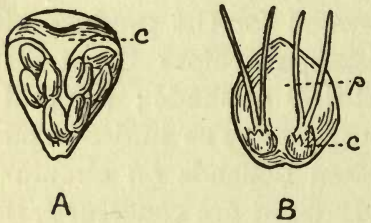


FIG. 40.—A, Staminate flower of Hazel; *c*, bract. B, Two pistillate flowers of Hazel; *p*, bract; *c*, perianth.

Selecting a bud with protruding styles, the outer bracts should be removed. Within these come two to four foliage-leaves, and inside of all the flower-buds. There may be eight to sixteen buds, but only some of these mature. Each bract bears two flowers, and each flower has two stigmas. The ovary is two-celled, and there is a very small perianth above it. Below the ovary an involucre is seen; this develops into the leafy cup of the hazel-nut, and may be compared with the large three-lobed scale of the hornbeam, the hard cup of the acorn, the case of the nuts in the beech, and the very prickly covering of the fruit in the sweet chestnut; for all these structures are formed from the bracts of

the flower. The nuts of the hazel are, to some extent, dispersed by the nuthatch. This bird very cleverly wedges the nut in the

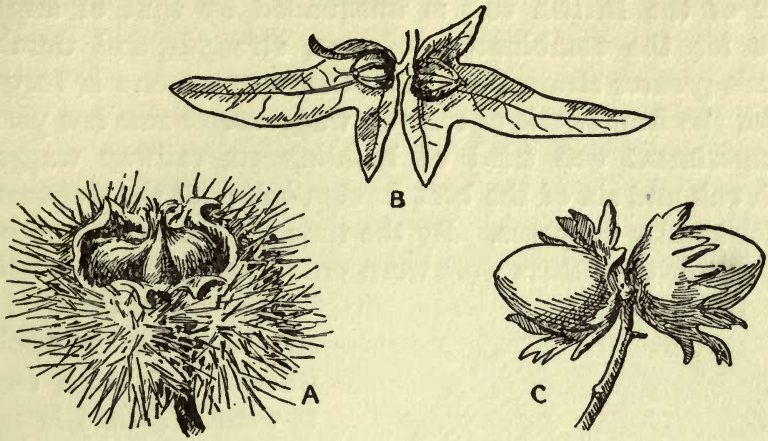


FIG. 41.—A, Prickly involucre, enclosing fruit of Sweet Chestnut; B, leafy involucre, with fruit of Hornbeam; C, involucre and nut of Hazel.

bark of some tree, then breaks open one end and picks out the seed, often dropping it. The branches of the hazel form rods and staves, which are used in making hoops for casks and as walking-sticks. The hazel is often planted in hedges.

TREES PLANTED FOR TIMBER

Many of our woodlands, though by no means the majority, are planted and maintained entirely for the sake of timber. When this is the case many circumstances have to be considered. Some trees naturally produce much more timber than others. From this point of view that tree is best worth planting which will yield the highest possible percentage of good timber and the least possible percentage of firewood. When the branch of a tree is cut across, the wood is seen to be of two different colours; the darker wood in the centre is the hard wood; the lighter, outer wood, is the sap wood, which is useless for timber. Many different kinds of woods may be seen at sawmills. The larch is naturally a good timber-producing tree; the oak, if left to itself, will be apt to spread out horizontally, producing a short trunk and large crown, and then the yield of timber is small. Some trees have soft wood throughout; the birch, for instance, has no hard wood. The

oak, elm, ash, beech, alder, and sycamore are hard woods; the larch is considered a medium wood as regards hardness. The timber of the British oak is unequalled by that of any other species for the combination of size, strength, and durability; it stands greater strain than any other species, and is very much used for the framework of railway waggons. Some few years ago the experiment was tried of building six railway waggons of British oak and six of the best foreign oak; all the waggons were used for similar purposes. By the time the six British ones came in for repair, the others were worn out. For general wheelwright work, where there is great strain, as in the spokes of wheels, and much exposure to weather, there is nothing equal to our oak. From a saw-mill a section of oak, larch, and beech may be obtained and compared with each other; the section should be three or four inches thick, and, if varnished, it keeps cleaner, and may be used year after year for lessons. The most noticeable character about the sections is the arrangement of the wood in rings. This is due to the fact that trees do not form wood of the same quality, or texture, throughout the year. The wood formed at the end of the summer period of growth is very different from that produced in the spring, when the winter's rest is over. The late-formed wood is closer than that of spring, and as the spring growth of one year immediately follows on to the summer or autumn growth of the preceding year, distinct rings are formed, each ring representing a whole year's growth; the age of a tree, when felled, is thus known. The average age of an oak is nine hundred years, and it may even reach fifteen hundred; yews are said to attain some three thousand years.

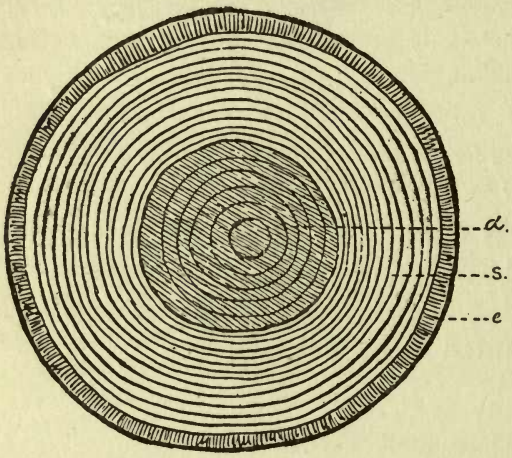


FIG. 42.—Branch of Larch (transverse section). *d*, Heart wood; *s*, sap wood; *e*, bark.

Some trees deteriorate if a wood consists but of the one

species; for this reason, mixed woods occur more often than pure woods. Schools within reach of the Forest of Dean have a Nature-Study lesson at their very doors. Up to the end of the eighteenth century, as history records, this forest consisted of a mixed crop of oak and beech, in the proportion of one oak to two beeches; the oaks were renowned for their size, and for the first-rate timber they produced. During the last century the forest was thinned excessively. On these cleared areas fresh oaks were planted, and apparently protected for a time; but there was no underplanting with beech, and the forest was thrown open unreservedly for grazing purposes. The result is, that the young oaks are low of stature, and can never equal those of former days; the boles are short, for the branches begin very low down; the timber is bound to be poor. The want of underplanting with some tree like the beech, which, owing to its dense foliage, would have enriched the soil with fertile leaf-mould, and would have protected it from too great evaporation, combined with over-thinning, and the injury done to the young trees through unrestricted grazing, account for the condition of this forest. Under the present management there is underplanting with beech, and gaps are being filled up with other trees, such as sycamore, ash, and larch.

Larch used to be extensively planted in pure woods, and there is hardly a part of the country where plantations of young larch trees are not to be seen. At the present time larch is being underplanted with beech, silver fir, or spruce, in order to prevent larch disease spreading through whole woods.

Mixed Woods

Oak and beech are peculiarly adapted to each other; the oak has a deep-rooted system, the beech a shallow one; the beech has dense foliage, the oak an open canopy; the rapidity of growth, and the dense shade of the beech has the effect of forcing the upward growth of the oak, the lower branches are killed off, and long, straight, clean boles are formed. The only danger is that the beech may oust the oak, but this can be averted by appropriate thinnings, or by giving the oak, which is a much slower growing

tree, a start in the first instance. The two most common species of oak are the sessile-acorned oak (*Quercus sessiliflora*), and the stalked variety (*Q. pedunculata*); although the former has practically sessile acorns, the leaf-stalks are from half an inch to an inch long. This is the species present in the Forest of Dean, and generally in the west. Although *Q. pedunculata* is very abundant in the deep marls and clay of Somerset, it is the soil that determines the question; *Q. sessiliflora* can thrive in shallow soil; *Q. pedunculata* likes rich, deep, moist ground. The branching of the oak is characteristic, and gives the tree its gnarled and rugged appearance, so that it is easily recognised; the branches are less twisted in the sessile-acorned oak than in the stalked species.

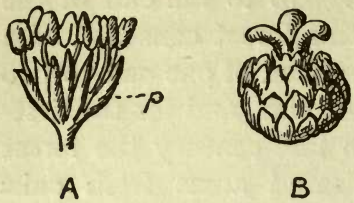


FIG. 43.—A, Staminate flower of Oak; *p*, perianth. B, Pistillate flower of Oak, with bracts forming the capsule.

The oak flowers in April or May. The staminate flowers are arranged in long, hanging catkins, but they are not nearly as closely packed as those of the hazel, and as they are green, not yellow, they are less conspicuous. Each staminate flower has from six to twelve stamens.

The pistillate flowers are far fewer, and are borne on short erect stalks; they are situated above the staminate flowers of the same branch; the pollen from the pendulous catkin is carried by the wind to the pistillate flowers of the branch beneath. Each pistillate flower has a three-celled ovary; as a rule only one ovule develops, so that the acorn is one-seeded.

The beech is in most respects a contrast to the oak. Its bark is smooth, that of the oak fissured. Its colouring too is different; in the beech there is a greyish tinge more marked in some trees than in others, whilst the bark of the oak is a decided brown. The leaves are different; the beech has a simple leaf with a delicately fringed margin, that of the oak is wavy and irregular in outline; when opening in spring, the delicate green of the beech is a decided contrast to the yellower colouring of the oak. The staminate flowers of the beech hang down in long stalked tassels, the anthers are yellow, and these blossoms are

Photo by Mr. Henry Irving.

COMMON OAK

Photo by Mr. Henry Irving.

BEECH

therefore more conspicuous than those of the oak. The pistillate flowers occur in clusters of two or three together, the bracts forming the bristly "cupule" which encloses the fruits. This box splits into four pieces, which turn back, showing the three-sided fruit, or "mast," as it is called. At one time swine used to be largely fed on these nuts, but at present they are left to squirrels and other denizens of our woods.

The hornbeam is sometimes mistaken for the beech, but is easily distinguished from it by the bark, which has white irregular lines, forming almost a lattice-work pattern against the dark ground. The leaves are somewhat like those of the beech, but broader at the base, hairy on the under-side and with dentate margins. The cupule is leaf-like, and may be an inch and a half in length.

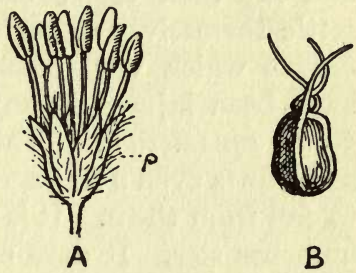


FIG. 44.—A, Staminate flower of Beech; *p*, fringed perianth. B, Pistillate flower of Beech.

In natural woodland there seems no doubt that certain trees are associated with certain soils; the beech, for instance, likes chalk; the oak clay, or deep sandy loam. It is a question, however, whether the fact of lime, or clay, or sand being present in the soil has as much to do with the preference of a tree for a certain soil as its capacity for retaining moisture. The oak is a case in point. It thrives both on clayey marls and in deep sandy loams; now clay retains moisture, but sandy soils are porous. The oak likes only deep sandy soils, for in these its roots penetrate as much as 5 feet, and obtain a regular supply of water from the subsoil; in fact, the oak is indifferent to lime, and therefore grows well in deep moist marls which contain lime, and also in sandy soil, provided it can get enough moisture from the subsoil. Most trees like soil with plenty of humus, or decaying organic matter; this is largely supplied by the leaves of the trees themselves. In woods, skeleton-leaves are often to be picked up; these are produced by the decay of the softer tissues of the leaf. Probably insects first attacked the leaf, riddling it with holes, then the work of minute fungi began, until everything was destroyed except the harder parts of the

leaf, the nerves or veins. Gradually, very largely owing to bacteria, the softer parts of the leaf which had thus decayed would become food material for large fungi such as toadstools, or for mosses which fruit early in the year, thriving on the decay of the preceding autumn; these in their turn would decay, and add materially to the leaf-mould, which is often several inches in thickness. It is not only leaves that add to the richness of the soil. Old bark, rotten twigs, covered, it may be, with lichens and mosses, add, in their decay, to the depth of the soil. Even dead logs enrich the soil. Supposing a tree gets wounded, or in any way unhealthy, fungi very soon attack it and destroy the softer tissues, leaving spaces into which insects can easily creep and lay their eggs; bark beetles, centipedes, woodlice quickly settle themselves in such wood, and thus help on its decay. A fungus which very commonly attacks branches of trees which have been injured in any way is the saddle-back fungus (*Polyporus squamosus*). This has fruit bodies of enormous size, sometimes even 2 feet across, and it takes five days for the spores to fall from them. It is easily recognised by its ochre colour and immense size. It does not appear to attack branches or trunks the bark of which is intact.

Some idea of the decay that goes on in autumn in a wood may be obtained by noting the number of fungi found in it. In the Plate a group of Fly Agarics is seen at the bottom of a birch; they are very easily recognised by their scarlet colour of the cap, with white warts, and by the ring of tissue attached to the stem, left by the cap.

The depth of humus, then, is the important factor as far as the soil is concerned. It may be measured by a borer or geotome. This is a stout iron tube, marked in inches, with a handle at one end and a sharp cutting edge at the other; the tube should be from ½ to 1 inch in diameter. It is fitted with a removable rod, flattened into a disk at one end, and having a handle at the other. This is necessary for forcing out the soil. The geotome should be about 20 to 24 inches long. With such an instrument it is possible to see how deep the surface soil containing the humus is, and at what depth the subsoil begins. It is the decaying organic matter that gives the very dark colour to soil, particularly in woods and forests. This humus also protects the soil against changes of

temperature. It has been found that the mean annual temperature of forest soil is decidedly lower than that of soil in the open; the temperature of the surface soil varies with that of the air, therefore to get a right estimate the temperature must be taken at different depths. On the continent, and in America, exact records of soil temperature have been kept for some time, and of late years in this country also. Another important use of the humus is to prevent evaporation of water from the soil. It has been calculated that the evaporation from forest soil with a deep layer of leaf-mould is less than one-fourth of that evaporated in the open, and about one-half of that evaporated from forest soil without a thick layer of humus, thus the roots of the trees get a more constant supply of water than plants in the open. Here the mosses do a valuable work. The Feather-Moss absorbs five times its own weight of water, the Bog-Moss seven times its own weight.

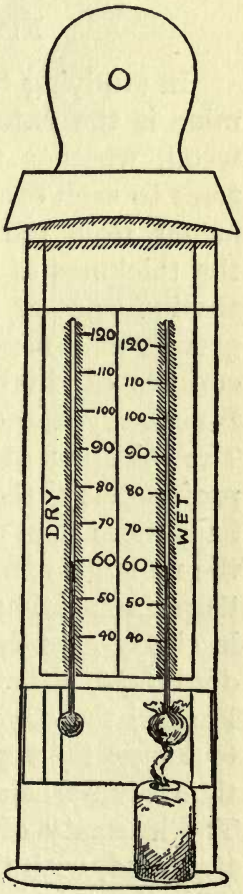


FIG. 45.—Wet and dry bulb hygrometer.

EFFECT OF WOODS ON CLIMATE

It follows, from what has been said, that woodlands have a considerable effect on the climate of a district. Owing to the taking in of carbon dioxide by the leaves of the trees for the purposes of assimilation the air is purified. In decomposing this carbon dioxide the oxygen is returned to the atmosphere. Observations show that the air in a well-wooded district has more ozone than that of the open country. The ozone is greatest in winter and at the edges of the woods.

They also tend to make the air moister. The degree of humidity in air may be measured by a wet and dry bulb hygrometer; readings should be taken at least three times a day; at 6 a.m., 1 p.m., and 6 p.m. The difference in the temperature indicated by the two thermometers is noted, and the degree of humidity

calculated according to tables which have been worked out, and are usually supplied with the instrument.

Wooded districts tend to make a climate more equable. Their temperature is higher during the night and lower during the day, the difference being most marked in summer and autumn. Trees vary very much in their effect on temperature; the beech has double the effect of the spruce in July; on the other hand, the spruce has a far greater effect in winter than the beech. One result of this more equable climate in the neighbourhood of woodlands is, that vegetation does not suffer so much from extremes of weather, from frost or drought.

Effect of Light on Undergrowth

In studying the vegetation of woods, the first thing to determine is the nature of the wood, whether it is a pure or mixed wood, whether there is coppice or not. The closeness of the trees to each other; the height of their boles, that is to say, the height from the ground at which the lowest branches begin; the thickness of the foliage, should all be carefully noted. Then the influence of the tree on the shrubby and herbaceous undergrowth may next be observed. The shrubby undergrowth often consists of climbing plants that can straggle out to the light; Blackberry, Honeysuckle, Wild Roses, are very constant in woods. The thickness of the shrubby undergrowth in its turn affects the profuseness of the herbaceous vegetation, for the factor which perhaps more than any other determines the richness and variety of the undergrowth is light. The intensity of light is less important than its duration. Warming states that in Finland barley ripens in eighty-nine days, whilst a little farther south it takes a hundred days, although the rays of light there are stronger; but in Finland the days are longer, and the barley is therefore exposed to longer light per day, and this greater duration of light more than counterbalances the difference in the strength of the light. The intensity of light in a wood varies with different parts of the wood, with the denseness of the foliage of the dominant tree, with the thickness of the shrubby undergrowth. An easy way of measuring this is with an ordinary exposure meter, such as

Mr. W. B. Crump, Halifax.

SCOTS PINE WOOD

Note scanty undergrowth

Mr. W. B. Crump, Halifax.

BEECH WOOD

Note absence of undergrowth

Photo by Miss E. Tidman.

UNDERGROWTH OF OAK-BIRCH WOOD

Consisting of Grasses, Ferns, Blackberry, Betony, Spurge, &c

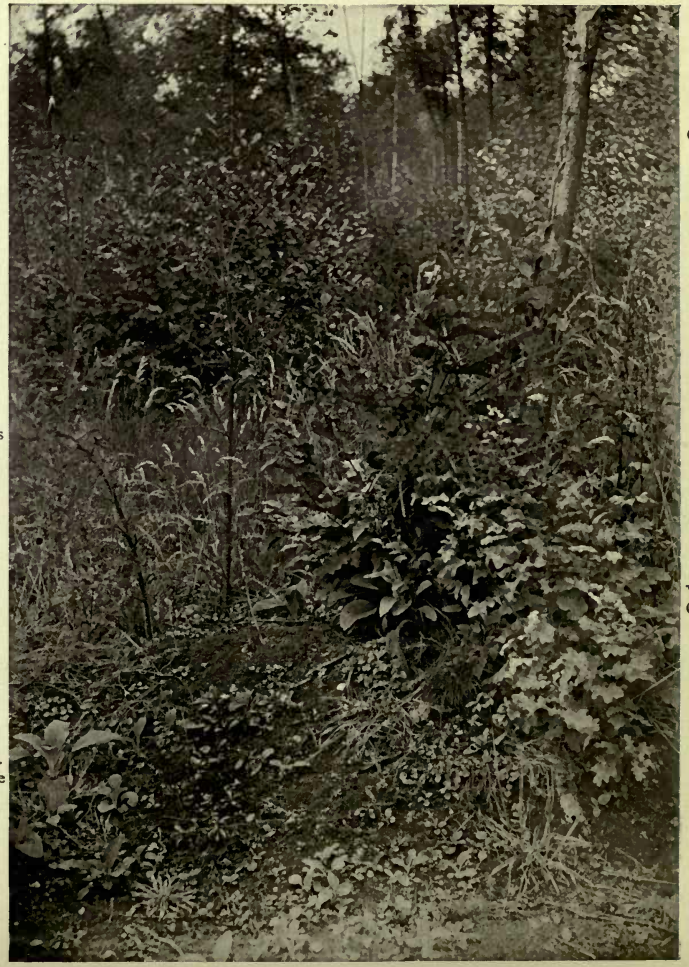


Photo by Miss E. Tidman.

UNDERGROWTH OF OAK-BIRCH WOOD

photographers use. Sensitive paper is exposed to the light until it gets a certain shade, which is indicated by the side of the exposed paper, the number of seconds being noted. In this way the intensity of the light at the fringe of a wood may be compared with the light of its shadiest part, and with that of intervening areas. Then the herbaceous undergrowth of the same areas should be compared. On May 23, observations were made by a botany class of about ten girls on the undergrowth of a wood. The part of the wood observed was carefully outlined in a 6-inch ordnance map; then the girls picked one of each species of the herbaceous plants, and a complete list was made. This was done in three different parts of the wood; the number of species obtained at the fringe of the wood was sixty, whilst that of the inner part of the wood was only forty. The effect of the denseness of the foliage of the trees composing the wood is well seen in a beech wood, which should be carefully observed in early spring, and the same area again in summer. The early flowering plants, such as Bluebells, Wood Anemones, Lesser Celandines, will often be very abundant; but in summer, when the beech leaves are fully out, there is hardly any herbaceous undergrowth, for no light gets through. Then, plants which can do without light thrive, and the Bird's Nest Orchis, or Toothwort, or Broomrape may be found.

One effect of the difference in the intensity of light at the fringe of a wood and in its thickest part is seen in the deeper green of the leaves, and even in the petals of the flowers. There is less chlorophyll in the leaves of a tree from the inside of a wood than in those taken from the edge, and the difference in intensity of colour is also seen in some of the herbaceous plants, though less markedly in some than in others.

Light is the principal, but not the only, factor affecting the herbaceous undergrowth. The depth of humus, and consequently the degree of moisture, is almost equally important. The undergrowth of a Scots pine wood may be compared with that of an oak from this point of view. To begin with, the leaves of the Scots pine remain on the tree for over two years, and when they do fall they decay but slowly, and form humus which soon dries up. The undergrowth is therefore scanty. Where the trees are close, giving deep shade, the Hair Moss (*Polytrichum*

juniperinum) and the Broom-Fork Moss (*Dicranum Scoparium*) occur in patches. Towards the fringe of the wood Bracken is abundant. These with grasses form the greater part of the undergrowth. A plant that is to be found in the pine woods of Scotland is the little *Linnæa borealis*, the one plant that Linnæus allowed to be named after him. In an oak wood the case is very different. In the month of August, by no means the best month for botanical observations, as many plants have ceased to flower by that time, the following notes were made on the herbaceous vegetation of an oak-birch wood in Gloucestershire. In the lighter, drier parts of the wood Foxgloves and tall Thistles (*Carduus crispus*) were conspicuous; both these plants belong to sandy soil. Centaury, Wood Sage, Wild Angelica, Self-heal, Cowwheat, and Wood Betony were still in flower; the paths in places were covered with Cudweed. In the more swampy parts of the wood, Watermint, Sedges, and Lesser Spearwort were the characteristic herbs, growing together very thickly. Among the spring plants, Primrose leaves were seen, but not in any quantity; Wood Spurge was more common, and the Daffodil the most abundant. In the parts of the wood where the trees were closer together a dense undergrowth was formed of Mosses, Ferns, and Grasses; Bracken and Polypody were the most common; the Rose Bay Willow-Herb, the Meadow-sweet, Woodruff, Angelica, were more conspicuous than in the lighter parts of the wood, for the closeness of the trees not only provided greater shade but deeper humus. In an oak-hazel wood of the same district the undergrowth was somewhat different. Wood Sanicle, of which there had not been a trace in the oak-birch wood, was abundant in the oak-hazel; the flower was over in August, but the leaves were very frequently found. Mr. Moss, who has investigated the herbaceous undergrowth of ash, oak, and oak-hazel woods in the Bridgwater district of Somerset, notes that this plant is abundant in the ash and oak-hazel woods, but is only occasionally found in pure oak woods. Another spring plant that was far more abundant in the oak-hazel wood than in the oak-birch was the primrose. This is also the case in Somerset, where the primrose is so abundant in the ash and oak-hazel woods as to rank as a subdominant species. Cudweed, which was very abundant in certain

parts of the oak-birch wood, was not found in the oak-hazel. Its presence has also been noted in oak woods and its absence in oak-hazel. These differences may, no doubt, be explained by the fact that the shade in an oak-hazel wood is greater than that of an oak-birch. It is probably for this reason that in oak and oak-birch woods bracken is found to be very plentiful, whilst in oak-hazel it is somewhat rare. Bracken must have light, and therefore flourishes best at the fringe of woods, or in those woods in which the trees have not a close canopy. The thinning of trees often favours its development, so, too, does the depredation of rabbits on the shrubby undergrowth, for in both cases more light is admitted. It is found that the herbaceous undergrowth of oak woods to some extent depends on whether they are situated in upland or lowland districts. The former are usually on drier and more rocky soil with little humus, whilst the soil of the lowland wood is damper and far richer in humus. The difference in moisture affects the foliage of the trees; it is denser, the shade is greater, and the herbaceous undergrowth more prolific. Lowland oak woods are rich in bulbous and early flowering species, such as Anemones, Wood Sorrel, Early Orchis, Bluebells, Daffodils, Woodruff, Wild Garlic. The upland wood has far fewer species, about one-fourth the number found in the lower wood, and the character of the vegetation is different; it consists of plants adapted to a drier soil, such as Foxglove, certain Potentillas, Golden Rod, Hawkweeds and Grasses, such as *Molinia cærulea* and *Deschampsia flexuosa*, which are characteristic heath plants. The same difference has been found in ash woods. In drier and more exposed places, especially where the soil is shallow, the ash is usually dwarfed; but where the soil is deeper and damper the ash reaches its normal height, and the herbaceous undergrowth is considerable; Dog's Mercury and Wood Garlic literally carpet the ground, whilst Bluebells and Bracken are scarce.

There is no doubt that the ash is an indigenous tree; it was probably the dominant tree of the historic forest of Mendip, stretching along the Mendip hills above Wells and Cheddar, for remnants of ash woods are still to be found in the copses which spring up naturally in this area, as in Ebbor Gorge. It grows on any good moist soil, provided it is deep enough. In winter it may

be recognised by its black buds and stout twigs, for, as the leaves are compound, consisting of several pairs of leaflets, their weight is considerable, and could not be supported by slender twigs. The leaves come out after the flowers, and are among the earliest to fall in autumn. The flowers blossom in April or May. Both staminate and pistillate may be found on the same tree, or only one kind on a tree. This accounts for the fact that many ash trees have no fruit. The stamens are dark purple, and the pistillate flowers a greenish-yellow. The ovary is two-celled, with one or two ovules in each cell, but as a rule only one seed develops. The fruit is winged. The Mountain Ash, or Rowan, has leaves similar to those of the ash, but it is a rosaceous tree, and is easily distinguished from the other by its flowers and its red berries. Its flowers are not unlike the hawthorn blossoms, and have very much the same structure as those of the apple or pear. As far as has been observed, the following plants are characteristic of ash woods growing on limestone, but are absent from oak and oak-hazel woods: Hellebore Viridis, Mountain St. John's-wort, Blood Geranium, Solomon's seal, Lily-of-the-Valley. This may be due to the fact of lime in the soil, as these plants are characteristic of the oolitic limestone of the Cotswolds, where the beech is more abundant than the ash.

Effect of Moisture

The effect of moisture on the vegetation of woods is very evident in a county like Northumberland, where there are many ravines and mountain torrents, with woods sloping down to the water's edge. One of the conspicuous trees in such a situation is the Alder. It may be recognised by its rough, black bark, by its horizontal branching and slightly upward bend of the terminal twigs, and by the dark reddish-brown woody scales of the catkins, which remain on the tree long after the seeds have fallen out.

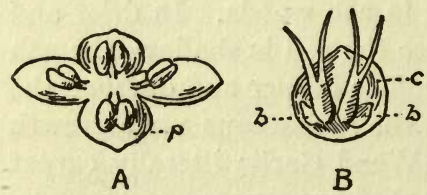


Fig. 46.—A, Staminate flower of Alder; *p*, perianth. B, Pistillate flower of Alder; *c*, scale covering two flowers; *b*, scale belonging to single flower.

The staminate catkins are two or three together and hang

down; the pistillate ones of the same branch are above them, in short, erect spikes. Each staminate flower consists of a perianth and four stamens, the whole being situated, with two other flowers of similar structure, in a scale. The pistillate flowers are arranged, two together, on a scale; each single flower has two bracts, and consists of two carpels with two styles. Another shrub or tree characteristic of streams is the Willow. There are a larger number of species belonging to the genus Salix. It includes the Sallow (*Salix Caprea*), found commonly in hedges, to which it gives their golden appearance in March; also several willows, most of which require an expert to identify them accurately. The willows have staminate catkins on one tree and pistillate on the other, and some species, *e.g.* the sallow, are pollinated by insects. The staminate flower consists of two stamens and a greenish nectary situated at the base of a bract. The pistillate flower is composed of two carpels and also has a nectary.

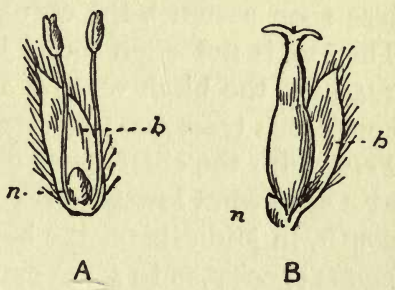


FIG. 47.—A, Staminate flower of Willow. B, Pistillate flower of Willow; *b*, bract; *n*, nectary.

The herbaceous vegetation of woods with numerous mountain streams will naturally consist of plants that like damp situations. The most common plants in the wetter parts will be the Golden Saxifrage, the Water Avens, Red Campion, Meadow-sweet, and Sedges. In a mixed wood with a river running through it, and with dense shade, some of the most conspicuous plants found in August were: Sweet Cicely, Giant Campanula, Enchanter's Night-shade, wild Strawberries and Raspberries, several grasses, but chiefly the Reed Fescue (*Festuca sylvatica*), Wood Sage, Figwort, Woodruff, etc.

Many of these plants like deep shade and moisture; two of them, Sweet Cicely and Giant Campanula, are characteristic of the north rather than of the south.

The influence of trees on herbaceous vegetation is seen not only in woods but in the lanes or pastures bordering on woods, the trees of which overshadow the adjoining hedges. Plants which belong to woods, such as Woodruff, Wood Sanicle, Wood

Violets, may under these circumstances be found in lanes; or in a pasture separated from the adjoining wood by a cart road, some feet in width, if the trees overshadow the road sufficiently to cast a deep shade over it. Cowwheat, Betony, and St. John's-wort may occur in the part of the pasture nearest the wood, which through its greater area abounds in the usual pasture plants: Knapweed, Medick, Yarrow, Agrimony, Wild Carrot, Flax, etc.

Effect of Altitude

Certain trees are found to belong to different altitudes. The greater the height above the sea level, the more stunted the tree, which may attain only the dimensions of a shrub. The willow, birch, rowan, and ash are occasionally found as high as 1700 ft. on the Pennine range, but they are very stunted. At about an altitude of 1500 ft. a rapid stunting in growth begins, and the tree soon assumes the shrubby habit unless artificially sheltered. The oak is not often found in our islands at a greater height than 1250 ft., the birch reaches 1750 ft., and the Scots pine and other coniferous trees 2000 or more. In the sub-Alpine region of north Perthshire the chief trees are the birch, the larch, and the pine; at a somewhat lower level oak woods predominate; whilst farther south, in Midlothian, the beech thrives, and, though not an indigenous species, is to some extent ousting the oak on account of the deep shade cast by its foliage and its greater rapidity of growth.

The birch and Scots pine are often associated together in forests; they are seen in perfection in Sweden, where the trees are closely planted and therefore grow to a greater height than with us. The tall, straight trunks of the birch with their silvery bark form a delightful contrast to the warm red colouring of the pine. The birch will grow literally anywhere. It may be seen on mountain sides clinging to rocks; it is equally at home in the humus of old woods, or by the sides of the pavement in suburban streets. It is indifferent to heat or cold in the sub-arctic and temperate climates, and is found as far north as Lapland. Like the oak and beech, it is a catkin-bearing tree. The staminate flowers are ripe by April and hang down, whilst the pistillate ones of the same branch are above them and catch the pollen

Photo by Mr. Henry Irving.

BIRCH

Photo by Mr. Henry Irving.

ASH

carried by the wind from the staminate catkins of another branch. After fertilisation these catkins become conelike, and the bracts of the pistillate flowers are then developed into organs of dispersion, which in October scatter the fruits far and wide. Modern artists, in particular Leader and Whistler, have made the birch familiar even to those who seldom get into the country.

The Scots pine is one of our three native conifers. It is a tree belonging to the post-glacial peat swamps, and it is believed that the Black Wood of Rannoch on the south shores of Loch Rannoch is a part of primitive Caledonian forest. Existing pine woods have as a rule been planted; for although the pine does produce seed readily, and although seedlings are very numerous, they are constantly eaten down by sheep, rabbits, or deer, and it is only when growing in isolated places, such as on islands in mountain tarns or rivers, that they escape destruction. Pine woods are commonly found near heather moors, and that there is some relationship between the heather moor and the pine is now generally admitted; it is never found in association with Cotton-grass moors. When the pine has favourable soil it develops a tap-root which penetrates to considerable depth, but in shallow soil the tap-root is not developed. The needle-like leaves remain on the tree for several years, and are always found in pairs. Both staminate and pistillate flowers occur on the same tree, but each set respectively occurs on different branches. The staminate inflorescence is formed at the base of the present year's shoot, and consists of numerous flowers, arranged in the form of a cone. Each staminate flower has numerous stamens which form quantities of pollen, for the tree is wind-pollinated. In the month of June, three distinct sets of pistillate cones will be found on the same tree: small reddish ones at the apex of the shoot of the current year, green succulent ones near the end of the shoot of the preceding year, and brown woody ones near the end of the two-year-old shoot. Each cone consists of scales arranged spirally on a short thick axis, the ovules being borne at the base of the scales. In the young red cones the scales are not tightly pressed together, in order to allow of the pollen falling on to the ovule. On the other hand, the scales of the green cones are very tightly pressed together in order to protect the ovule, for

fertilisation takes place in these cones; in the brown woody ones the scales are separate, for the seeds are then formed and ready to be dispersed. Thus pollination takes place in the young red cones; fertilisation in the green ones in the year following pollination; and dispersion of the seed, which is furnished with a wing, from the brown woody cones borne by the two-year-old shoot.

Evergreens

The Scots Pine is an evergreen. There are not a large number of evergreens in the British Isles; they are rather characteristic of countries with long summer droughts and moist winters, and therefore belong to climates such as the Mediterranean district, Cape Colony, S. Australia, the coast of California, Chili, etc. The essential character of an evergreen compared with a deciduous tree is that green foliage-leaves are present at all seasons of the year, whereas a deciduous tree during the winter is without green foliage-leaves, the leaf-scars under the buds denoting their position before they fell off in the autumn. In many evergreens the leaves last only a year, the old leaves falling as soon as the new ones come out; in some trees, as in the Scots pine, they last several years, and in other species of pine even longer. The leaves of evergreens are usually leathery in texture, and the upper surface is often glossy. The trees are low in stature. Amongst evergreens in this country may be mentioned the Holm Oak (*Quercus Ilex*), the Box, the Holly, and the Spurge Laurel. Box trees form part of a mixed natural wood on Box Hill near Dorking, the other trees being oak, beech, and yew. That this is a natural wood and not a plantation is rendered probable from the hundreds of seedlings found under the trees, and from the size to which the trees grow, for in gardens where the Box is planted it is hardly more than a shrub. The wood used at one time to be very much in demand for wood engraving. The Holly, like the Box, has a very fine grain wood, and is very hard; the bark is used in the preparation of bird-lime. It grows at an altitude of 1000 feet, and thrives best in damp air; the Forest of Dean has magnificent specimens. In bud, each leaf has two minute stipules, which drop off as the bud opens.

In habit, the holm or holly oak resembles the olive tree of the Mediterranean. It has a much thinner bark than that of our native oak, and it is black not brown. The lower leaves sometimes develop spines, which resemble those of the holly, hence its name. Evergreen shrubs characteristic of woods are the Spurge Laurel, the Ivy and the Privet, the last belonging to thickets, but also very much planted in hedges. The spurge laurel has very glossy leaves and thick black berries. The leaves of the privet may persist until the new ones appear, hence it is sub-evergreen.

Thinning of Woods

Woods are often spoilt by injudicious thinning. The present custom in many parts of these islands is to thin woods heavily, much more so than is usual in Continental forests. In the opinion of German experts, our trees are thinned too soon; they consider it better to plant trees close together, say 3 feet apart; then the lower branches, not getting much light, have a tendency to come off without much difficulty, and thinning is thus effected naturally. To overthin leads to the deterioration of the timber. Within reasonable limits, thinning is advantageous. Supposing, for instance, that beech and oak are being grown together, the thinning of the oak trees would give the beech seedlings more room to develop, and the underwood would be far thicker and a greater quantity of brushwood would be obtained. The difficulty is to hit the happy medium, and not to thin so much as to injure the timber. The effect of thinning on the herbaceous undergrowth is very marked. Where a part of a wood has been thinned, herbs spring up rapidly, and the ground which may have been before but sparsely covered soon becomes carpeted, owing to the greater light admitted.

After a season or two, the herbaceous forms of woodland vegetation will be followed by plants not specially characteristic of woods; shrubs, such as the blackberry and wild raspberry, thistles and nettles, will gradually oust the more woodland plants. These in their turn will be followed by the hawthorn and birch, and if the ground is left undisturbed forest trees will in course of time make their appearance.

Something of this kind may be seen even at the fringe of

woods or plantations, and some idea may be obtained of the plants that succeed each other, if a piece of ground hitherto employed for corn or pasture be allowed to revert to forest.

Trees are often thinned for pecuniary reasons, especially in the case of those trees whose thinnings are easily marketable. Early thinnings may be used for fuel; the wood of some young trees, as for instance ash and larch, sells well and is in demand. In thinning it is important to keep the leaf canopy intact, and this is best managed by planting the trees close together and letting the lower branches drop off naturally. When trees are felled their places should be taken by young trees, which may be grown in a nursery garden on the estate. Too often woods are allowed to get "gappy," as foresters say, owing to the want of young trees to take their places. It is often less expensive to grow these on a large estate than to buy them from the nursery garden. On the Earl of Cawdor's estate in South Wales there is a four-acre nursery garden from which some 90,000 forest trees are issued annually, and therefore any area which has been felled can be quickly replanted.

Value of Different Trees as Timber

Before steel and teak were used for shipbuilding the oak was very much in demand. Now its wood is used for the framework of waggons, for wheels, pit props, paving blocks, cross beams of telegraph posts, and for buildings and furniture. The Gloucestershire oak has a high reputation and is unequalled by any continentally grown oak in strength and durability.

The wood of the ash is adapted for purposes where flexibility is of importance: "The English ash is about the only ash that will bend" was the assertion made by one witness before the Committee inquiring into British Forestry. It is therefore very well suited for carriage poles, oars, axe and hammer shafts. The ash is often grown in hedgerows and in coppices. The wood of the young trees is especially elastic, and bears a greater strain than any other timber of the same thickness. Unfortunately, it exhausts the soil and starves other plants, therefore farmers do not care to plant it much. The beech is not very valuable as

timber, but its wood is in demand for mallets, shuttles, spools, rollers, and above all for chairs. Nearly all the beech timber grown on the Chiltern Hills is sent to High Wycombe to be manufactured into chairs; its value is about £20,000 a year, but so great is the trade that £80,000 worth of beech is imported from abroad. Larch is extensively planted, especially in Wales, and the timber sent to the colliery districts, where the wood is much in demand for pit props. The posts of fences are obtained from both the larch and the spruce. The wood of the hazel makes good walking-sticks, hoops for casks, and staves. Willows are often cultivated for basket making. The village of Mawdesley in Lancashire has been famous for more than half a century for its willow beds, and the interesting thing about the cultivation of the willow in this district is that there is very little wet or marshy land, and the willow is therefore grown under conditions similar to those of ordinary farm crops, such as potatoes, cabbages, corn, etc. The wood of some species of willow is used for cricket bats.

Seasonal Changes

Deciduous trees possess a wonderful power of adaptability to the seasonal changes which characterise a temperate climate. Those who from childhood have been accustomed to the beauties of spring, when the buds burst forth in all their greenery and "the small fowles maken melodie" in their branches, can hardly realise what it is to live in a country where the trees are evergreen and the leaves do not fall until the new ones are ready to take their place. Why should leaves fall in temperate climates some months before the new ones are ready to come out? It is the fact of winter that makes the difference. The low temperature of the winter months causes growth which had been active in the spring and summer to stop, very often entirely, and the plants have a resting period. In the autumn it is evident that many changes take place in deciduous trees. The most obvious is the change of colouring, which lends such great beauty to an autumn landscape. The leaves of the oak assume a rich russet-brown hue; those of the beech turn from deep green to orange and warm ruddy brown, which almost blazes when lit up by the rays of the autumn sun.

Looking down from a height of two thousand feet it is possible to tell by the colouring the limit of the oak on the hillside, and to recognise even at a distance the greater height above the sea-level at which the beech is found, at any rate in some counties. Most trees have their distinctive autumn tints; the hornbeam turns from green to yellow, then ruddy gold, and finally a rusty red, the tint that persists throughout the winter. This change of colour is due to the breaking up of the chlorophyll granules, owing to the lower temperature combined with the less intense light. Brown, yellow, or red pigments are thus formed, and give the characteristic colour to the tree. This change of colour is followed, in the majority of trees, by a falling of the leaves. The time of leaf-fall varies with different trees. The ash, though one of the latest to burst into leaf, loses its leaves first; the beech may retain its leaves on its lower branches throughout the winter. The elm gets a dull dark green tint, then orange, after that pale yellow, before its leaves begin to fall, and the rapidity with which the tree is stripped of its foliage is noticeable.

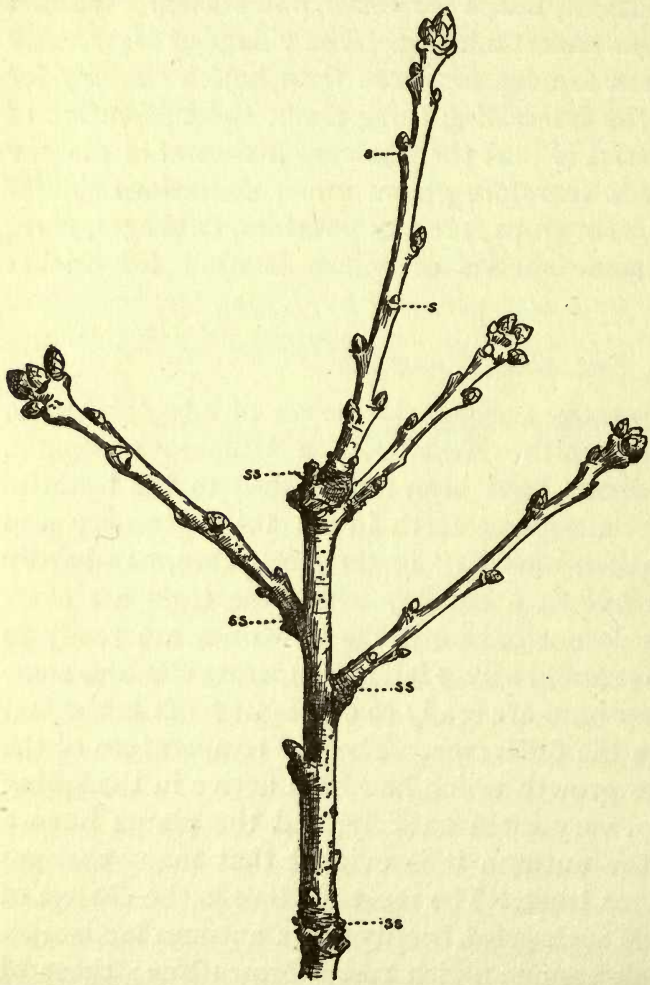


FIG. 48.—Two-year-old twig of Oak. *s*, Scar of attachment of last year's leaves; *ss*, scars left by scales of last year's bud, marking the limit of a year's growth.

The base of the leaf-stalk of a fallen leaf is yellow, owing to the development of cork. As soon as the cork is formed, water, and the substances it contains in solution, cannot get from the stem to the leaf. Not getting nourishment, and not being able to make starch, owing to the partial decomposition of the chlorophyll, the leaf is starved and falls, leaving a scar just beneath the bud formed in its axils. These scars are very large and horse-shoe shaped in the horse-chestnut, showing plainly the position of the wood bundles which conducted water from the stem to the leaf. They may also be distinctly seen in the ash, but are less conspicuous in the beech.

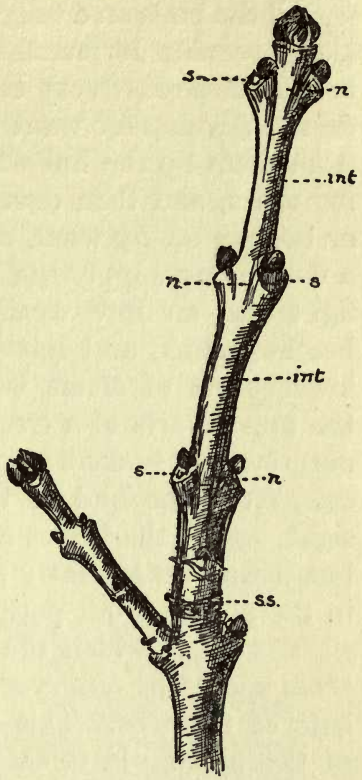


FIG. 49.—One-year-old twig of Ash. *n*, Node; *int*, internode; *s*, scars left by last year's leaves; *ss*, scars left by last year's bud-scales, showing the limit of the year's growth.

In the winter the buds are protected by bud-scales, which prevent the damp and cold reaching the young foliage and floral-leaves within. The difference in the position of buds, and therefore of branches, may be studied in the oak and in the ash. In the former case the buds are much more crowded at the apex of the twig, and they are alternate, not opposite, as in the ash. The twig of an ash terminates in a leaf-bud, and just below the apex there are two axillary buds, one on each side of the apical one. The branching of this tree is far simpler than that of the oak, whose branches are more crowded. The ash often has remarkably long shoots, and the year's growth of a twig may reach a considerable length. In the oak the internodes are generally far shorter, the nodes consequently much nearer each other, and the branches crowded. The length of each year's growth may be easily seen in the winter, when the leaves have fallen, for the scars left by the scales of the last year's apical bud form a ring round the stem of the twig. In Fig. 48, two years'

growth of the oak is easily traced; in Fig. 49, that of the ash, only one year's growth is visible.

All the buds on a twig do not necessarily develop into branches. Many remain dormant, ready to develop if through injury any branch dies off. Very commonly the buds at the base of a shoot do not develop for want of nourishment which has been snatched from them by the buds above. Such buds may remain dormant for years, and then develop if a branch above has been pruned or broken off by wind, or the weight of snow. The thinning of a wood may supply the necessary stimulus, through the greater light and air now available. This accounts for the fact that beeches, elms, and limes often have bushy outgrowths on the lower parts of stems which had been naked. The cutting off the upper parts of a tree will, for the same reason, stimulate the outgrowth of suckers from the base of the stem, as in the elm, ash, oak, etc. The bud of the plane should be examined. At first sight, whilst the leaves are on the tree, it appears to have none; but if the leaf is gently pulled off, the bud will be found nestling in the hollowed-out petiole, which covers it completely.

The angle which the branches make with the shoot bearing them should be observed, as the mode of branching is characteristic of the tree. This depends to some extent on the insertion of the buds. It is easy to see in winter that some buds are almost at right angles to the shoot, others again are almost erect, practically parallel to the shoot, and in some trees the buds may be inclined at an angle of 45°. It is thought that on the whole the upper and stronger shoots make a more acute angle with the parent stem than the lower ones. It will be found that the branches of a tree do not always maintain the same inclination to the parent shoot. To realise how they may differ, trees may be drawn in winter, when the branching is clearly seen.

Trees and shrubs are specially protected in the winter by bark, which is formed on their trunks and branches. It arises in this way. The outer skin of the stems of most trees and shrubs cannot grow as fast as the underlying tissues, and therefore cracks. Through these cracks water and insects might find their way, but a layer of cork forms beneath the outer skin and gradually spreads all round the stem; it may be recognised by

its yellow colour. Cork does not allow water to penetrate it, consequently the tissues outside it dry up and peel off. This is the first bark of the tree. In some trees this is repeated year after year; bark is formed and peels off. But more generally a new set of cells nearer the wood begins also to form cork, and as everything outside the cork dries up the bark becomes of considerable thickness. Bark is impermeable to water and to gases except at certain spots. On twigs, little excrescences of a different colour from the bark are often seen; these are lenticels or cork-warts. They are openings in the bark, and correspond to the stomata of leaves. By means of them oxygen can reach the inner tissues of the stem, and carbon dioxide can be got rid of. In the birch and cherry, the lenticels have the appearance of long transverse lines on the bark. In winter the lenticels are closed with cork cells, to exclude air; in spring the cork cells are very loosely packed, so that interchange of gases between the inner tissues and the air is possible.

Trees with thin bark often have thick foliage, and cast deep shade; this is true of the beech and hornbeam. Both these trees have smooth grey or brownish-grey bark; that of the hornbeam is marked in white lines, which give it a tessellated appearance. Trees that have a thick, rough, furrowed bark, like the oak, often have less dense foliage, and are light-loving.

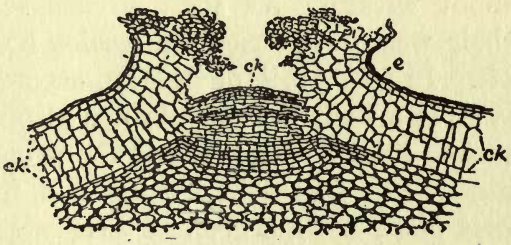


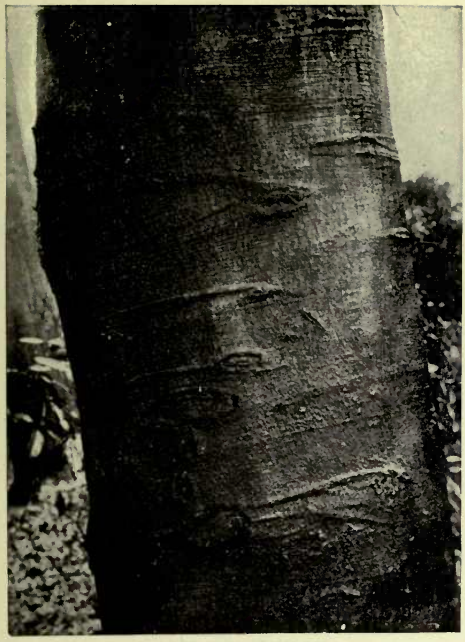
FIG. 50.—Lenticel closed in winter. *e*, Epidermis; *ck*, cork.

Some trees have bark that peels off regularly in thin scales. The Scots pine, plane, and birch are instances of this. In the Scots pine the scales of the trunk near the ground do not peel off; the bark in that part of the tree is thicker and shows longitudinal fissures, whilst higher up the scales peel off, leaving a brownish-red surface characteristic of the tree. The plane casts off its bark every year in large thin plates, exposing a pale yellow surface. In the birch the greater part of the bark is white; it peels off in very thin plates horizontally, leaving dark irregular rings, which accentuate the silvery whiteness of the trunk.

Trees may often be identified in winter by their bark. The lime may be recognised by its sooty markings. The ash, if over forty years of age, has fissured bark, with deep furrows, though hardly as deep as in the oak; the maple has very fine fissures. In lopping off branches, great care has to be taken not to injure the bark, for certain fungi attack injured limbs of trees.

Bark is valuable for the tannin it contains. Young oaks are stripped of their bark in May, just before the leaves burst forth. The bark is stripped off before the tree is cut down, the first ring extending from just above the roots to the height of two and a half feet. When stripped, the bark is put out to dry for about two weeks, and then cut into small pieces and sent to the tanners. The bark of the birch is used for tanning certain kinds of leather, particularly Russian leather.

The first sign of spring in trees is the swelling of the buds, which seem to grow visibly under the genial warmth and moisture of a showery April day. The bud-scales, or stipules, as the case may be, begin to unfold owing to the pressure of the growing shoot within. As soon as the scales unfold, the leaves push their way out; then the scales hang down and gradually drop off. In late April, or in May, according to the season, the ground is strewn with the light-brown stipules of the beech, or the green scales, tinged with pink of the sycamore. To watch the unfolding of the leaves in spring is a fresh delight each year. The best plan, if trees are not near one's house, is to pick buds that are just bursting, and watch them unfold. Even in winter, if placed in warm water, buds will usually burst in a warm room. The beech is one of the most beautiful to observe. The leaf is folded like a fan, and, as the stipules separate, the leaves spread out fanlike, showing a delicate, ciliate margin. Sometimes, as in the ash, cherry, hazel, elm, and ash, the leaves are folded in two from the midrib like the two pages of a book, and each half spreads itself out. The arrangement of the bud-scales and leaves of the ash are seen in Fig. 51, which is a drawing of a transverse section of a bud. The bud-scales, like the leaves, are opposite each other. Each leaf is compound, consisting of seven or more leaflets. In the centre two leaves are seen opposite each other; at right angles to these are two more leaves, each



BARK OF BEECH

BARK OF BIRCH

BARK OF ASH

BARK OF OAK

Photos by Miss E. Tidman.

composed of seven leaflets; again at right angles to these are two more, and so on. In the section, only seven leaflets, although the ash has eleven leaflets, for all are not cut through.

A very noticeable feature in leaves when they first come out is their fluffiness, owing to the downy covering of their surfaces. One of the trees in which this is most remarkable is the White Beam tree (*Pyrus Aria*), which can be distinguished from other trees in a wood by the white, woolly appearance of the budding leaves. The horse-chestnut also shows this well. The length to which a shoot may grow in one season varies very much; it may be only an inch or two, it may be more than a metre. Something depends on the age of the tree, on the season, on the soil, and on its environment generally. Trees, however, which do not like shade seem to form long shoots very rapidly; the birch, the ash, the alder struggle up into the light as quickly as possible. Short shoots, on the other hand, are common in the beech, in the oak, and in pines; in many cases the same tree will have both long and short shoots, as different circumstances will affect each year's growth.

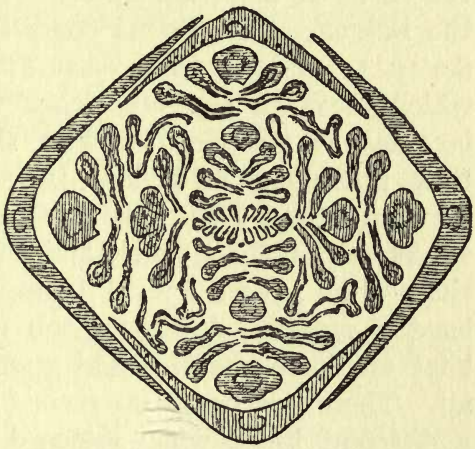


FIG. 51.—Leaf-bud of Ash. (Transverse section.)

Many trees flower before the leaves come out; in some cases, as in willows and osiers, to secure insect-pollination. Where the flowers are insignificant they are often grouped together in catkins, and are conspicuous by their number or scent; rosaceous trees as a rule have showy flowers, which blossom before the leaves; the Blackthorn and the Almond are well-known examples. A Nature Study lesson might well be given on the time of flowering of the trees within reach of a school and on their methods of pollination; about May, when the flowers of many trees are out, would be a good time to choose. Later in the summer the fruits and seeds, with their methods of dispersion, would form

another interesting lesson. Some trees do not form seed regularly. The Common Elm is a case in point. This tree was introduced into England by the Romans, and does not seed nearly as regularly as the Wych Elm, which is indigenous. The common elm is propagated by suckers, not by seed. It differs from the wych elm in its greater height and finer grained wood. Its seed, when formed, is nearer the notched end of the fruit. Elms would not hold their own in woods, but would probably soon be ousted by other trees ; they are found in parks or in avenues, and are often planted in hedgerows.

Thus, as the seasons come round, they bring with them a regular succession of changes in the life of a plant. What is the cause of these changes ? Is the plant merely responding to the influence of external conditions, or do plants inherit a tendency to change with each season ? There are many facts which seem to support either view. There is no doubt that increase of temperature does shorten the resting period, and that prolonged cold does lengthen it. The mild weather of November and December 1907 led many plants to flower some weeks earlier than usual, and to keep their leaves much longer than usual ; and a cold spring may retard vegetation for at least a month. A comparison of records of early flowering, if kept for some years, would give surprising results. This is not all. There are cases on record in which plants have adopted a different habit when exposed for a sufficient length of time to a different environment. Schimper mentions certain deciduous trees which, growing on the flanks of the volcano of Gedeh in Java, where the climate is temperate and constantly humid, have adopted the habit of the evergreen. He says that the buds expand not simultaneously but successively, so that an individual plant bears at the same time spring, summer, autumn, and winter shoots. In the course of a few years the resting period of a plant disappears in a warm, humid climate. In the cultivation of varieties new plants have been produced in which the resting period differs from that of the parent stock. Facts of this kind do show the immense influence exerted by external conditions, as would be expected. At the same time, environment is not the only factor to be considered. The

internal changes taking place in the plant must have some influence, though in the present state of our knowledge it is not possible to estimate it exactly. How far, for instance, this regular cycle of changes is dependent on the lessening of the food supply is not known. Certainly, in the case of bulbs, corms, rhizomes, which store up food for the winter, there can be no deficiency of nutrition. To what extent these seasonal changes are due to heredity it is impossible to say. Probably many factors combine to produce them, and they may be divided roughly into two classes, the one class being represented by what we call heredity, whilst the other comprises all those which act on the plant from without. In both cases, however, it is a reaction on the part of the *living organism*, whether the stimulus be given directly or indirectly from without or within.

Suggestions for Practical Work

The following suggestions are made for work out of doors with classes engaged in Nature Study :—

I. Trees.

In winter—

Note the character of the bark ; the bud-scales ; the branching ; long and dwarf shoots ; the height of the bole.

In spring—

The bursting of the scales and opening of the buds ; the manner in which the leaves unfold ; the time of flowering, and the method of pollination.

In summer—

The degree of shade cast by the foliage ; the kind of fruit formed.

In autumn—

The fall of the leaves, the autumn tints; the fungi in the wood and on the bark.

II. Woods.

Distinguish between a wood maintained for game as well as for timber, noting the difference between the coppice and the over-wood. Note which trees or shrubs are grown as coppice, which as timber.

Make as exact lists as possible of the herbaceous undergrowth in different woods, and compare with each other ; compare also different parts in the same wood, and woods of the same tree at different altitudes or in different situations and soils.

III. Timber.

Visit any saw-mill within reach of the school. Get sections of the different woods being used; make drawings, showing thickness of the heart wood and of the sap wood.

At the saw-mill, note the lengths in which the wood is cut, and any process of manufacture that may be carried on there.

Bark may be obtained from the yard of the saw-mill, and the structure examined.

IV. Effect of Trees.

i. On soil; compare the depth of leaves in different woods.

ii. On moisture of the air; with a hygrometer compare the humidity of air in a wood with that of air in the open.

iii. On temperature; trees shelter from cold winds and help to make climate more equable.

iv. On purity of air; they increase ozone.

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CHAPTER X

Plant Associations

Although the number of species of plants making up the flora, even of such a small area as England, comprises several thousands, yet every one knows how frequently large tracts of country are mainly occupied by one species, which gives to the vegetation its characteristic aspect. This is so true of natural woodland that it is possible to speak, as we saw in the last chapter, of Oak, or Pine, or Birch woods, as the case may be. Similarly, heaths are practically taken possession of by one or two species of grasses, and so too are our pastures and meadows, although, when more closely examined, the vegetation is found to be more diverse than a casual glance would lead us to suppose.

The Social Habit

Trees and Grasses are the best instances of the social habit in plants, but they are by no means the only ones. Many Sea-weeds, and also plants belonging to marshy ground, exhibit this tendency, which as a rule is more marked in aquatic than in land plants. The Sea-weed, *Sargassum bacciferum*, of the Sargasso Sea; the Grass, *Phragmites communis*; and the Reed, *Scirpus lacustris*, are some of the most familiar examples. Among land plants, in addition to trees and grasses, may be mentioned Mosses and Liverworts, and such flowering plants as Heather and the Willow-Herb. The effect of agricultural operations, too, is to increase the domain of certain social plants; for many wild species are destroyed, whilst a particular species is being cultivated for food.

Certain plants, on the other hand, may be said to have the social habit developed in a different way. They are found living a life of close relationship, not with their own, but with other species. Many Lichens and Fungi, certain Mosses and Liver-

worts, are closely associated with trees, living on their wood or bark. One of the most common Lichens on trees is the *Usnea barbata,* sometimes called the Beard or Tree Moss. It flourishes on old birches and pines, clothing them with a shaggy grey fleece (Fig. 38). The smooth bark of the Holly is often covered with black lines, looking like Hebrew writing; this is the Lichen, *Graphis elegans.* Lichens are most abundant on trees in those parts of the country where the towns are not only small but infrequent, as in Somerset and Gloucestershire, for they thrive best in pure country air. On the Oak and other forest trees a Lichen which is supposed to resemble the tissue of the lungs is often found; this is *Sticta pulmonacea.*

On the ground at the base of the trunk of trees the Grey Trumpet Lichen frequently occurs in dense colonies. It is interesting to note that these Lichens often follow each other in a regular order; certain species frequent young twigs, certain others drier and more exposed branches. Others, again, belong entirely to the oldest branches. In our latitudes the organisms living on bark are almost entirely confined to non-flowering plants; in the tropics there are many Orchids and plants belonging to the Fig tribe which make their home on the bark of trees.

In woods there is also a definite fungus flora, which differs according to the dominant tree, no doubt partly owing to the difference in the humus. It has been suggested that fungi with coloured spores are more generally characteristic of Pine woods; whilst the white-spored species predominate in Oak and other woods of broad-leaved trees. The so-called "Cup Fungus" (*Peziza*) is a fungus growing on dead sticks in woods about Christmas time. The cup is red.

The Agarics form a very important group of Fungi. They include Mushrooms and Toadstools. The Fly Agaric is a particularly handsome species, not infrequently to be found under Birch trees (see Plate). Its cap is scarlet; the gills on the under surface are white, and in this species a ring of tissue left below the cap is very clearly seen attached to the stem. In autumn a large number of different Agarics are found in woods on dead logs and old stumps.

Certain Mosses grow on the bark of trees, especially along the

GROUP OF FLY AGARICS GROWING AT THE FOOT OF A BIRCH.

HARD FERN AND MOUNTAIN BUCKLER-FERN.

line followed by the rain water when trickling down the trunk. Many species form a carpet. Some grow on stones, covering them entirely. These are generally very minute, and many of them belong to the genus Weissia. Others are found at the foot of trees growing on the exposed roots. One of the most beautiful is the Fern Moss ; it is very abundant in the west and south of England, reaching perfection in the damp woods of Devonshire. The Hair Moss (*Polytrichum*) (Fig. 26) and several species of the genus Mnium (Fig. 22) are characteristic of woods.

Besides Mosses, many Ferns contribute to the carpet of a wood. The Shield, the Oak, the Polypody, and the Beech Ferns are the most common, and in Pine and Oak-Birch woods, the Bracken. The Shield Fern (Aspidium) and the Polypody both have their sporangia arranged in circles on the under side of the frond; the Polypody, however, is a very much smaller fern than the Shield Fern, with thicker wavy leaves, whilst the Shield Fern has very thin leaves and the fronds form a circular tuft two or three feet high; those of the Polypody are not more than a foot in height, and often less. The Oak Fern is also a Polypody, belonging to moister situations than the common Polypody; its fronds have long stalks, and the leafy part may be four to six inches long. The Lady Fern is not unlike the Male Shield Fern, but its stalk is less scaly than that of the latter, and its fronds reach the height of two or three feet. The Hard Fern (*Lomaria* or *Blechnum*) is very common in some districts, and is one of the best known ferns where the climate is not too dry, or where lime is absent from the soil.

Thus the vegetation forming the carpet of a wood is of extraordinary interest. It is never the same for long together, but varies almost with each month of the year : in the autumn it is the Fungi that claim attention ; in the winter, the Liverworts and Mosses ; in the spring, the early Flowering Plants. At all seasons the trees—with their bark-growth, their buds, their branching, their colouring—afford a fascinating study. Moreover, the vegetation differs with each wood, owing to the difference in the humus and amount of moisture, and the humus depends on the dominant tree. To compare woods with each other, noting the resemblances in the presence of great diversity ; to try to account

for the differences, and to interpret their past history by the vegetation of the present time, are some of the problems now being studied in what is known as Plant Ecology, that is, the study of the habitats of plants.

Parasites

Plants which live on other plants are known as Parasites; those which get their food from decaying leaves or wood, or any part of a plant, are called Saprophytes. Amongst the Fungi, Mosses, and Liverworts, both parasites and saprophytes are found. Some Flowering Plants are also parasitic in habit. The Broomrape, Dodder, Toothwort are true parasites; whilst the Cow-wheat, Bartsia, and Eyebright are only partly parasitic, for they do not derive their nourishment entirely from other plants. The Toothwort is a plant without green leaves, growing on the roots of Poplars and other trees. The seed germinates on damp earth. If the radicle in its growth meets with the living root of an Ash, or Poplar, or Hazel, it fastens on it at once, and develops a kind of sucker by which it clings to its host. The seedling Toothwort now begins to feed on its host, and grows rapidly, producing fleshy scale-like leaves, which overlap one another closely. The scaly stems branch underground and may cover a square yard. The flowers and leaves formed above the ground have a purplish tinge, but no green colouring matter. This is therefore a true parasite. The Broomrape and Dodder also have no chlorophyll.

Fig. 52.—Toothwort (*Lathræa squamaria*).

The Cow-wheat, the Rattles, the Eyebright, and many other plants belonging to the Scrophulariaceæ, are only partially parasitic. They have well-developed seedlings, and it is not until they have reached a certain stage of development that they begin to prey on other plants. Besides this, they have green leaves, and can therefore use the carbon dioxide in the air. Many of these plants are annuals, and occur by hundreds and thousands close together. One has only to think of the Eyebright in pastures, of the Yellow-

rattle and of the Lousewort to realise their social habit. These semi-parasitic plants do not injure their hosts to at all the same extent as the true parasites. These green-leaved parasites are very social plants; hundreds and thousands of specimens are found close together. The Eyebright is so prolific in mountainous districts that when its flowers are open, regular white lines seem to stretch across the pastures. It is parasitic on the roots of grasses, and is called in Germany "Milchdieb," (milk thief), from the popular belief that it injures the grass and makes the milk less good. The Rattles have long roots which grow horizontally, not vertically, in the upper layers of soil, seeking the root of some grass or sedge on which to fasten their suckers. Should the Rattle not be able to find a host—as the plant on which it preys is called—the growth of the root ceases.

FIG. 53.—Red Rattle (*Pedicularis palustris*).

SAPROPHYTES.—Some Flowering Plants growing in woods derive their food either entirely, or partly, from the humus formed by the leaves of the trees, and therefore may be said to depend on the tree for nourishment. The Enchanter's Nightshade is an instance of a plant with green leaves which also feeds on the humus. Others, like the Bird's-Nest and the Coral-Root Orchids, have colourless leaves and feed entirely on the humus. The Bird's-Nest is widely distributed in pine woods and in those consisting of deciduous trees. Both stem and flowers are of a light brown colour. The roots interlace and bear a certain resemblance

FIG. 54.—Eyebright (*Euphrasia officinalis*).

to a bird's nest. The Coral-Root has an underground stem, somewhat like the tangled roots of the Bird's-Nest, but it has no true root; the rhizome branches, forming a mass not unlike a piece of coral. Every year pale greenish shoots arise from the underground stem, bearing small flowers with a scent suggestive of vanilla; later, green fruits develop and turn brown when they ripen. This Orchid belongs to E. Scotland. It must not be confused with another plant, also called Coral-Root, which belongs to the Cruciferæ and is not a saprophyte. Many other plants, especially in moorland regions, are saprophytic in habit. The Moor Mat-grass (*Nardus stricta*), some Sedges and Rushes, certain Gentians are instances of this. When these plants are taken up from their natural habitat and planted in a garden they usually live only for a short time, even though the clods of peat in which their roots are imbedded are transplanted with them. It is supposed, therefore, that the organic compounds formed by the decaying vegetable matter differs in character under the different conditions of temperature and moisture which obtain on a moor and in a garden.

Associations of Plants in the same Habitat

Plants which differ from each other in many respects may yet be associated together in the same habitat, if similar conditions of light, moisture, wind, etc. suit them. Thus it has been shown that certain plants belong to woods; these would not be found on sea-cliffs or on exposed commons, where there would not be enough shade or moisture for them. From this point of view all plants may be arranged in three or four well-marked groups:—

1. Hydrophytes. These comprise all aquatic plants, whether entirely or partially submerged, provided that there is not less than 80 per cent. of water in the soil.

2. Xerophytes. These include rock, desert, and moor plants which like a soil with less than 10 per cent. of water. With this group may be associated those plants that will tolerate salt in the soil; these are found on sand-dunes, and are known as Halophytes.

3. Between the Hydrophytes and Xerophytes come those plants which like a regular rainfall and a soil more or less rich in humus. These are called Mesophytes. The vegetation of our

woodlands is largely mesophytic in character, though some xerophytic plants are to be found in the drier, upland woods, and some hydrophytic in the swampy or boggy portions of lowland woods. Moors, on the other hand, have a xerophytic type of vegetation, and rivers, ponds, lakes, marshes, a hydrophytic.

In studying Plant Associations it is usual to try and determine the dominant species. In woods, as we have seen, the chief tree is noted; then the sub-dominant species, and lastly the herbaceous undergrowth. This method may be applied to any natural area, as a wood, a hedge, a pond, a moor, etc. The dominant species gives the name to the Plant Associations. Thus the plants found growing together with the Heather form a Heather association; those with the Cotton-Grass, a Cotton-Grass association, and so on. Sometimes it is difficult to decide on a dominant species, for two plants may be competing with each other and be almost equal as regards the number of the individuals. In some commons it would be difficult to say whether the Heather or the Gorse was the dominant species; the association would then be called a Heather-Gorse. In woods it is often impossible to fix on one particular tree as dominant above all others; such woods are named after the two trees which are most conspicuous, as Oak-Birch, or Oak-Hazel woods. The sub-dominant species are those which are most abundant next to the dominant. In a wood it is often some shrub, such as the Hazel or the Blackberry, or Rosebriar; these would all be grouped together as sub-dominant. In a Cotton-Grass moor, the Heather might be the sub-dominant species, together with certain Sedges and Rushes. The lesser herbs, which in a wood often comprise a large number, form the herbaceous undergrowth.

During the last ten or twelve years attempts have been made to map the vegetation of various districts. The object of these vegetation maps is to indicate what plants grow together under more or less uniform conditions of soil and climate; what plants stand in any relationship to each other, and above all, how the present vegetation of any given area has arisen. This grouping together of plants in associations, according to the nature of their habitat, received a strong impetus from the work of Professor Warming, the Director of the Botanical Gardens at Copenhagen,

who published in 1896 his *Okologische Pflanzengeographie*, in which he suggested definite lines of study. In France, Professor Flahault of Montpellier published a vegetation map of the whole country in 1897. He based his survey on the distribution of trees; but this would not form a satisfactory basis in our islands, because there is so little primitive forest left, and this was the experience of Mr. Robert Smith, whose vegetation map of the Edinburgh district was the first of the kind published in Great Britain (1900). Since then there have been botanical surveys of various districts: parts of Yorkshire and of Somerset; the valleys of the Tyne, the Tees, and the Eden have been mapped.

Practical Work

For Nature Study work it will be best to select some natural area within easy reach of a school, and to observe what plants grow together there. It might be advisable to begin with a hedge—especially as hedges are very characteristic of England. In some parts of the country the dominant species will be the Hawthorn; it may be the Willow, or the Box, or the Yew, or the Privet. The sub-dominant species in a hedge will include, in all probability, some tree or shrub; the Ash, the Elm, the Hazel are often planted in hedges, and sometimes, as in the case of the Hazel, entirely overtop the Hawthorn in parts so entirely as to conceal it. Climbing plants are very usually sub-dominant species in hedges; these will afford considerable material for Nature Study lessons. The herbs at the bottom of the hedge should also be noted. These will probably vary on the two sides of the hedge, especially if one side of the hedge is next a pasture and the other next a road. It will be noticed—and this can be tested with the photometer (p. 157)—that the intensity of light varies considerably along a hedge-bank. At the top the light is often feeble, owing to the shade cast by the hedge; this is the region of climbing plants, or of plants with long, erect stems. Lower down the hedge-bank the light is stronger, and the herbaceous growth there is greater. If there is a ditch at the bottom, aquatic plants may be found. The light is also stronger on the south side than on the north, and the plants differ corres-

pondingly. Hedgerows are particularly interesting in wilder parts of the country where they are not trimmed too frequently, as many of the natural wild plants of the district take refuge there.

If nothing but a rubbish heap is to be had, observations on Plant Associations can still be made. Here the type of vegetation is usually distinctly xerophytic. The interesting problem is to find out how the plants on the rubbish heap got there. If near a brewery yard, the explanation is easy. In the barley imported from abroad, many seeds of foreign plants are brought over and effect a lodgment on any heap of rubbish. A corn store with wheat from America may account for several of the plants found on the mounds, covered, it may be, with Nettles, Docks, Ragwort, Thistles. One of the most common plants on city rubbish heaps is the Annual Mercury, with dark green leaves and opposite branches. Very small staminate flowers, with yellow anthers, are borne by slender upright flowering branches. The pistillate flowers are not on the same plant as the staminate; the branches bearing these are much shorter than in the case of the staminate ones. This city plant is not unlike the Dog's Mercury found in woods and shady hedge banks. Another very common weed on waste places is the Hedge Mustard, a forlorn-looking plant. The lower leaves are much cut up, and have a large terminal lobe; the upper ones are narrow. The flowers are yellow and very small. The pods are pressed closely to the stem. Another Crucifer, with small white flowers and flattened seed-vessels, that frequents rubbish heaps, is the Hoary Cress (*Lepidium draba*).

FIG. 55.—Annual Mercury (*Mercurialis annua*). Young fruits on left side.

The same rubbish heap should be constantly visited, in order to find out what new specimens locate themselves there from time to time. Another situation that is very fertile in unexpected plants is a railway embankment. Plants are not much disturbed

there, and seeds which may be blown by the wind from luggage vans have a very good chance of developing. If near a new railway line a record might be made of the plants that first come up, then of those that follow the next season, and so on. In this way some idea of the struggle for existence that goes on amongst plants will be obtained. In the case of the plants that survive, it will be interesting to try and find out why they can live together; the depth to which their roots penetrate often suggests an explanation. One may be a surface plant, the other may have a deep-rooted system; or one may afford just the right degree of shade to the other; or one may draw on certain food material in the soil that the other does not want. As a rule, plants which are closely allied to each other do not frequent the same habitat. Primroses and Cowslips, both belonging to the same genus, are not only not found together; but where one is abundant in a neighbourhood, the other is usually scarce.

A different line of study might be followed. Instead of observing the plants growing together in the same habitat, all the plants of an order might, as far as possible, be examined to find out something of the distribution of that order. The Grasses and the Orchids are found in practically every kind of habitat: there are wood and moor grasses, pasture and wayside grasses; some are characteristic of riversides, others of bogs. The variety of structure in even such a common plant as a grass is amazing, and can only be realised by putting typical grasses side by side. Some have their leaves spread out, others inrolled; some are bristly or hairy, others smooth; some have a divided sheath, others not. All these differences have a meaning, which can often be explained by reference to the habitat. With Orchids there is immense variety. Some are adapted for life in a bog, others for life on a limestone pasture; some are found at the edges of woods, others like the deep shade of the beech.

The different species of any genus might be studied in the same way; thus one species of the Forget-me-not will be found by the stream, another on the side of dusty roads. One species of Ranunculus is a corn weed, another floats on ponds, a third is characteristic of meadows, a fourth of marshes on moors or in woods, a fifth belongs to hedges; and all these

have some difference in structure which fits them for their special habitat.

The influence of man on Plant Associations is immense. Sometimes land is drained, and the plants that like moisture naturally disappear. A few years ago a very rare species of Ranunculus (*R. ophioglossifolius*) was found in Gloucestershire; now it is extinct in the county, owing to the drainage of that particular spot. The cutting down of trees, or the planting of woods; the building of houses, or the pulling down of buildings and allowing more light to enter; the opening up the country with railways, or the abandoning a district—all affect the vegetation. The more civilised a country is, the less is Nature seen in her simplicity. The influence of man has always to be borne in mind when seeking to account for the presence of any plant in a given locality.

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CHAPTER XI

The Vegetation of Commons, Heaths, and Moors

In past centuries the amount of common land in England was far greater than at present. Gradually a good deal of it has become enclosed, as it was considered wasteful to leave so much uncultivated. There are still, however, all over the country, and more particularly in the neighbourhood of London, tracts of uncultivated land known as Commons. Wimbledon Common, Hampstead Heath, Blackheath at once occur to the mind. In the country, many commons are now devoted to golf-links. It is difficult to draw a hard-and-fast line between a common and a heath. In botanical language a heath denotes a tract of country covered with certain grasses; such tracts are spoken of as Grass Heaths. The grasses growing on a common are kept short by the grazing of animals, and on the whole the vegetation of a common is more limited than that of a heath, though this is by no means invariably the case. The commons of Surrey, for instance, are often clothed with vegetation: Gorse, Heather, Juniper, Bilberry, even Clematis and Dog Roses may occur.

A moor is characterised, in the popular mind, by the presence of heather and various heath plants, by certain well recognised moor grasses, by mosses such as the Bog Moss. Great stretches of moorland occur in the north, and more rarely in the south. At the present time, the moors of some parts of Yorkshire have been mapped out botanically, and it is usual now to speak of a Heather, or Cotton-Grass, or Bilberry moor, according to the dominant plant.

Formation of Peat

The character of the vegetation on commons, heaths, and moors depends principally on the presence, or absence, of peat; it is therefore necessary to understand what peat is, and how it

is produced. The formation of peat can be observed now, and there are instances on record of peat districts which have arisen with great rapidity. In 1651, the then Earl of Cromartie relates that a district near Loch Broom, on the west of Ross-shire, was covered with standing wood, the trees being entirely leafless and stripped of their bark. It was a pine forest in one of its last stages. Some years afterwards, when again in the neighbourhood, he found the plain completely bare of trees and the whole ground covered with moss. Upon inquiring what had become of the trees, and who had carried them away, he was told that they had all been uprooted by the winds and lay underneath the green moss. Before 1699 he states that the country people came there to dig turf and peat. Thus in half a century a peat-bog was formed on the site of a pine forest. In Ireland there are vast peat districts; it has been calculated that peat-bogs occupy at least one-seventh of its area. Extensive bogs are also found in Scotland and in the west and north of England. They are formed in alluvial districts: Sedgemoor consists largely of peat, which it is known existed in the time of the Roman occupation, for they burnt it in their kilns; now the district is very well drained, and the formation of peat is a thing of the past.

To understand the structure of peat, a peat-bog where the peat is being cut should be visited. Three layers can be made out: on the top, the brownish layer of roots and fibres, not very closely woven together, which is being dug out in square sods to be used as fuel. Underneath this comes a blacker mass, consisting of decomposed plants and looking like rotten wood. This is lignite. It is much less compact than the topmost layer, but still is firm enough to dig out in what is popularly called "long squares," which are dried and stacked. The third and lowest layer is not unlike coal in appearance. The thickness of each layer varies from a few inches to several feet. They rest on an impervious soil, such as boulder clay or shell marl, for the peat could not have been formed unless the bed on which it rests was water-tight. An examination of a peat-bog then shows that peat is made up of the roots, stems, leaves, and other parts of plants, chiefly of Mosses and Liverworts. These gradually decay, and in decomposing give off oxygen and hydrogen, the solid carbon remaining behind.

As decay proceeds the peat gets more and more solid, until brown coal or lignite is formed, and finally coal, in which the original woody structure is not perceptible to the naked eye, although sections under the microscope may show spores, fibres, etc.

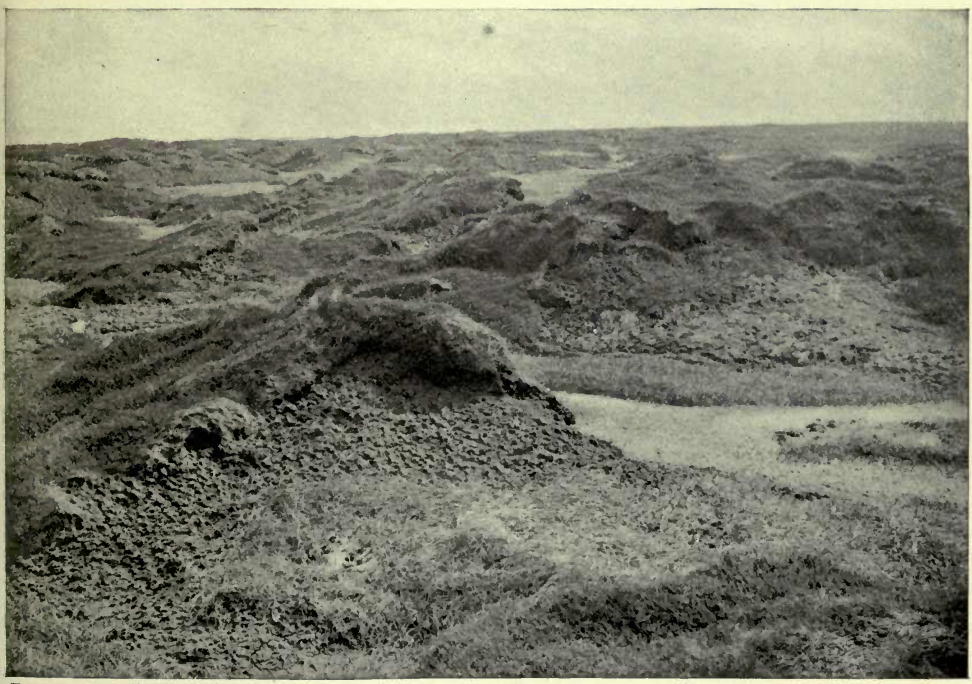
Peat is not often formed in tropical regions, for decomposition goes on too quickly to allow of an accumulation of vegetable remains; where, however, plant remains accumulate more rapidly than they can be decomposed, the formation of peat begins; and, once begun, generally proceeds quickly owing to the peaty acids that are formed and have no opportunity of draining away. Anything which hinders drainage and promotes stagnation helps in the formation of peat. When plants at the edge of a pond begin to grow inwards; or a spring is dammed up by marshy plants, circumstances arise favourable to the formation of peat. Where a district is well drained, peat cannot be formed. The surface of a peat-bog varies very much. Sometimes it is green with living moss; it may be brown or even black. The moss that is of most frequent occurrence in peat-bogs is Sphagnum, which is called Bog Moss on that account. Others mosses may be found: the peat in the fens of Lincolnshire is formed mainly of *Hypnum fluitans*, and in the ancient peat beds of Scotland, with Arctic floras, no traces of Sphagnum have been found. It is, however, the chief constituent of recent peat in Ireland, Scotland, and England.

In peat-bogs remains of trees may be seen, and at first sight it may be difficult to realise that the Bog Moss can have had anything to do with the fact of trees being buried in peat-bogs. It is suggested, however, that the immense quantity of water which this moss is capable of holding has caused the roots of the trees to rot and eventually to be blown down. Then various Fungi and Mosses would grow over them, and in time the trees would be completely buried in the bed of peat, and add considerably to its thickness.

Peat is not being formed to any great extent at the present time; in many parts it is in a state of denudation. If the bog is on a hillside, channels and furrows begin to appear in the peat, and may be even twelve feet in depth. As the channel becomes widened by the stream cutting its way down, the roots and stems

From Dr. Woodhead, Huddersfield.

HEATHER (*Calluna*) MOOR, ON DRY SHALLOW PEAT



From Dr. Woodhead, Huddersfield.

DENUDATION OF PEAT

From Dr. Woodhead, Huddersfield.

GRASS HEATH (Nardus chiefly) WITH RUSHES

From Dr. Woodhead, Huddersfield.

VACCINIUM MOOR (Bilberry and Cowberry)

of large trees are exposed. Sometimes even as many as three forest beds, separated by a layer of thick peat, without any traces of tree remains, may be seen. Professor Lewis gives the following results of the investigations of some twenty-four districts which have been investigated during the last three years between the south of Scotland and the Shetland Islands, Aberdeenshire and the Outer Hebrides.

1. Recent peat.
2. Forest.
3. Peat-bog plants with Arctic plants.
4. Forest.
5. Peat-bog plants.
6. Arctic plant bed.
7. Peat-bog plants.
8. Forest.
9. Arctic plant bed.

Those that are interested in these peat remains cannot do better than read Dr. Lewis' paper in *Science Progress*, October 1907.

Shallow peat may be formed in any badly drained area where there is a certain amount of stagnation of water.

Heather Moors

One of the most characteristic plants of shallow peat is the Common Ling or Heather, perhaps the most widely distributed of our wild plants; a few inches of peat are quite sufficient for it. The structure of the flower is worth noticing. Both the calyx and corolla are pinkish-purple; the calyx is much larger than the corolla, and consists of four distinct sepals, whilst the corolla, though in one, is almost divided into four petals. The anthers open to let out the pollen by pores, and have at their base two horned spurs

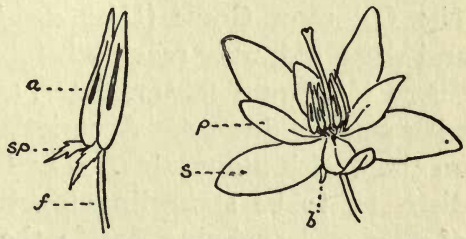


Fig. 56.—Flower of Ling. A single stamen on left. *a*, Spores of anther; *sp*, horned spurs of anther; *f*, filament; *p*, petal; *b*, bract.

There are two other species of Heath very frequently found on moors. The Bell Heather (*Erica cinerea*), easily recognised by its egg-shaped corolla; and the Cross-Leaved Heath (*Erica tetralix*) with leaves, four in a whorl, and spreading. The flowers of this species are large and pink, and the plant is very hairy; it likes wet situations. There are two other Heaths, found in S. Ireland but not elsewhere in the British Isles; they belong to the Pyrenean region. Here it may be mentioned that there is a curious resemblance between the floras of Cornwall, West Ireland, and the Pyrenees. It is supposed that, at a time when the western coastline of Europe was far more extended than at present, migrating birds were able to carry seeds across from the Pyrenees to W. Ireland, and that owing to the milder climate these plants have remained there.

A plant often associated with Heather on commons is the Gorse, or Furze, or Whin. This plant does not require peat as heather does, but is rather characteristic of sandy soils; still, these plants are often found together, the rosy purple of the heather side by side with the golden blossoms of the gorse. It was on Wimbledon Common that Linnæus, as Mrs. Browning relates, knelt down when he saw the Gorse in bloom and thanked God for having made the world so beautiful—

> Mountain gorses, since Linnæus
> Knelt beside you on the sod,
> For your beauty thanking God.

The Common Gorse (*Ulex europæus*) flowers early in the year, and when old, may reach a height of four or five feet; the Dwarf Furze (*U. nana*) flowers later, and is of a deeper golden yellow with smaller flowers. A variety of this species is very abundant on the Welsh mountains. The Gorse and Heather seem, in some districts, to be struggling together for existence; the presence of peat will probably decide the matter. In many parts of the country peat is becoming denuded, owing to great dryness from better drainage. If peat disappears in any district the Heather will probably be ousted by the Gorse. Both these plants are well adapted for dry situations. Their leaf-surface is very much reduced; in the Gorse many of the leaves are spines, in the Heather

HEATHER MOOR WITH COTTON GRASS BOG.

LING, WITH A LITTLE BELL HEATHER AND BOG MYRTLE.

SHEEP'S SCABIOUS (*Jasione montana*) AND RUSHES IN THE FOREGROUND.

they are very minute, thus there is little transpiring surface, and the plant is able to do with very little water. Heather is not found on damp peat, but on thin, dry peat. Some Heather-moors are characterised by the abundance of the Bog-Myrtle (*Myrica Gale*). This is generally found in badly drained situations, as on the clearings of Birch woods, and is often associated with the Cotton-Grass and other marsh-loving plants, such as the Lesser Spearwort, the Bog-Asphodel, Reeds, etc.

Cotton-Grass Moors

The Cotton-Grass is a Sedge, not a Grass. Sedges, Rushes, and Grasses occur together on moors and have a superficial resemblance, but may easily be distinguished from each other by the following characters. Grasses have hollow stems which are circular in outline, and their leaves are arranged in two rows alternately; Sedges have solid, angular stems, with their leaves in three rows; whilst Rushes have cylindrical, sometimes jointed, leaves, and the perianth of the flower is membranous. In the Cotton-Grass the long cottony filaments represent the calyx and corolla; within them are the stamens and ovary. The Cotton-Grass requires plenty of moisture, and is therefore found in bogs on moors; in such situations the Heather disappears. It may be found at the edge of a bog which is drier than the central part of it. When the Heather is the dominant plant in any part of the moor, the plants found with it form what is known as a Heather association; when the Cotton-Grass is dominant, the plant association is a Cotton-Grass or Eriophorum association. One of the sub-dominant plants found associated with the Cotton-Grass is the Bog Moss (Sphagnum). Sometimes this moss becomes the dominant plant in cases of extreme moisture, and then the plant-association is a Sphagnum, not an Eriophorum association. Very few plants are found with the Cotton-Grass; there are often two or three species of this Sedge present in the same bog, together with another Sedge, the Tufted Scirpus. The Common Crowberry does occur, but is not common in Cotton-Grass bogs. At the edge of the bog, Heather may be present. The appearance of a Sphagnum bog depends almost entirely on the rainfall of the year; it requires

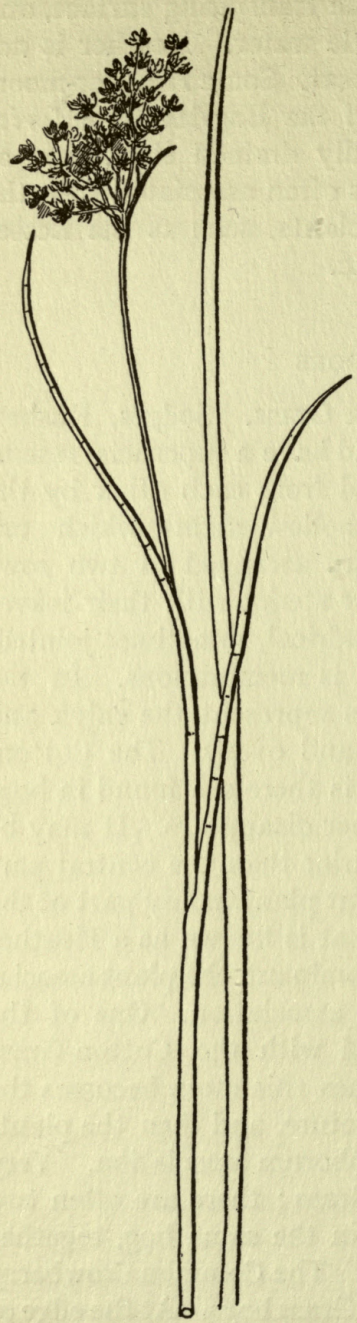


FIG. 57.—Jointed Rush (*Juncus articulatus*).

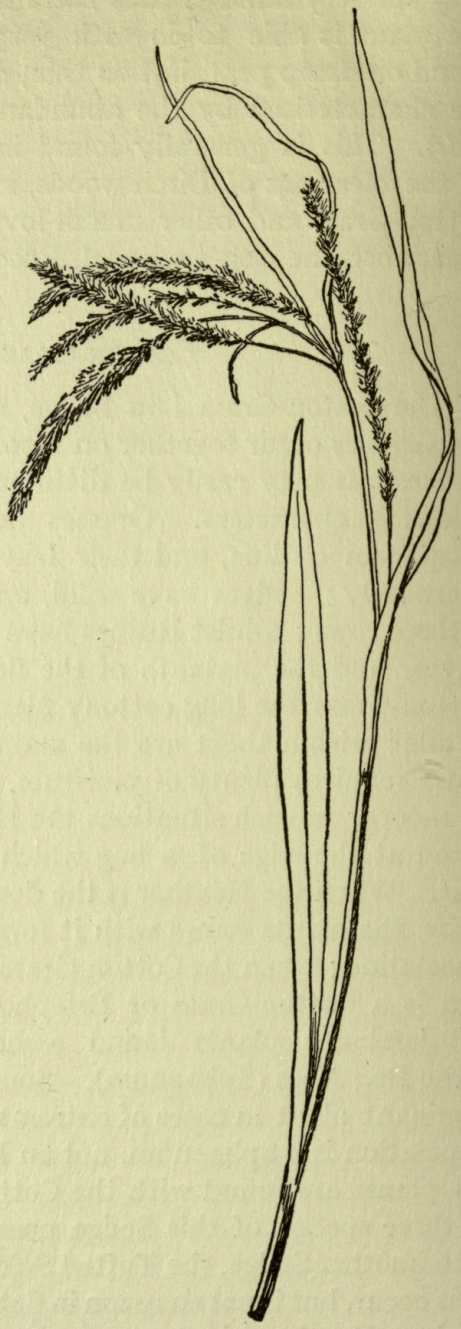


FIG. 58.—Pendulous Carex (*Carex pendula*). A Sedge.

a great deal of moisture. Sometimes, when the summers are very dry and the bogs are much less moist than usual, the Bog Moss may begin to look almost dried up, instead of the yellowish-green by which it is at once recognised from the surrounding vegetation. It is not easy to find the fruit of this moss, for it more generally forms young plants at the ends of its branches. The fruit or capsules are red, and about the size of a very large pin's head; they are borne on much shorter stalks than the capsules of many mosses, and may be found in the month of August. The plants which are most frequently found in association with the Bog Moss are the Cloudberry, the Cranberry, and the Cross-leaved Heath. The Cloudberry belongs to the same genus as the Blackberry, but it is a very different plant in appearance. It is not found in the south of England, but belongs to high altitudes and latitudes. In fact, it is a true Arctic plant, most at home in cold and exposed situations. It is a small plant, with a creeping stem and one-flowered shoots. The fruits are large and orange in colour. The Cranberry is a very delicate, graceful plant, with threadlike stems and tiny dark green leaves, the edges of which roll back, almost concealing the white under side. The slender flower-stalks bear bright rose-red flowers, the stamens of which have purple filaments and yellow anthers. The berries are large, at first greenish; then they turn red and are much used for food.

FIG. 59.—Bilberry (*Vaccinium Myrtillus*).

BILBERRY MOORS

Heather does not appear to thrive above 2000 feet. When this height is reached it gets stunted and less abundant, and the Vacciniums then become dominant. The two most common

species of Vaccinium are the Bilberry (*Vaccinium Myrtillus*) and the Cowberry or Red Whortleberry (*V. Vitis-Idæa*). The fruit of the Bilberry is very well known, but the flowers are less familiar. They droop, are pink, and in shape not unlike those of the Lily-of-the-Valley. The Cowberry is a small mountain shrub, with dark green, shining leaves, a bell-shaped pink corolla, and a dark red-berried fruit. Below a height of 2000 feet the Bilberry is often found associated with the Heather or the Cotton-Grass; above that height, especially in dry, rocky, wind-swept situations, it becomes the dominant plant. The accompanying photograph of a Yorkshire moor shows the Bilberry and the Cowberry, forming, as it were, the sky-limit of the moor, where it is exposed to all weathers and where the influence of man is but slight. The Crowberry (*Empetrum nigrum*) is constantly found on Vaccinium moors. This is a small heath-like shrub, with evergreen leaves, the edges of which roll back as they do in Heaths. The flowers are very small; the fruit is black and about the size of a pea. In general habit it is not unlike one of the Heaths, the Trailing Azalea (*Loiseleuria procumbens*), which is confined to the Highlands. Another plant, even more commonly associated with the Vacciniums, is the Heath Rush (*Juncus squarrosus*). This Rush differs from the majority of species in having the flowers distinct instead of clustered together.

FIG. 60.—Cowberry (*Vaccinium Vitis-Idæa*).

FIG. 61.—Crowberry (*Empetrum nigrum*).

The moorland of our northern counties thus shows three very well-marked types:—

1. Heather moors, with Ling the dominant

plant, up to an altitude of 2000 feet. These are situated on dry peat.

2. Cotton-Grass boggy moors on very wet peat, reaching their greatest development from 1200 to 1600 feet.

3. Vaccinium moors above 2000 feet. Here the Alpine region is reached, and many of the plants are truly Alpine in character.

Sphagnum bogs occur in small areas on all these moors.

Alpine Plants

There is naturally only a sprinkling of Alpine plants in the British Isles. They are found mainly on the mountain-tops or exposed moors of the Scotch Highlands, on the fells of the Lake district, and in West Ireland. One of the Scotch mountains most rich in Alpine species is Ben Lawers. At a height of about 3000 feet the vegetation on these mountains becomes very stunted; Mosses and Lichens predominate, the Staghorn Moss (*Lycopodium clavatum*), dwarf plants of Crowberry and Bilberry occur, but sparingly. In the sheltered crags and wet places the Alpine Meadow-Rue, the Alpine Lady's Mantle, several Saxifrages, the Scurvy Grass, the Moss Campion, are recorded by several observers. These plants resemble each other in certain respects. They are all small, for tall plants would not be able to stand the wind, which is felt even in the sheltered parts of these regions. They are usually perennials, coming up year after year without making seed. They grow thickly together, forming dense cushions, and thus are kept warm; they are very hairy or downy plants; the flowers are borne on short stems, which do not take long to grow, so that the plant is ready to flower as the summer, which is late in the Highlands, arrives. Although the flowers are often small, they are conspicuous by their colouring. The Moss Campion (*Silene acaulis*), found on Ben Lawers and other Scotch mountains, has large, bright pink flowers, each borne on a short flower-stalk. The whole plant forms a cushion-like growth, owing to the continual branching of the stems; the leaves are very tiny and undivided; a mass of this plant with its pink flowers standing out conspicuously from its cushion makes

a brilliant patch of colour. The Alpine Lady's Mantle, is also interesting. It differs from the Common Lady's Mantle found in pastures and meadows, by having hairy leaves which are very much cut up. The hairs are long and silky, and give the plant a silvery appearance. The flowers are small, and differ from most rosaceous flowers in having no corolla and a four-divisioned calyx. Some rare Saxifrages grow in the Highlands. The species most familiar to many people is the Meadow Saxifrage, which is not an Alpine plant. The usual mountain species resemble it in having white flowers, but very much smaller ones; the only one with purple flowers is *S. oppositifolia*, a tiny creeping plant with leaves in four dense rows. It is to be found on damp rocks in mountainous districts.

The little Snow Gentian also occurs on Ben Lawers. This is a very minute plant, easily passed over on account of its small size. It has dark blue flowers, as most of the Gentians have. The Field Gentian and the Autumn Gentian are very common, and found on hills of about 1000 feet high, even in the south of England. It is interesting to notice that the Scurvy Grass (*Cochlearia officinalis*) is a characteristic plant of mountains, for it is found also on cliffs, very abundantly off the Cornish coast. It has the small white flowers of the crucifer type, and fleshy leaves. Many plants which belong to hills or mountains also occur on the seashore, for these two situations resemble each other in their want of a regular supply of moisture.

Alpine plants are often very successfully cultivated on rockeries in gardens. The one essential is that the rockery should be well drained and the plants sheltered from wet by putting bits of glass over the very woolly ones. In their natural habitat Alpine plants are protected during the severe weather by the snow which covers them, and the air is dry, not moist, as in this climate. There should be plenty of stones on the rockery. On them many of the Alpine Saxifrages grow very well, and with the first bright spring weather put forth a wealth of blossom, which would hardly be expected from such small plants. Sometimes, instead of a rockery, Alpine plants are kept in a greenhouse during the winter, in order to protect them from damp, and are planted out when the winter rains are over; but there is no reason why they

should not be kept out of doors the whole winter, provided the woolly plants are kept free from damp.

There is a very successful Alpine garden in Cheltenham, which consists of a rockery particularly well drained; the plants are out all the winter, the very woolly ones being covered with glass. They do very well indeed.

From what has been said, it is clear that the vegetation of moors is chiefly xerophytic. A moorland region is a meeting-place of extremes: its climate consists of intense heat or intense cold, of extreme drought or soaking rain; a moor is often far drier in a hot summer than any ordinary pasture; the ground is parched and scorched, whilst in winter it is frozen or covered with snow for months. Only a xerophytic vegetation is adapted to such conditions. Even the plants that live in bogs, although in water, appear to be xerophytic in character. Many of them have reduced leaves and a thick cuticle. Clements suggests that those bog plants which appear to be xerophytes at one time lived in xerophytic situations, and not in water. He thinks that Grasses, Sedges, and Rushes are extremely slow in adapting themselves to new conditions, and therefore have retained the xerophytic habit although living in water. In support of this explanation he urges that many of these bog plants have structures which are characteristic of water plants, as, for instance, air passages. He urges, too, the fact that side by side with these bog xerophytes are found plants which are typical hydrophytes, namely, Marsh Marigold, Water Buttercup, etc., and that the one locality cannot be at the same time suitable to both hydrophytes and xerophytes. He therefore regards apparently xerophytic bog plants as gradually adapting themselves to an aquatic environment.

Bog plants will be more fully discussed in a subsequent chapter on Aquatic Vegetation.

The frequent presence of the Birch in the peat of the Heather and Vaccinium moors shows that they have been derived from primitive forest. The same thing has been found in Germany and N. Europe generally, and it is thought by some people that many of the Heather moors in the north of England might be successfully re-afforested, if desired, with coniferous trees. In

many parts of Yorkshire, pine woods are to be found on the edge of heather moors. At the present time many of those moors, especially in Scotland, are preserved as grouse shootings, or as sheep-walks. In order to preserve a good growth of young heather, the old is often burnt. It has been found possible, too, to reclaim many of the Cotton-Grass moors by letting sheep graze on them; then the Heather gradually re-establishes itself where the Cotton-Grass formerly was; thus the burning of the Heather and the improvement in drainage may in time convert a Cotton-Grass into a Heather moor. In ways of this kind the vegetation of a district may in course of time be considerably altered by man.

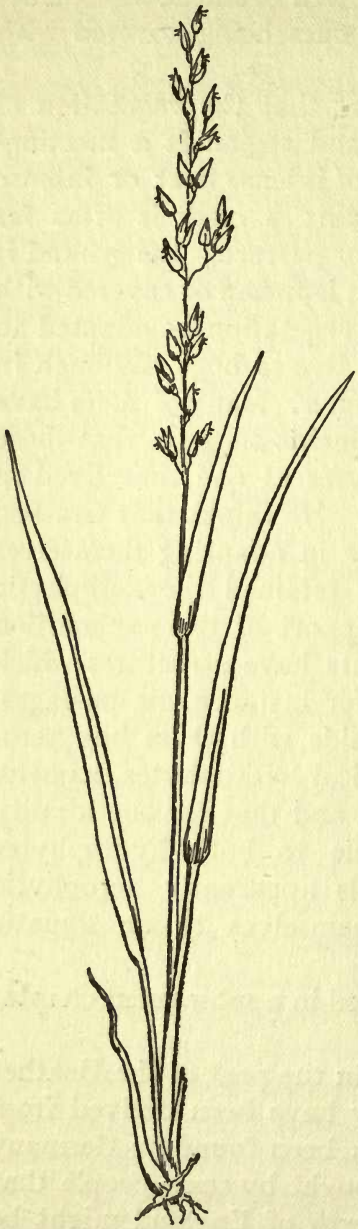


FIG. 62.—Purple Molinia (*Molinia cærulea*).

GRASS HEATHS

Grass Heaths occur at all altitudes above 1000 feet. They often form a transition between cultivated land on the one hand, and the Heather moor on the other. The two grasses most characteristic of these heaths are: (1) The Moor Mat Grass (*Nardus stricta*), one of the dominant plants of dry heaths; and (2) the Purple Molinia (*Molinia cærulea*), characteristic of wet heaths. The former is easily recognised in autumn and winter by the white colour of the dead stems. It grows on well-drained steep slopes, very often on glacial débris, either with no peat at all or with a very thin layer. The Purple Molinia, as it is called from the purple-blue flowers,

is very conspicuous during the flowering season, July and August. It frequents badly drained ground containing a good deal of peat, and is therefore not found with Heather, which likes a drier situation. In the Hebrides the stems are made into ropes, mats, and baskets; the fishermen especially value the ropes made of this grass, for they last a long time without rotting. Moor and heath grasses have very thick, stringy roots, which, unlike those of most grasses, are not easily broken; thus they bind the soil together. Their leaves roll in at their edges, which are usually thickened. This prevents too rapid evaporation, for a much smaller leaf surface is exposed.

The Moor Mat Grass (*Nardus*) has bristle-like leaves, and the flowers are all turned towards one side. It has a straight, hairy style, not plume-like, as in most grasses. The "awns" are very short. Sedges and Rushes are very often associated with this grass, and make the soil sour. The Purple Molinia differs from many other grasses in having no ligule or membranous outgrowth at the junction of the blade of the leaf with the sheath; this is represented by a tuft of hairs, and the leaves taper to a point. These two moor grasses are easily distinguishable from each other. The Mat Grass is very slender and wiry, not more than a foot high; whilst the Molinia is coarser and often three feet high.

FIG. 63.—Moor Mat Grass (*Nardus stricta*).

The plants commonly found with these grasses are, as would be expected from the nature of the habitat, different in the two cases: where the Moor Mat is dominant it is usual to speak of a Nardus association; and on those grass heaths dominated by the Purple Molinia, of a Molinia association. The most marked difference is the absence of Heather in the Nardus association. Besides, the Heath Rush, *Juncus squarrosus*, which likes a drier situation than the majority of Rushes, the chief plants of the Nardus association are: the Blue Moor Grass (*Sesleria cærulea*), the Tormentilla, the Dwarf Furze, the Bilberry, the Staghorn Moss, and the Heath Bedstraw. Most of

these plants have already been described (p. 196). The Tormentilla belongs to the same genus as the Silverweed; it has yellow flowers, but only four, not five petals. It is a plant very characteristic of heaths and commons, and sometimes is only a few inches high, but its growth varies very much with its situation. It is a very widely spread plant, frequenting not only heaths and moors, but pastures and even open woods. The Bedstraws always have their leaves arranged in whorls, and very small white or yellow flowers. The Heath Bedstraw has six leaves usually, and white flowers. It is a plant about six inches high, with small leaves, each pointed at the tip. This plant bears a general resemblance to the Goose-Grass or Cleavers, so common in hedges. The Staghorn Moss is not really a moss. It belongs to the group of non-flowering plants known as Lycopodiums or Club Mosses. The leaves are very small and crowded on each other, not unlike the arrangement in a moss. The spores are contained in bags called sporangia, which are borne in erect spikes about one, to one inch and a half, long. When ripe the spores are shed in the form of fine yellow dust, which falls in great quantities. This plant belongs to hilly pastures and heaths, but is far more common in the north than in the south of our islands. Sometimes the chief sub-dominant species of the Nardus heath is the Bilberry; sometimes the Common Ling. It seems certain that many of the Nardus heaths, with Ling, were not so long ago Heather moors. Owing to grazing by sheep the Heather has been ousted and the Nardus has taken its place.

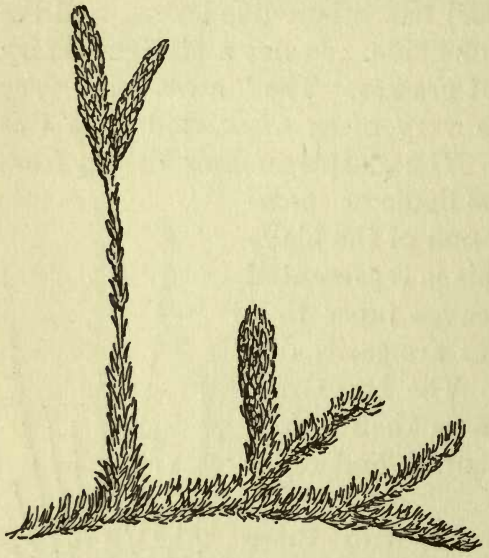


FIG. 64.—Staghorn Moss (*Lycopodium clavatum*).

The Molinia plant association is a larger one than the Nardus. Besides many species of Carices and Rushes, Heather is con-

spicuous. In autumn this type of grass heath may be recognised by the reddish-brown colour due to these three sets of plants. It could not be mistaken for a Nardus heath, which is whitish in appearance. The chief plants, in addition to those already mentioned, are : the Bog-Asphodel, the Marsh Pennywort, the Bird's-Eye Primrose. The Bog Moss is often present in considerable quantity in the wettest part of the heath. All these plants like a wet situation. The Bog-Asphodel (*Narthecium ossifragum*) has the habit of an Iris, and the same sword-shaped leaves ; but its flowers are like those of the Lily. It is difficult to say when it is most beautiful, when in flower in July or in fruit at the end of August or September. In the Lake district it is often seen covering extensive tracts, and the deep yellow flowers with their scarlet anthers and woolly filaments are very striking when seen in a mass. The colouring of the fruit in autumn is in its own way as beautiful ; the perianth of the flower has turned to orange, the fruit is a reddish-brown, easily recognisable at a distance. The Marsh Pennywort (*Hydrocotyle vulgaris*) is thus named from the leaf, which is in the shape of a penny. The leaf-stalk is attached to the centre of the leaf. The flowers are very minute and greenish, with a tinge of pink. The stem creeps along the wet mud of the bog or marshy ground of the heath, rooting at every node and giving out small tufts of leaves and flowers. The Bird's-Eye Primrose is very different in appearance from the Common Primrose. It has smooth leaves, which are white and mealy beneath, and umbels of lilac flowers with a yellow eye ; the calyx is nearly as long as the corolla, and the fruit is twice as long as the calyx. It is a plant confined to the northern counties of England, to one or two counties of Scotland, and is unrecorded in Ireland.

FIG. 65.—Bog-Asphodel, with fruit at left (*Narthecium ossifragum*).

On the whole, the Molinia heath is more extensive than the Nardus; in some parts of the northern counties it may stretch for miles on gently sloping, badly drained ground. These two types of heaths represent respectively those developed under extreme conditions of dryness and moisture; as conditions change, every possible gradation may occur.

Limestone Heaths

It is not always possible to draw a hard-and-fast line between natural pasture and a heath. They may merge into each other. In Somerset, heath plants, such as the Ling and Bell-Heather, are found growing side by side with plants characteristic of natural pasture, on carboniferous lime-stone. Where the soil is shallow, pasture plants assert themselves; where it is more than three inches deep, heath plants are found. This observation bears out the conclusion of the German botanist Graebner, who in his work on the heaths of North Germany states that typical heather formations can thrive in a soil largely impregnated with lime salts. The soil of the limestone heath is not peaty, but is of the nature of a red marl. Heather and heath plants are found in Somerset on old ant-heaps,—"emmets' batches," as they are called locally. The dominant plants on those limestone heaths are: Furze, Hawthorn, dwarfed in growth, Ling, Bell-Heather and a species of the grass Fescue. In Yorkshire, some of the pastures are heathy in character, and are said by the farmers to be "running back to moor."

Grass heaths may occur at altitudes above 1000 feet. When they occur at a height of two or more thousand feet they are often characterised as Alpine Grass heaths. On such a heath the Mat Grass is often replaced by the Heath Rush, and Alpine plants may be found in sheltered crevices or by the side of the mountain streamlets. The Blue Moor Grass (*Sesleria cærulea*) is also commonly found in these situations. This grass belongs especially to northern limestone hills; it has narrow, flat, blue, stiff leaves, the stomata of which are sunk in and guarded by six cells instead of two, thus preventing too great transpiration.

From the point of view of Plant Associations, heaths may be classified as follows :—

1. The Nardus heath, in well-drained situations.
2. The Molinia heath in wet situations.
3. The Alpine Grass heath, generally above 2000 feet.
4. The Limestone heath, in which heath plants are found side by side with the herbs characteristic of natural pasture.

The grass lands of our islands are insignificant compared with those of the Continent and of America, namely, the steppes of Russia, the prairies of North and the pampas of South America. The chief grasses forming the primeval steppes in the district of the Black Sea are two species of Stipa. One of them, *Stipa pennata*, is grown in our nursery gardens and is very well known in this country. The grain bears a long and beautiful feather, more than a foot in length, by which it is dispersed. In Schimper's *Plant Geography* (p. 598) it is thus described: "When observed from a distance, many places covered with the Stipa formation resemble sandy hills; on near approach the sandy grey tint is converted into silvery white, and the appearance of this restless, ceaselessly swaying grass land reminds one vividly of rippling water, and, in spite of its entire monotony, gives one a subdued and pleasing impression." The plants found in association with the Stipa formation are comparatively few, and belong to sandy soil. The American prairie is also of the nature of a steppe; the land is nearly flat, but here and there interrupted by river-beds, along which there is considerable vegetation. The dominant Grass is known as Buffalo-grass. The pampas in the north of S. America are less monotonous than the prairies, owing to the greater vegetations. In the province of Buenos Ayres, however, the grass lands extend for hundreds of miles without any rising ground, and dull monotony is as characteristic here as it is of the prairie. Our islands are, it is true, small; but it would be difficult to find a greater variety of scenery than they contain, and at any rate it is hardly possible to complain of monotony even in the dullest county! A few miles by train can take one away from the barest landscape to hills, or streams, or wooded dells

The Vegetation of Commons

To turn now to our commons. Lists made of plants growing on commons in Gloucestershire show that the most abundant are: Thistles, Colt's-Foot, Ragwort, Bird's-Foot Trefoil, Scabious Cinquefoil, Tormentilla, Harebell. The Colt's-Foot is one of the first to flower; it may be seen in waste places, on railway banks, on stony bits of commons as early as February. Its yellow ray florets make it conspicuous, and attract any insects that are about. The nectary of the inner florets can be seen through the corolla tube by holding up a floret against the light; it is at the base of the style, and looks a darker yellow than the rest. In this plant there is a division of labour: the ray florets attract insects, the inner ones provide the nectar. The leaves of the Colt's-Foot come out long after the flowers and are very large, sometimes five or six inches across. They are very downy underneath and rather prickly at the edges; their hairiness adapts them to dry situations. There are many species of Thistles. One of the most abundant on commons is the Dwarf Thistle, which has hardly any stem. The Spear Thistle may also be easily recognised by the terminal lobe of the leaf, which is longer than the other lobes and shaped like a spear. Amongst rosaceous plants may be mentioned the Salad Burnet and the Potentillas. The former has its flowers crowded together in a head; the staminate ones are distinct from the pistillate. Neither has petals. In the staminate the anthers

Fig. 66.—Tormentilla (*Potentilla Tormentilla*).

swing at the end of the long filaments, and the pollen is conveyed by the wind to the pistillate flowers, which are easily recognised by the red styles. The Cinquefoil is abundant on commons, and derives its name from the five leaflets which make up the compound leaf. It has yellow flowers, very like those of the allied species, Silver Grass. There is no flower of the common more graceful than the delicate Harebell. The radical leaves are rounded, and generally wither before the flowers open, so that one is more familiar with the upper leaves, which are narrow.

FIG. 67 —Milkwort (*Polygala vulgaris*).

Just as the grass heath may be invaded by plants from an adjoining natural pasture, so too may the common. The Milkwort, Thyme, certain Clovers, Eyebright—all pasture plants—are often found side by side with the Thistles and Scabious, which are more truly characteristic of dry, exposed situations, like that of a common. When the common is situated on a sloping hillside the Bracken may be the dominant plant. The distribution of this Fern is worth noting. It is found in woods composed of trees with an open canopy; it covers the slopes of treeless hillsides, which were at one time probably occupied by light Oak scrub, or by Pine and Birch; it will grow on clay, and still better on a sandy soil. The plants associated with it vary with the habitat. On May Hill Common, situated on the borders of Gloucestershire and Herefordshire, the Gorse and the Heather are the two chief sub-dominant forms. In an Oak wood it is found in conjunction with the

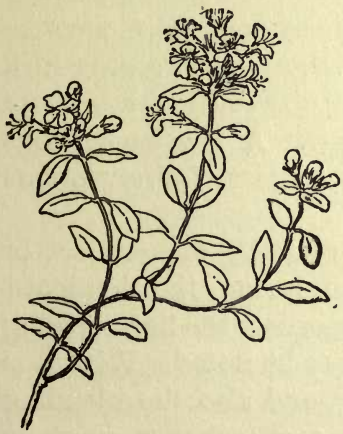


FIG. 68.—Thyme (*Thymus Serpyllum*).

Holcus Grass and with the Bluebell. Investigations have been made as to the depths at which these three plants are found in the woods around Huddersfield. The Holcus roots are on the surface, the Bracken rhizome below that, and the bulb of the Bluebell lowest of all; each thus drains a different layer of soil.

The fronds of the Bracken are more erect in certain situations than in others. If the leaf-stalk is cut across a yellowish-brown tissue may be seen underneath the skin and scattered about inside. This tissue is the one which largely supports the frond, and is known as the "oak." It is more developed in the erect fronds than in those that droop; therefore, in the Bracken of a common than in that of a wood. The underground stem grows horizontally at a depth of from six to eighteen inches. Every year it grows forward a few inches, so that the new roots and fronds occupy a fresh position.

All commons are not as bare as these just described: in certain parts of Surrey, as in the neighbourhood of Hindhead and Haslemere, or in Kent, there is a far greater wealth of vegetation. There may be found such shrubs as the Guelder-Rose and the Holly; the Clematis and the Honeysuckle; low lying herbs, as the yellow Rock-Rose and the blue Speedwells, and in boggy patches even the Sundew and the Cotton-Grass.

Practical Work

In observing the vegetation of any given area, as a moor, a heath, or a common, it is essential to make exact records in a note-book. The most valuable notes of observation are those which have some definite purpose in view. A few suggestions are therefore now made in order to secure a series of observations on definite lines.

1. The colouring of any given area may be one subject of observation. The colour of the plants in spring, the dominant tone of colour in the area which is being observed, the harmonising of the different colours with each other may be noted. With this may be contrasted the autumn colouring, and also the blending of the colours of the different plants with each other to produce a certain tone of colour. A good example of this is seen in the

autumn tints of the Heather, the Bog Asphodel, and the Purple Molinia Grass.

2. The time of flowering of the different plants in a given area may be accurately recorded and compared with that of the same plants growing a few hundred feet higher in an exposed situation. The season is later on hills than in the valleys beneath.

3. Observations on Plant Associations. The best way of beginning is to fix on some common, or other natural area, within easy reach of the school or the children's homes. Too large an area should not be selected at first. Every plant growing in this area should be recorded from the months of February to October. Those that flower at the same time should be arranged together in the same list; those that belong to the drier portion of the area together; those that are found in marshy ground in another list; and so on.

It should be noted each season which plant is dominant, and whether there are any well-marked sub-dominant species associated with it. A map of the area selected may be drawn to scale, and the two or three plants inserted in it. Supposing that in a little bit of common the Gorse and the Heather are the two chief plants, the exact position of each should be indicated on the map, and the following year it should be noticed whether one seems to have encroached on the other.

The plants which grow in the same habitat may be compared with each other, to see whether they resemble each other in any particular character; such as the succulence of their leaves, or the reduction of the leaf-surface, or the development of thorns, or their low growth. In this way it will be possible to form some idea of the characteristics of the vegetation of different natural areas.

This observation of Plant Associations is comparatively new work in this country. It is therefore wise not to generalise too hastily, but to compare one's own observations with those of others. At the present time, vegetation maps of different parts of England are being prepared, and will be found helpful.

4. The distribution of any common wild flower is often very interesting. In the neighbourhood of Cambridge, for instance, the exact places in which the Oxlip is found; or in the Yorkshire

moors, the exact habitat of the Bilberry; in a common, the position of the Ragwort, may be carefully recorded. Then the reason for the habitat should be sought. Very often it will be found that the degree of dryness or moisture is the determining factor.

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