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FIELD & FOREST

FIELD AND FOREST

An introduction to the lives of plants

by

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Illustrated by the Author

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Preface

When I began this book I had three objects in mind. First, to write a simple account of the lives of plants for all those country lovers who are no botanists but who would like, nevertheless, to know something of the ways and habits of wild flowers. It seemed to me that there was room for such a book, which should stress the 'aliveness' of plants and should be written with as little recourse as might be to the technical vocabulary of the botanists.

Secondly, my object was to communicate, if possible, a little of my own pleasure in the study of plants in the places where they grow, and of my own sense of the oneness of the natural world and the interdependence and interaction of all its parts from inanimate matter to Man himself.

Thirdly, I wanted to prove, if I could, that it was possible to write of even a scientific subject in language more colourful than the grey words of the textbooks.

To any reader who may wish to do a little botanising for himself I have two words of advice to offer. One is to provide himself with a pocket magnifying glass and use it constantly to examine all plants: a whole new world of exquisite detail will thereby be revealed to him. And the second is—if he has the least talent for drawing—to record his observations on paper. Both lens and pencil will add immeasurably to his pleasure, as they have to mine.

When in doubt on any matter of botanical fact I have referred to Fritsch and Salisbury's excellent textbook *Plant Form and Function.*

Chepstow, Mon. ISLAY MANLEY
1953–54

I

Winter

THIS morning, a week from the shortest day, it is snowing and now if ever the earth may be said to be dead. The green glow of life is quite withdrawn, for the sombre mourning hue of the evergreens under their lamb's pelts of snow is more black than green. And black, too, are the writhen boughs of the deciduous trees, black against the soiled-white sky, black against the immaculate white snow; for these are the colours—the no-colours—of winter as of death: black of mourning, white of the shroud, unclean pallor of the dead. But earth is not dead, for only yesterday, before the snow came, a dandelion glowed under a south facing hedgerow and it was the snowflakes themselves which today shattered the last golden petal of a buttercup—symbol of June—which has grown and thriven this three months past at the edge of the lawn.

Clear the snow covering from a patch of the fallow garden earth and you will find the sodden flowers of speedwell and red archangel and the yellow buttons of groundsel, shivering and sad indeed, but alive still and able to struggle on to maturity and seed-setting if the thaw should set in. Peer into the field hedges and before long you will see the paired new leaves of the honeysuckle, grey and small as yet with the cold, but ready at once to freshen and grow at the first hint of warmth. The buds are fat on the sallows and every here and there through cracks in their thick, brown scales the gleam of burnished silver gives promise already of Easter palms. Down by the stream amethystine leaves are breaking on the alders, close pressed against the dark twigs, and on the branch tips, beyond the black skeletons of the old year's cones, are bunched the tight catkins, tinged with purple, of

the new year not yet born. In every hedgerow and wood the lambs' tails of the hazel and the red, horned catkins of the birch are ready formed, and waiting only for the release of those warm streams which will enable them to grow and hang out their pollen-covered tassels to the fertilising breeze of spring.

Last year, at this season, after a night and day of softly falling snow, I walked by the edge of a neglected coppice. Before me, from the black boles of the trees, stretched a white, unbroken coverlet, unsullied by a single blemish. No crow or magpie had lit there to scuffle the surface and stain it with scatterings of the underlying earth; no rabbit had left the track of its lolloping feet; the windless night had blown down no twig to lie blackly against that immaculate expanse. Then, suddenly, I came upon a hidden hollow where the snow was sprinkled over with a pale confetti that seemed pink against the whiteness. When I stopped to examine the tiny fragments I saw that they were of two kinds: one, the heavier, was shaped like the heraldic fleur-de-lys and the other was winged like the smallest and most fragile of dun-coloured butterflies. For a moment I was at a loss to know what they were but then, looking upwards, I saw a birch tree etched in its infinite grace against the winter sky and I knew that these were its fruits. So charming were the dainty seeds and their three-lobed scales that I broke off a twig from the drooping branch above me and took it home to study at my leisure, and, when I had admired it enough, I put the black twig into a vase of winter buds and berries which stood in my warm kitchen.

There was then no living colour about it save the reddish underhue of the bark and of the twin curved catkins at the twig tips. The ripe 'cones', like elongated burrs, were brown without and ochreous within. The disc at the base of each and the central thread to which the scales were attached were of a pale dun colour and, where the scales had all been shed, these—the disc and the thread—remained, bristling like tiny,

bent rapiers. The leaf buds, pressed against the stem, were dark and lifeless and the whole branchlet at a distance seemed the same. But, on a morning about three weeks from the day on which the twig had been gathered, specks of brilliant green burst forth at the tips of many of the leaf buds and from that morning on, day by day, I saw the birch branch come to life. First, the stiff catkins drooped and loosened; their hue changed from a dark red to a pastel purple and this became laced with a network of creamy lines; these lines grew broader and took on a yellower tinge until, at last, the fully expanded catkins hung in soft, downward curves, pairs of sulphurous tassels banded with mauve. Meanwhile, the green tips of the winter buds spread slowly into leaves, folded at first along the veins, like fans with serrated edges, but soon lengthening and widening into a pointed oval, and in the heart of each cluster of miniature leaves appeared a tiny, upward-pointing thumb which was the bud of the female catkin. The colour of the fragile foliage and of the flower buds was a tender, translucent green which there is no word to describe, and the effect of them was as of living points of flame against the dark wood of the branch. So the 'dead' twig came to life though the draggled world outside the window still lay in the mire of winter.

Here was proof that the earth was not dead: no, not even sleeping, but withdrawn and fortified against the enemy of winter drought. Water lies everywhere: in pools when the gale winds blow, in translucent sheets of ice under the north-easter, in soft, yet solid flakes when the snow falls, as today. But whether in pools or sheets or flakes it is shut off by the cold from the roots of all growing things which must have a certain degree of warmth before they can perform their function. The great deciduous trees, like beleaguered garrisons, hoard their summer-won resources and cut down every unnecessary expenditure of water. Little by little, as the days shorten in autumn, they withdraw the nourishment from their leafy extremities and store it in trunk and branch,

passing at the same time, it is believed, all waste products outwards to the leaves, and the chemical changes involved in the great transfer turn the woods golden and bronze and scarlet. At last, when all of value has been safely moved and all refuse expelled, the leaves themselves must be cast off, for the foliage of a single tree will transpire twenty gallons of water in a summer day. As growth ceases and the autumn retreat into the wood begins a line of cork is formed below each leaf-stalk until soon or late—soon in the ash, late in the oak—the leaf is quite shut off from the twig on which it grew. Deprived of all nourishment it dies and is severed by the wind, leaving a scar where it grew, and decays and in its decay feeds again the parent tree. But, in the axil of each leaf a new bud has been formed, holding in miniature the frail, green leaves of spring, but armoured now in thick scales against the cold and drought: a token, a promise amid the stark boughs that life will flow again here when the quickening sun returns.

Not all green things denude themselves in this way, for water may be saved by other means. The holly and the laurel, the fir and the pine, the yew, the juniper and the whin, though they do not stand bare at winter's approach, yet do not die of thirst. Holly's leaves are covered in a thick cuticle, pierced by few stomata, or breathing pores, and those few closed in winter; the thick-skinned needles of the conifers, with stomata sunk in pits, present but little surface for evaporation; and the spines of gorse, which are modified leaves and stems, follow the same method as the conifers. The foliage of these three is well-equipped, also, to withstand winter's gales, for the wind can get no purchase on spine or needle, and the broader leaves of the holly are hemmed with a rim of strong tissue which defies the wind's utmost rage to tear.

It is strange to look out on an English winter landscape, sodden with rain, and consider that those bare boughs, those sombre, harsh-foliaged firs, those shining, tough-leaved hol-

lies owe their aspect to the same cause that makes the blue gum drop its leaves in the waterless heat of summer in the Australian Bush, or the oleander and holm oak grow thick, protective skins against the desiccating sun. The hot drought of summer, the cold drought of winter bring forth the same defences from the plant which must have moisture to live.

But cold is a danger, too, in its own right, to the herbs whose delicate leaves are killed by frost, and they have their ways of guarding against it. The perennial herbs, for the most part, withdraw what may be moved of their aerial substance and store it underground in stocks and bulbs and corms, leaving the summer framework of leaves and stems to wither and decay; and from these subterranean stores they draw in spring to start their new season's growth. It is because the daffodil on the lawn—like the bluebell and all other bulbs—relies upon the stored nourishment from its leaves to start its spring growth that you must spare these leaves at the first mowing of the lawn; to cut them before they have withered is to weaken the bulb. And in the same way, if you would weaken nettles in a garden, you must cut them when they are in full green growth, for then the winter stores have been expended and no adequate replacements have yet been laid in.

Some few perennials—as the wintergreen daisy and dandelion and many of the grasses—and all biennials in their first year are so hardy as to flaunt some part of their greenery above ground all winter through. They are but lowly herbs, however, close pressed to the earth, when the dark days overtake them. The perennials among them have shed most of their summer finery and the biennials have not yet obtained it, for their first year has been spent in storing below ground—as the carrot does in its swollen taproot—the substance which, in their second summer, they will spend lavishly on leaf and stem, flower and seed; two seasons is the life span of the biennial and before a second winter they are dead.

The summer annuals have no defence against winter's rigours: they must make haste to flower and set and shed their seed, so that in this form, as seed, encased in a hard, impervious coat, they may pass the dread season safely in some warm cranny of the soil. The individual dies, but the race lives on. There are some annuals so perverse, however, as to choose to germinate their seeds in autumn: of such are certain forget-me-nots and the poppy who are thus compelled to pass a stunted and sunless youth and must wait for spring to grow freely and bloom and set their seed.

So, I look out on this winter's day and know that there is no death here. All movement may have ceased but the slow falling of the snow, all colour faded but the red and orange of the bird-tattered hedgerow hips and the crimson of the holly berries, but I know that dormant life lies hidden beneath the black bark of the trees, beneath the shroud of the snow, that colour is waiting in the dark buds of ash and oak and chestnut from which it will soon burst forth in a blaze of green.

2

Spring in the Woods

As the shortest day falls further and further behind, and first the dunnock and the wren and then the thrush and blackbird and, finally, the chaffinch join the robin in his waking song, a gradually increasing restlessness invades the mind, caused by a sense of the precariousness of life and of its shortness, and by the conflicting desires that winter should give way quickly to the longed-for spring, but, at the same time, that the days should pass slowly so that no sign of the year's rebirth may go unnoted. Such signs for many days past—for weeks even—have not been wanting. Though a sullen sky still hangs low over the purple, leafless woods and withered, tawny pastures, and damp exhalations from the rain-soaked earth tinge the atmosphere, so that it is as though the hills and valleys were washed with sombre indigo, yet, in the secret places under hedgerows, in sheltered coppices and in the forest among the dead year's leaves a million points and splashes of new green show that already the flood of life and growth, with ever-increasing momentum, is flowing back once more into its green channels.

Little by little, as winter recedes, the strengthening sun has dried out and warmed the garden soil until at last it can be dug and raked to the fine tilth beloved of all plants, wild and tame alike—for even the flowers of the field will not thrive unless their roots can 'breathe' and grow. Soil is no haphazard pudding of particles of different size but has a definite structure. In each crumb of soil is a skeleton of sand grains round which cling particles of clay and humus, held together by the tension of the tenuous water films surrounding each fragment. Ideally to suit the growth of plants these crumbs should be loosely packed and neither puddled nor

caked, for without air roots cannot 'breathe'. In gardens we aerate the soil by digging and raking and breaking up the clods, but in nature, where the perfect texture is seldom found, the worms are the chief aerators and, after them, the insects of the soil and the bacteria and fungi, and frost is the great clod-breaker. So, after the winter cold has done its beneficent gardener's work, and when gradual warmth has awoken the creatures of the earth to their ceaseless labour of cultivation, all things are fit once more for the germination of the seeds.

Now, a million tiny seed-coats swell and crack along the line of least resistance, a million pallid rootlets thrust out and downwards through the micropyle and, attracted by gravity, turn this way and that in search of water and nourishment, and a million fragile plumules force their way upwards towards the light—spearpointed the better to penetrate the soil, or heads bent to protect their tender leaflets against earth's friction. These last weeks they have been emerging on every hand: single, hair-thin points of grass, twin bat's ears of chickweed and speedwell, shepherd's purse and goosegrass—all pale at first while they drew still from the stores packed with them in the seed, but soon turned green and self-supporting by the sun.

Most of the earliest sprouts were from seeds of annual weeds, self-sown last autumn, for these must make haste to embark on their short life as soon as conditions of warmth and air, moisture and light permit. But some may have lain dormant in the soil for many a year until the autumn digging brought them up from the airless, lightless depths of the subsoil into the warmer layer of the surface tilth. Seeds of shepherd's purse, charlock and plantain, buried deep by the plough or covered with brushwood and rubbish, will sleep unharmed for half a century if need be and still be capable of life, as farmers know to their cost when they plough up old pastures and the inextinguishable charlock turns their fields yellow. The seeds of the tender wood sorrel will not

do this, nor the fluffy seeds of willow, for it is said that they will not live a week once they are shed.

Most seeds will sprout at once when all things are favourable for their growth but some must have a time of after-ripening—as, for instance, the meagre seeds of the wood anemone which, after they fall in summer, continue to develop throughout the autumn and the winter, and time their ripening for those few weeks in spring when a warm, strong sun floods through the bare boughs of their woodland canopy. Earlier it is too cold for them, and later the leaves of the forest trees will hide the light from them. Haws and blackberries, too, must lie awhile before they can germinate: the blackberry until the damp soil has decayed the hard coat of its seed; and haws until chemical changes within the seed have enabled it to increase the materials needed for renewed growth. Holly and ivy seeds, too, must, I think, spend many months in the soil before they germinate, for it was early January when I saw a seedling holly with its first pair of delicately toothed true leaves, and at that time the berries were still crowding the holly twigs above; and even before that, in December, the seedling ivies were thick under the wall, though that year's fruit was green as yet along the wall-top.

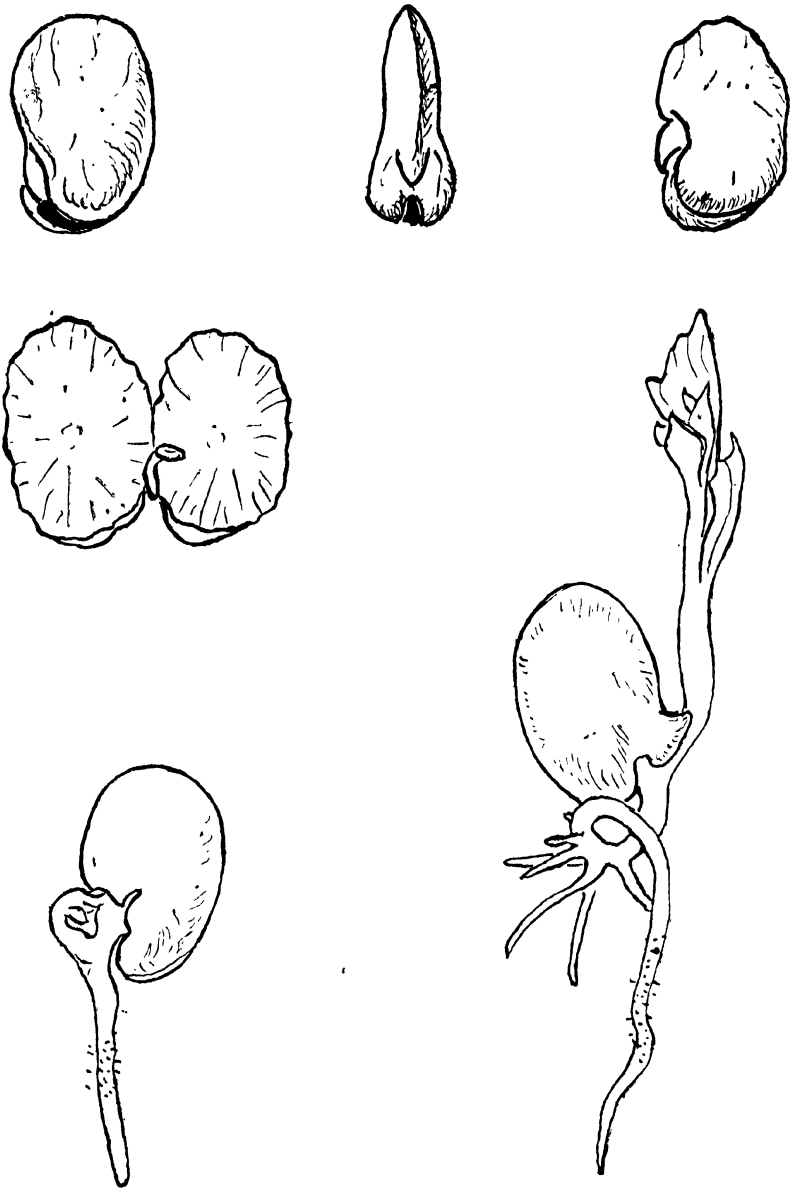
Anxious to see once more with my own eyes the process of germination, in the first week of the New Year, I pushed two broad beans into a bowl of garden soil and keeping them moist set them in a warm place to grow. A third bean I soaked in water until it had lost its wrinkles; then, gently squeezing it, noted where a little moisture frothed out at one end of the scar along the rim. Here was the micropyle, the tiny hole through which the bean seed had drawn in the water with which it was swollen and out of which the first root would thrust its way. Then, carefully I drew a sharp knife round the rim, cutting the hard outer coat and disclosing the two ivory seed leaves, pressed closely together, face to face, and at their point of junction a small, pointed tooth

—the radicle—fitting into a pocket under the scar on the outer coat. Gently I prized the leaves apart and there, above the tooth, was the tiny plumule—the infant shoot—white, minute and formless to the naked eye.

After a few days I dug up the first bean in the bowl and saw that the radicle had now pierced the micropyle and thrust downwards, like an ivory bodkin, into the soil. Just behind the tip the root hairs showed, like a white fur, with particles of soil clinging to them to prove that the work of gathering nourishment had already begun. Meanwhile the plumule, emerging from the seed coat just above the radicle, had turned in the other direction and thrust upwards, with bent head shouldering its way through the earth. The brunt of the wear and weight of the soil particles were borne on the crook of the lengthening stalk, while the delicate, creamy leaves, bent back against it and folded into their smallest compass, followed after the sturdy stem unscathed.

When the second bean had thrust above the surface of the soil and unbent its back, and when the first leaves had unfolded and slowly lost their pallid hue and turned a yellowish green, I dug up this seedling also. Now the single bodkin root had branched into three side roots, each with its little fluff of hairs through which the watery soil solutions flowed. The seed coat was decaying fast and the two cotyledons—or seed leaves—within it were diminished to a quarter of their once plump bulk for their work of nourishing the nurseling root and shoot was nearly done. Henceforth these could make their own way, each contributing its share to the growth of the new plant: the shoot to make food out of air and sunshine and the root to anchor the shoot and find water and minerals for its sustenance.

As the seed of the broad bean germinates, so in the main do the seeds of all flowering plants, though with many variations of detail. The net-veined, dicotyledonous plants enclose two seed leaves within the seed coat and the monocotyle-



GERMINATION OF BROAD BEAN

Bean with and without seed coat. Seed leaves parted to show plumule. Emergence of radicle and plumule. Root and shoot established.

donous, or one seed leaved, contain but one. These cotyledons may remain below ground, as they do in the broad bean, or they may emerge above ground, pushing their way through the soil under the protection of their hard coat, as in the sunflower and many other plants. The seed leaves may contain all the store from which the seedling has to draw before it can fend for itself, or they may share their nursing duties with a substance called the endosperm which, in general, envelops the cotyledons and fattens them until they, in turn, can pass on the nourishment to the seedling. The friction of the soil may be taken by the looped hypocotyl, which is the little stem below the seed leaves; or by the bent stalk of the plumule, as we have seen in the broad bean; or by the seed coat itself, as in marrows, sunflowers, cucumbers and onions; or a special sheath, called the coleoptile, may be developed to take the wear and tear, as happens in the pointed shoots of grasses. As for the radicle, it pursues a more or less unvaried course, except that the main root system of the monocotyledonous plants develops as a fringe of adventitious roots below the crown rather than as a branching taproot.

So the seedling—root and shoot—is established. And, as it grows to maturity, a third part, besides the leaves and stems, is developed on the shoot and this is the inflorescence. Each of these main parts—the root, the shoot with its leaves and branches and the flower—is structurally fitted to play its own particular role in the maintenance, growth and reproduction of the plant. The roots' main function is to provide safe anchorage and stability. Most dicotyledonous seedlings have, at first, a single taproot which suffices to keep the shoot anchored and upright but, as the aerial portion of the plant grows taller, it tends to become top-heavy and at this stage lateral roots are put out which act as stays against the toppling pull of gravity and as anchors against the drag of wind. These side roots, instead of growing straight downwards, branch out more or less hori-

zontally and fairly near the surface of the soil where they form a stable platform. They thicken with the growth of the plant and, in forest trees, often increase to such a size that they emerge above ground and then have the appearance of buttresses supporting the base of the trunk. Very tall, top-heavy plants, such as the giant balsam, *Impatiens glandulifera*, and, among the monocotyledons, maize, supplement the underground root system by putting out adventitious roots from some of the lower nodes of the stem, and these, when they reach the ground, become additional props. The mechanical structure of a root is that which is best calculated to withstand the pulling strains to which it is subjected: the harder tissues of a root are concentrated at its core where they form a strong central strand, like a steel wire running through a hawser, and the softer tissues gathered round it give it flexibility.

The stem's function is to support the foliage and flowers so that they may get their share of air and sunlight, and in typical upright plants it must be strong enough to bear the weight of these and, at the same time, to withstand the bending strains of wind. The smaller plants rely for rigidity chiefly on the turgor of their cells: as long as each cell remains fully expanded by liquid they can hold themselves upright, but if moisture is withdrawn or withheld they become flaccid and wilt at once. Bigger and taller plants with a greater weight of foliage to support need something more than turgor to keep them erect, and their stems are reinforced with strong tissue, so disposed as best to withstand the bending strains to which the plant will be subjected by the wind. Mechanically, resistance to such strains is best secured by a hard perimeter surrounding the inner, softer core, and the stems of many of the larger herbaceous plants are so constructed. Ridged stems, each ridge a strand of reinforced tissue, are common among umbelliferous plants, such as hogweed and cow parsley, and the square stems of the Labiates—the dead nettles and their kin—have hard walls

with four strong columns, one at each corner. Still larger plants, such as shrubs and trees, need greater support again, and this is supplied by dead, woody—or lignified—fibres interspersed among the living tissue. These fibres consist of long, narrow, needle-shaped cells, interlocking with each other in such a way as to give the maximum of elasticity and strength. The woody branches of forest trees which must support an immense weight of summer foliage are buttressed below, at their point of junction with the main trunk, with additional bosses of such strong tissue.

The process of gathering nourishment for immediate and future needs is carried out partly by the above-ground and partly by the underground portions of the plant. The main task of finding and absorbing the raw materials of food is performed by the root hairs which suck up from the surrounding soil the watery solution of mineral salts which it contains. The chief elements in this solution are the hydrogen and oxygen which go to make up the watery base, together with calcium, iron, magnesium, nitrogen, phosphorus, potassium and sulphur, and each of these elements is necessary in some way to the well-being of the plant: the water itself because it maintains the turgor of the cells, and acts as a means of conveyance for raw materials and manufactured products from one part of the plant to another, and also, combined with carbon-dioxide from the air, serves as the basis of all plant foods; nitrogen, sulphur and phosphorus because, with the help of potassium and of calcium, which is also used in the cell walls, they form the vital protoplasm; magnesium and iron because they are necessary to the formation of the green colouring matter by whose agency the plant is able to feed itself. Other trace elements are also often absorbed, but the exact use to the plant of some of them has not yet been worked out by the botanists.

The root hairs then pass this mineral solution back through root and stem to the green factories in the leaves where, by the process called photosynthesis, the water and salts are

combined with carbon dioxide gathered from the air and thus manufactured into sugars, starches, fats, proteins and cellulose. The simplest, and possibly the first, of the substances so formed are the sugars such as grape-sugar and fruit-sugar which consist of carbon, hydrogen and oxygen in the proportion of 6 parts of carbon and of oxygen and 12 parts of hydrogen. Slightly more complicated are other sugars such as cane-sugar and maltose in which the proportions of the constituents are nearly doubled. All these sugars are soluble in the cell sap and are used for the everyday needs of the plant, especially at the growing points. They may also be stored, as cane-sugar is in the root of the sugar beet and, of course, in the stems of sugar cane, but the compacter starches, which are built up from the simple sugars, are the more usual reserve foods, and it is these which plump out the potato tuber and many other underground storage organs, and which form the chief winter food reserve in the trunks and branches of trees and the stocks of perennial herbs. In seeds, too, the starches are often stored as a first food supply for the young plant and it is to this fact that we are indebted for our daily bread which is made out of the seeds of the grass called wheat. Grains of starch may also be formed in the leaves of a plant as a temporary measure, particularly on a bright day when the business of photosynthesis is so brisk that sugars are formed more quickly than they can be dispersed through the plant. In this case the grains are usually re-converted into sugar and appropriately distributed during the night.

The fats and oils which occur in many plants are of a more complicated structure than the carbohydrates—the sugars and starches—from which they are formed. They occur in many different parts of a plant but are commonest, perhaps, in seeds where they are stored as an alternative food reserve to starch, and most commercial vegetable oils, such as linseed, caster oil and cotton-seed oil for cattle cake, are expressed from such oily seeds.

Carbohydrates, elaborated still further and with the addition of nitrogen and sulphur, make up the proteins, the simplest of which are used for storage in association with starch and oil. Peas and beans, as is well known, contain substantial quantities of protein, as does the outermost layer under the skin of a potato. The more complex proteins go to make up the protoplasm which fills each cell and is the basis of all growing things.

The last substance to be built up from the relatively simple carbohydrates is the cellulose which forms the walls of the multitudinous cells of the plant.

Besides these food materials, other substances are manufactured by the plant, such as tannins, resins and alkaloids—the last often poisonous—whose exact use is not yet fully understood; together with pigments to stain the petals and other colouring matter whose purpose is more obscure; ethereal oils for scent and protection against heat; growth hormones to promote growth at root tip and bud and other growing points. Two of these additional substances must be particularly mentioned as they both have an important part to play in the production of food. These are the enzymes and the green colouring matter called chlorophyll.

At every stage in the building up or breaking down of the substances needed for food one or other of the so-called enzymes is present. It is not an essential component either of the original substance nor of the finished product, but acts, as it were, as a catalyser in the chemical reaction which changes the one into the other. Many of these enzymes have now been identified and each one has charge, in general, of only one particular reaction. For instance, the enzyme diastase is always present when starch is broken down into the simpler sugars, maltose and dextrin, and the enzyme pepsin has a, so to speak, digestive action on proteins, breaking them down into substances which are more easily diffused through the plant.

The second important substance is chlorophyll, the com-

posite pigment which colours the green leaves and stems of the vast majority of plants and is present also, though hidden, in the brown and red bodies of seaweeds and the bronze foliage of the copper beech. In the higher plants it is generally, and most abundantly, produced in the leaves whose shape and position particularly fit them to catch the maximum of light. For, not only is light essential to the production of chlorophyll, but it is this green colouring matter which traps certain of the light rays of the spectrum and thus provides the energy necessary for setting in motion the process of food production; only in certain simple organisms such as yeasts and bacteria is chlorophyll dispensed with. On the plant's ability to utilise the sunlight depend not only its own existence but also the existence of any life at all upon earth, for, in the last analysis, every creature from an amoeba to man himself feeds, at first or second hand, on the organic substances produced by the photosynthetic process. If earth's mantle were not green we might not be here to enjoy the sight of it, for it is by virtue of the colouring matter in the cells of its green parts that the plant is able, in the presence and by the energy of sunlight, to manufacture the basic food of all living things.

The last part of the plant to develop is that which is concerned with reproduction and with the spread and, if possible, the increase of its species. This part is the flower and its later development, the seed. Most botanists hold that in origin a flower is no more than a cluster of leaves, modified in various ways in order to fulfil the purposes of reproduction. Their food manufacturing function, together with their green colour and broad shape have been exchanged for more specialised duties and the colours and shapes that best suit these. In a typical flower a first whorl of leaves has become the styles, each terminating in a sticky knob, the stigma, and leading down to the ovary, or female part of the flower which, after fertilisation, will ripen into the seed. A second ring has narrowed into stamens, consisting of long

filaments surmounted by pouch-like anthers which contain the flower's male element, the pollen. A third has become the corolla, showy and brightly coloured and often perfumed in order to attract the insects which are required to fertilise the flower. And a fourth ring is now the calyx whose function it is to protect the developing bud. All four rings are inserted round what was once, a stem tip but has now become compressed into a small cone or disc, called the receptacle, or floral axis.

Roots, root hairs, stems, leaves and flowers, these are the standard parts of a flowering plant, but some possess additional aerial or subterranean organs. Below ground these may take the form of underground stems, or rhizomes, which, branching out in every direction and putting up new aerial shoots from their tips or at each internode, serve to spread the plant; or of tubers, corms or bulbs whose functions are, firstly, to store over winter the stocks of food manufactured by the summer leaves so that these will be available again when the season of growth comes round, and secondly, by breaking away from the parent plant and producing new roots and shoots of their own, to spread the species. In structure some of these swollen underground organs are modified stems as they are in the potato, or swollen taproots such as that of the carrot; corms, like those of the crocus, are enlarged stocks; and bulbs may consist either of overlapping, succulent, underground scale-leaves inserted round a disc-like stem, as they do in the onion, or be composed, like bluebell bulbs, of the fleshy bases of foliage leaves.

Above ground, apart from bracts, scales and stipules which are all modified leaves, or parts of leaves, a plant may possess tendrils, spines, thorns or hairs. Tendrils help weak-stemmed plants to maintain and improve their position among stronger neighbours. Spines protect their owners against the depredations of browsing beasts and are curiously and somewhat inexplicably associated with a dry habi-

tat. Thorns, to some extent, fulfil both the foregoing functions: they are a protection against animals and, at the same time, are an aid to stability. The functions of hairs are exceedingly diverse and form a most interesting study in themselves. They may be protective or attractive, or may be modified to perform many specialised duties, and their form varies with their function. Short, backward-pointing hairs are a protection against insects; covering stems and leaves they prevent invasion by voracious creatures in search of green food, and placed in the throat of a flower they protect its nectar from the depredations of unauthorised visitors. In a flower's throat they also help to prevent rain and dewdrops from filling the corolla and chilling the tender reproductive parts. And another of their waterproofing duties is when, as innumerable tiny papillae covering the petals of a flower and giving them their velvety bloom, they serve to repel moisture and keep the petals dry. Woolly, cottony or silky hairs clothing the surfaces of leaves, by maintaining an insulating layer of damp air between the leaf surface and the atmosphere, keep the leaves cool, and, by slowing down transpiration, prevent undue desiccation by wind or sun, and the tiny aromatic hairs which cover so many plants in arid regions exude sweet-smelling ethereal oils which perform the same cooling and conserving functions.

The hairs on chickweed stems and leaf-stalks are also in some sort protective against drought. They are extremely absorbent of moisture and, in addition, are so arranged in a double row down one side of the stem that they are able to canalise any excess water which they cannot themselves absorb and lead it down to the roots where it is most needed.

The nettle's protective armament which serves to discourage bigger depredators than the insects, namely, browsing animals, also consists of hairs, but modified in a special way so as to contain and transmit an irritating poison. Each hair consists of a bulbous base which holds the poisonous

liquid and tapers upwards gradually to a very narrow neck surmounted by a globular swelling, like the tiny, round head of a pin. The lightest touch breaks off the pinhead, the sharp neck pierces the skin, and the poison in the bulbous base is forced by the slight pressure of contact up the tapering tube and into the flesh of the unwary meddler.

Another specialised defensive hair, and a most efficient one, is that which covers wallflower plants. Its purpose is to discourage attacks by slugs and snails. In form it is T-shaped, the very short downstroke of the T being the stalk, and the cross-stroke the operative part of the hair. This latter horizontal portion—which lies closely along the leaf and parallel to the stem—is sharply pointed at each end, and its walls are roughened with knobs of calcium carbonate. The rasping tongue of any slug or snail attempting to browse on a wallflower leaf is soon skewered by a number of these stiff, double-pointed needles and the unfortunate creature chokes to death.

Attractive hairs are not so common as protective ones, but an example of them is afforded by the hairy extra-floral nectaries on the bracts of cow-wheat and on the stipules of some species of vetch. The purpose of these is a little obscure, but they may be designed to attract ants which will, in turn, guard the plant against infestation by aphids; or their function, together with that of other forms of extra-floral nectary, may be to withdraw moisture from the cells of plants when these become over-turgid.

Of the various hairs with specialised functions four examples must suffice. First, the fine hairs on the branched styles of hemp agrimony which sweep pollen out of the anthers of their own flowers and hold it out to visiting insects so that these may carry it to stigmas of neighbouring blossoms. Second, the long, filamentous hairs crowning the seeds of such plants as willow and willow herb which form, as it were, a parachute by whose aid the seed is enabled to float far from its parent plant and thus conquer new territories for its spe-

cies. Third, the hooked hairs which cover the stems, leaves and fruits of goosegrass and whose function is twofold, those on the stems and leaves serving as climbing irons to aid the plant in its struggle towards the light, and those on the fruits as grappling hooks which will attach them firmly to such distributing agents as animals and birds. Fourth, and most interesting, the hairs which work the mechanism of bladderwort's insect trap. These are of two kinds: those within the bladder which, by sucking all moisture from its interior, draw its walls together and thus set the trap; and those around the mouth of the bladder which, when touched by a passing water insect, release the valve at the entrance to the trap, thereby causing a rush of water which irresistibly sweeps the insect into the bladder, there to perish and be absorbed at leisure by the plant.

The hair-like protuberances on the leaves of that other insect-eater, the sundew, are more in the nature of tentacles than hairs for they are somewhat complex in structure, each being many-celled and possessing a vascular strand of its own. Their function is, first, to entrap insects in a sticky liquid and then to drown them in digestive juices and absorb whatever of their substance may be so broken down and assimilated.

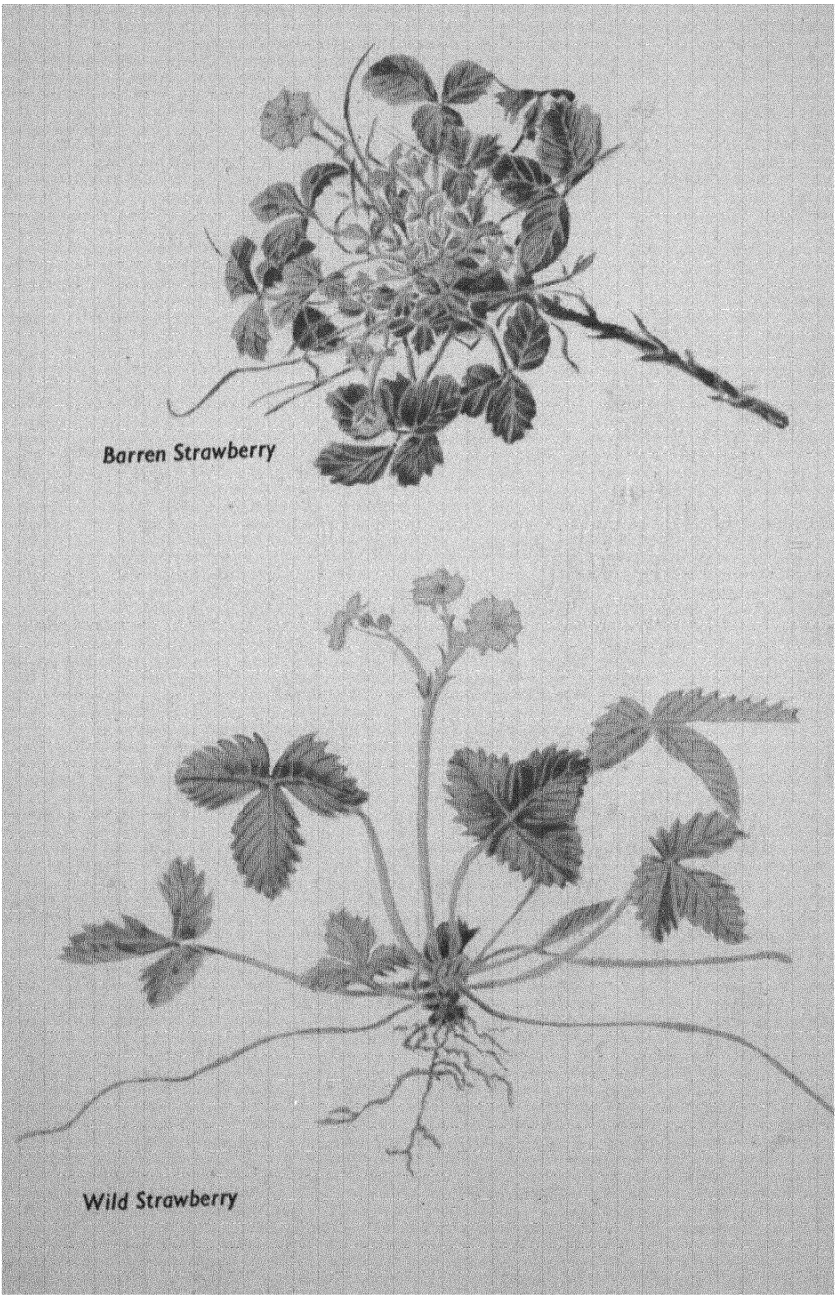
It is not only the seeds that have been stirring into life in these first weeks of the new year; perennial herbs, too, have been mustering up their stores and preparing to put forth new shoots from rootstock and crown, corm and bulb, and flowers, even, have bloomed here and there. It is more than eight weeks since the first colourless blossoms of the barren strawberry appeared, crouching in the shelter of a drystone dyke. Colourless they are, these fragile flowers, for they have not the body and glow of the truly white blooms of their cousins, the wild strawberries. 'Euery man knoweth wel inough where strawberres growe', said Turner, the herbalist, but few men know or care where the barren strawberry lives

out its modest and—to man—useless life, for its seeds are hard, inedible nutlets, gathered into a tiny dry cone which bears at first sight small resemblance to its cousin's fragrant fruit. Yet, on closer view, the tiny pips on the enlarged, scarlet receptacle of the wild strawberry are of similar form, though smaller than the 'barren' seeds. At flowering time it is easy to confuse these two, but barren strawberry's flowers are borne singly, not in clusters, its leaves are downy and less joyously green, and its habit more modest and self-contained, for it does not put out runners so freely as its riotous cousin. Altogether it is a humble creature, good for nothing but to enjoy the fitful early sunshine as best it may, gathering its greyish cups carefully together when the wind blows cold and skies are dark, but opening them so widely in the warm, sunny intervals that each heart-shaped petal lies distinctly outlined against the pointed sepals. Later on, in April, it will star every meadow and hedgebank but, even so, it will be an earlier blossomer than the true wild strawberry whose season does not come till May.

That was eight weeks ago. Since then, outside garden walls and along lanes leading to old cottages, there has flowered in fragrant patches the pale purple winter heliotrope. It is not truly wild but an escape from old gardens where it was once planted to provide nectar for early-waking bees. But now there are no bees about it, for hives which it once served have long since decayed and their inhabitants have been dead for many a year.

Then, in February, came snowdrops, growing untended beside a stream which flows through an abandoned orchard. Purely white they gleamed against the dark ivy leaves that clothed the ancient apple trunks, reminding one irresistibly—against one's will—of small, sun-forgotten snowdrifts, for never was flower better named than this nor more inextricably associated in mind with winter and snow. The snowdrop, too, is probably in origin an escape from gardens and it does not often penetrate far into the wild. I have,

Sallow
Alder
Hazel
Birch


Barren Strawberry
Wild Strawberry

however, seen it growing in the heart of a forest, its twin leaves and solitary, drooping bells rising in single plants from the biscuit-coloured carpet beneath straggling hazels.

In deep woods, too, far from all human habitation the evergreen spurge laurel has opened its greenish, fragrant bells and the butcher's broom put out its inconspicuous flowers—both true natives of this country. There is no beauty in butcher's broom but its quaintness gives it interest. Nothing could look less like a lily than this prickly, dull-green, dusty looking shrub whose tiny, whitish, purple-hearted flowers lie so closely against the midribs of the spine-tipped 'leaves' that they seem embroidered there; yet a lily it is. Furthermore, its 'leaves' are not leaves at all but flattened stems, called cladodes, a fact which explains the odd position of the flowers. The true leaves have been reduced to chaffy scales, clothing a vestigial stem, and a pocket lens will reveal them hiding beneath the spread perianths of the miniature blossoms.

In early March coltsfoot flowers in every shade of yellow from pale lemon to burnt sienna and deep orange-vermilion, emerging one by one, starred the hideous cinders by the railway, so that the goods yard became a garden and no longer a waste to be passed with averted eyes. This flower is a close relation of the winter heliotrope and the leaves of the two plants may easily be confused, but those of coltsfoot are larger and coarser and do not appear till the flowers have long since withered, whereas winter heliotrope blooms among its foliage.

Lastly, as the buds of garden daffodils were lowering their heads and even cracking here and there to show a golden gleam, the larches broke into flower. Passing a young tree one cold, bright morning in the third week of March, my eye was caught by a glow as of living coals among its bare twigs which showed as yet scarcely a hint of vivid green, and, looking more closely, I saw that this was caused by the sun shining on the upright cones of crimson, velvety scales

which were the larch's female flowers. Below the cones much smaller, hanging nightcaps of yellow scales formed the pollen-bearing male flowers. These are not truly flowers for they have no corolla, nor calyx, nor ovary, no stamens and no styles. The ovules lie naked between the scarlet scales of the female cone and are there fertilised by wind-blown pollen from the pollen sacs of the male catkins. A pollen grain lighting on the moist lips of the ovule's micropyle is sucked in by the gradual drying-up and withdrawal of moisture in the neck of the ovule. No sticky stigma holds the grain which grows no pollen tube to pierce the style and find its way through the ovary to the ovule. For the conifers are the most primitive of pollen-bearing plants, and were the first of all green things to experiment with an inert male cell—the pollen grain—in place of the active sperm which was the male cell of their even more primitive spore-bearing forebears.

Millions of years before the first true flowering plants appeared on the earth the conifers formed dense forests in many regions, and they, in turn, were preceded by spore-bearing trees, now all long since extinct. These early jungles were evergreen before the annual rhythm of spring growth and autumn fall had been established by the deciduous trees, and the conifers remain so to this day—except the larch which has progressed a little further along the road of evolution and sheds its leaves in autumn like its broad-leaved neighbours. But, to show the way it has travelled, a seedling larch retains its leaves for several seasons.

It used to be stated as a fact that in the ancient days when conifers were evolved all vegetation was on a bigger scale than it is today; that it was pre-eminently an age of large and long-enduring trees. These conclusions were based on the study of fossils, which are mainly of trees, and may well be erroneous, for it is certain that many more herbaceous plants existed than are recorded in the rocks, but the soft bodies of such small plants decay so quickly that fossilization

is rare. However this may be, the oldest and mightiest of existing trees are those giant conifers, the redwoods of California, which will live 4000 years and measure 300 feet in height and 100 feet in girth.

Their typical needle-like foliage and their symmetry of growth are two other characteristics that distinguish the conifers from the modern flowering plants. In the first they show themselves as innovators in their day, for the needle leaves, covered with thick cuticle, were the earliest answer to the problem of winter drought, and had to be evolved before the first trees could leave the hot, wet jungles in marshy estuaries and take to the cooler and dryer uplands. In the second they follow an old fashion, for the most primitive branch systems were all symmetrical. In conifers, upward growth resumes each season from the apical bud of the previous year's shoot, and the branches ray out from the lateral buds below it and themselves grow in length through the buds at their tips. But in deciduous trees the apical bud usually—though not always—withers, and growth continues through one or both of the lower side buds. Moreover, by no means every lateral bud below the apex gives rise to a branch, for more buds are produced than there are available stores to develop, so that some must remain dormant while others are fed. These dormant buds are, of course, capable of development if the need should arise—which is the principle that underlies all pruning operations. The conifers' symmetrical system is called monopodial branching, and the irregular and somewhat haphazard branching of deciduous trees is called sympodial. The first produces the straight, tapering bole and conical shape of the firs, cypresses and larches, and the second the gnarled and devious trunks and irregular shapes of oak, elm, beech and lime.

These last weeks, together with the seeds and shoots and blossoms, have come a thousand tiny signs of stirring life, and early in March on a day of sudden peace after a week of storms I visited a certain sheltered copse to note what I

could of winter's passing. This miniature wood is formed of oaks, birches and alders with an underbrush of light-starved hazels, blackthorns and dark hollies, and at one corner a grove of young aspens clusters round two towering balsam poplars. A small brook, scarcely more than a rivulet, running north and south, borders the copse and divides it from a rocky pasture. So narrow is the stream that in summer when apium and brooklime encroach upon its bed, and foxgloves, tufted hairgrass, marsh thistles and giant willow herb lean over its banks it is silent and nearly invisible, except where thirsty cattle have trampled a wide, muddy bay. But in winter, when the vegetation has died down, its rain-swollen waters run swift and clear, chuckling through narrow channels, bubbling round the many stones in its course and tinkling down miniature cascades.

To reach the copse I took a draughty lane down whose gully the north-west winds, laden with sleet, had for the last week blown unimpeded. Here were no signs of spring. The thin hedges, over-ready for the hedger's hook, held no colour as yet, and like the drab uniform of a conscript army the brown bark of the twigs hid the individuality of the hedgerow shrubs and reduced all to a serried anonymity. Yet on closer view, by a study of form and feature, each bush could be recognised—the thorny quick, the tangled blackthorn (black indeed with its long, cruel spines), the straight, smooth rods of hazel—and the sapling trees which here and there had grown unchecked among them might be known, too, if not at once by their form then by the colour and texture of their bark and the disposition and shape of the lenticels, or breathing pores, which, piercing the protective layer of cork lying beneath the epidermis, admit air to the cells of the cortex. The matt, grey bark of a young ash with almost invisible lenticels distinguished this sapling at once from that of a rowan, or mountain ash, whose bark, though grey, too, had a reddish undertone and a glossy surface liberally peppered with small lenticels. A sapling bole of

wild cherry was, as always, unmistakable; its banded bark was red, with a polished surface, scarred with many long, transverse strokes. A young silver birch stem had not yet acquired its silvery sheath but was a dark maroon red, and its surface was rough to the touch with innumerable, prominent breathing pores. The full-grown trees, too, which studded the field hedges on either hand and afforded shade to the cattle on hot summer days, though there was no hint yet of their characteristic foliage, might be known even from a distance by their shapes alone; fountain forms of lime, gnarled and massive oaks, heavy-headed, bushy-boled elms, compact and symmetrical sycamores, airy birches—each species proclaimed its identity by its mode of growth.

In the copse itself, too, it seemed at first that winter still brooded. Its sour breath hung in the damp air, an almost visible exhalation that misted the colours of the loosening catkins on hazel and alder and dimmed the bright, bent heads of dog's mercury thrusting through the sodden leaves. But, as I approached the aspen grove an aromatic breath from the balsam poplars gave a sudden foretaste of sweet-scented spring and I saw then that the stately trees were decked already with fat, red catkins and that a golden bough of mistletoe that clung to the bole of one of them was breaking into flower. It was a male plant as its yellow tinge denoted, and between its paired leaves and in the wide axils of its branches clustered the tiny cups of its anther-bearing petals, each brimming with a pale pollen.

Now, even the dull carpet at my feet held an interest, for I noted that the leaves which had fallen in autumn from the young aspens were not spread in a formless mass about the sapling boles but lay in drifted heaps of lacy fans. By some freak of decay only the softer tissues of each blade had disintegrated leaving intact the midrib, veins and branch veins, down to each tiniest gossamer ramification. These bleached and weightless skeletons of the living leaves gave an unforgettable demonstration of the net-veining which distin-

guishes the Dicotyledons from that other great division of the flowering plants, the Monocotyledons whose main veins run parallel and form no continuous network.

Down by the brook, under the overhang of the miniature cliffs eroded by the current, a primrose or two was already in flower and a ribbon of golden saxifrage, bright as sunshine, bordered the stream. And now I saw that even the very stream-bed itself was coming to life, for the rocks over whose dull surface on other winter days my indifferent glance had passed a hundred times without interest were breaking into vivid green where the liverwort *Fegatella conica* had started its spring growth. A portion of it crushed in the hand yielded an aromatic scent, and every here and there from the ravelled ribbon of its flat, creeping thallus arose little inch-high, olive-green groves of toadstool shapes. These were its fruiting bodies and the spores borne under the conical caps would soon be ripe for shedding.

The stream bank under the alders, and damp places in the wood itself were clothed with mosses and they, too, were preparing for reproduction. Their 'flowers' were opening on very hand and, seen under a pocket lens, most strange and beautiful they were. One, that of a common hair moss, was formed like a polished cornelian bowl, pinched round the rim into four or five bracket points. In colour it was between pale red and orange and was embossed within with triangular flakes of terracotta. Framing its paper-thin perianth were the green rays, tipped with red, of its leaves which descended the straight stem in stiff, even spirals like the bristles of a bottle-brush. Each stem of this species bore no more than a single 'flower', but each was of the exact height of its neighbours and so thickly did they grow together that the crowding cups formed a red mosaic on the green background of their foliage. The long, diaphanous petals of the 'flowers' of *Mnium hornum* which were traversed from tip to base by a transparent midrib appeared as though carved in chrysoprase. Like the ray florets of a daisy they clustered

round a central disc, but the disc of this blossom was not yellow. Seen close at hand it was a dull, dark brown, but at a little distance the light filtered through the translucent petals turned the brown to a shadowed blue, the colour of a summer sky at night. These flowers, too, grew on single stems in crowded companies and drops of moisture glistening on their petals turned them into jewels indeed.

The foliage of the mosses was as remarkable in its way as their 'flowers'. Two particular beauties it possessed—beauty of texture and beauty of form. One species grew in plushy cushions on the weathered rocks of the pasture and another was embroidered in delicate stem-stitch up the trunks of the trees. Yet another spread its soft carpets of fern-like fronds over the floor of the copse and a fourth covered the stones by the stream with a yellow-green brocade. The leaves of many of them were translucent, others had a silken sheen and others again seemed carved out of Chinese or Styrian jade . The stems and rounded leaves of one species which grew on shaded, marshy ground seemed composed of frozen sea water, and the spherical buds of unexpanded leaflets at the growing tips were like the bubbles of glass tossed by fountains. Every moss, absorbing moisture through its leaves, had been plumped out by the late rains to its shapeliest form and each, whether it grew on the arid rocks of the pasture or on the black ooze under the alders, was lush and green with the new season's growth.

So, signs of winter's passing were not wanting in the little copse and since then there have been many more: catkins lengthening daily on the hazels; honeysuckle leaves losing their chilly winter hue and flushing into healthy green; winter buds swelling on the forest trees, and tight, ochreous buttons of the unexpanded male flowers beading the outer twigs of yews. In sheltered hedge bottoms, first the furled pennants of cuckoo-pint and the celandine's silvered leaves, then croziered shoots of dog's-mercury and piercing bluebell spears have ventured to thrust through the warm cover-

let of moss and leaves. All these have been the distant voice of Spring, hailing Winter and announcing her coming, like the thin skirl of pipes, sad with distance yet exciting, that heralds the approach of an army.

Today is different. Today, Spring's voice is loud. The chiff-chaff, that far wanderer, is chanting in the hazels, flirting from twig to twig and shaking at each quick movement a cloud of yellow dust from the catkins which glow like amber pendants in the sunshine. The pollen so unconventionally dislodged by a bird's action and not the wind's may fall on the tiny, scarlet sea-anemones of the hazel's female flowers, gleaming today like rubies, and form a cobnut or two at the year's end. The sallow palms are alive with early honey-bees whose myriad humming may be heard afar off as they probe for nectar beneath the yellow stamens and collect the pollen for their bee bread. The leaf-buds on the horse chestnuts, swollen to many times the size they were in winter, have broken at last, and each shining, brown scale as it bent backwards has exposed the pale lime-green of the base of the scale above it, shining also as though glazed. Emerging from the topmost scales the tightly packed, nile-green leaves, like candles, rise from a candelabrum of delicately tinted, exquisitely glazed ceramic ware. The flowers of bullace and sloe are startlingly white against the black thorns from which they take their name, and beneath hazels, sallows and thorns and along every shady hedge a golden carpet is laid where celandines have spread their starry petals to the sun.

Celandine, the swallow flower; this is the true *Chelidonium*, for it is in its fullest glory when the swallows return. But the Latinists have shorn it of its rightful name and call it *Ranunculus ficaria*, the figgish frog-flower, or *Ficaria verna*, the vernal figwort, though it has nothing to do with either figs or frogs. *Chelidonium* of the Floras is that greater celandine which the Romans are thought to have brought with them

to these islands and which grows, rankly blooming the season through, by old buildings and in waste ground. It has its charms: the elegantly scalloped lobes and delicate, glaucus green of its leaves, and the pure yellow of its four fragile petals which fall at a touch; and its botanical interest, too, in its seed, crested like a cockatoo; in the long fruits which resemble the siliquas of the Crucifers and are quite unlike the pepper-pot capsules of the field poppy to whose family *Chelidonium* belongs; and in the unusual flower stems which arise, like those of fumitory, opposite a leaf and not in the axil of it as most flower stems do. Beauties and interest, yes, as all flowers have, but it is a rank weed compared to the bright celandine of the spring woods which 'growes in shadowy places'.

I suppose there is hardly a person in this country who does not know the true swallow flower, so plentifully does it bloom in its season. Even the dwellers in the dark towns of the north and midlands where the very harvest fields are grey with the effluvia of a thousand belching chimneys and only show their gold briefly as the cutter severs the corn stems—even they have noted the untarnishable petals of this bright flower gilding their blackened hedgerows, and have known then that spring had come. Yet, though all know it few have examined it closely, so here is its portrait. It is a moody flower whose moods depend upon the sun. On a cloudy day you will hardly notice it, for its dull-backed petals will be gathered close round its heart to protect the stamens from the rain or cold. But let the sun shine, as today, and the rays of the star-like corolla fall back and show their shining inner surface and seem to stretch themselves under the sun's caress, so that the expanded flower appears to have twice the size and thrice the brightness of the moody one. Now it shines in every part so that the dullest eye could scarcely miss it, for the polished leaves, too, reflect the light.

So it appears as it grows but, to see it more closely, take

a plant of it in the hand, roots and all. The roots are of two kinds: first, the usual slender branching system such as most plants have; and second, just below the crown, a fringe of downward-pointing fingers which are the tubers into which the plant packed its winter stores; they will decrease as aerial growth increases, but will swell again as the foliage dies down after flowering. From the crown spring many leaves, mattock-shaped with wavy edges and of a fresh, shining green, stained with plum colour and marked here and there between the radiating veins with silvery patches; and from among the leaves arise the flowering stems, three to four inches high. Some bear a pale leaf or two in pairs but most are bare save for their golden crown of open blossoms or greenish, mitred buds. Each flower has three green sepals, then, within them, three long petals of a burnished yellow, backed with olive green, and within these again, five or six more petals of the same sort with a tiny scale at the base of each behind which nectar is stored for the visiting bees and flies. Then comes a ring of many yellow stamens and, lastly, at the heart of the flower its cluster of carpels. The plant may be of the common sort which sets its seed as well as may be expected of so early a blossomer whose nectar wares are on sale almost before its insect customers have fully awakened from their winter torpor. But there is another race of celandines which sets but little seed and propagates its kind mainly vegetatively—often by means of tiny bulbils in the axils of the leaves. These bulbils are of the material of roots, crowned with a leaf bud, and each one, detached, will grow another plant. Something of the same kind may be seen in the sand-leek and the crow-garlic which bear heads of such bulbils in place of flowers, each miniature onion complete in every detail. The celandine that so propagates is independent of insects and seems to suffer no hurt from the lack of new blood from another member of its species that the normal cross-fertilisation of the seed provides.

In connection with this system of vegetative propagation, it is interesting to consider what, in fact, constitutes an individual in the vegetable world. It would seem that such plants as the bulbil-bearing celandine, or—more striking still—as the Canada weed which merely by increasing vegetatively (for no male flower of *Elodea canadensis* has ever been found in this country) has, in a hundred years choked all our waterways and ponds, have found the secret of eternal life, of direct individual survival, century after century, without the need of intervening death and resurrection in the seed. No need have these to freshen their powers by joining their life-stream with that of another individual; the new growth of this season past was as vigorous and fresh as the first shoot to spring from the seed and next season's too, will show no weakening, perennial they are, indeed, and perennially young, and only some natural cataclysm—some new ice-age or the end of the world itself—will dry up at last the unresting, ever-broadening stream of living protoplasm.

Of celandine there is little more to say save, first, to note that the carpels will sometimes set viable seed without pollination—as dandelion carpels also invariably do—thereby again, as with its bulbils, by-passing the normal reproductive method of cross-fertilisation. This seed, too, like the wood anemone's develops after it has fallen and is only fully ripe in the spring following its shedding. And, secondly, to mention in passing the celandine's one claim to originality among flowering herbs, namely, that unlike all other Dicotyledonous plants it emerges from the seed with but one seed leaf instead of two—in this single particular resembling the lilies and the grasses.

So, spring is here with its massed celandines, the first of those coloured carpets of blossom with which the woods deck themselves until the end of June. Soon the anemones will be in full blow, and with them a carpet of primroses, patterned and threaded with violets and frail, pale wood sorrel about mossy roots, and, after them, the ramsons and

bluebells, with patches here and there of fragrant woodruff. When the bluebells and ramsons have faded the deep woods will hold no colour again but their own green shadow till autumn sets them ablaze, but in the clearings and forest rides, well into summer, flowers will bloom as in a garden: yellow archangel, the deep-purple bugle, butterfly orchids and honeysuckle, scenting the late spring evenings, lowly mats of creeping jenny, yellow pimpernel and self-heal, and, at last, out-topping and hiding every other bloom, the innumerable spires of foxgloves, or dense purple thickets of rosebay willowherb.

It is no haphazard thing that flowering time in the deep woods is confined to the first months of the spring. Nothing in nature is haphazard, for every manifestation of colour, form, movement, size, from the folding of clover leaves at night, or the scarcely visible dark lines on the standard of the meadow pea, to the spread and shape of the forest oak, has a reason and a cause. So with the spring woods; they owe their colour and fragrance to the fact that the leaf canopy of summer has not yet developed and shut out all light from the forest floor. All green plants must have light, for only with the sun's aid can the green cells in the leaf manufacture the nourishment needed for the growth of root and shoot, flower and seed. To ensure that each shall catch the maximum of sunlight and so as not to impede each other, leaves are arranged in a variety of ways. In plantains, daisies and many other low-growing herbs they form a rosette, flat to the ground or spreading fountain-wise, and overlapping each other as little as may be. The square stems of Labiates, such as hedge woundwort, bear their leaves two by two, the first pair pointing north and south and the second pair east and west, decreasing in size as they ascend the stem and inclined at such an angle as not to overshadow the pair immediately below them. Woodruff has whorls of narrow leaves at fairly long intervals—a series of diminishing green ruffs. Trees, such as beech and elm, and many plants—of

which the sunflower is one—arrange their leaves in an open spiral, and the number of leaves to each turn round the stem tends to be constant for each species. Thus the sunflower normally fits in five leaves to each two complete turns so that only every sixth leaf is in a direct line above one below it.

And this is not all: trees and herbs will modify their natural habit to suit the light. Seedling ivy leaves grow alternately in two rows, one on each side of the stem, with their upper surfaces pointing to the zenith, but as the ivy starts its climbing life against a wall, or tree, the petioles of the leaves twist round so that the leaf blades are tilted sideways, with their backs to the wall and their faces to the light. The leaves of forest trees, whatever their natural arrangement on their first vertical shoots, whether two by two, as in the maple, or spiral, as in the beech, are very differently disposed on the horizontal boughs. Here, by twisting and turning and bending, each leaf is brought as nearly as possible onto a plane with its neighbours on the twig—a plane inclined to the light and as far as possible out of the shadow of the leaves above it. So all are able to perform the function for which they were created and no sunlight is wasted. Leaf mosaic, the botanists call this intricate pattern of leaf fitted in with leaf, and well is it named. In full summer, when the tessellated dome of the high woods is complete in its every intricate part, a vast shadow fills the forest and only the wind parting the boughs lets in, from time to time, a fleeting sunbeam to illuminate for an instant some plushy knop of moss or ashy cinder of lichen. Few things can live in this gloom except the mosses and their kind and the livid saprophytes, but the soil of the forest floor, enriched by the deaths of a million leaves, is too fertile to be wasted and, in the late winter and in spring when the boughs above do no more than temper the sunlight, the spring carpet flowers make full use of the rich humus. They start betimes to form their new season's leaves; some, even, like ground ivy and yellow archangel, will make their first new growth in autumn

directly the trees are bare and, resting only in the dead weeks of mid-winter, get away in earliest spring to a flying start; others, like dog's mercury and bluebell and the lowly moschatel, will send up new shoots at the first hint of winter's passing; and all will have flourished, flowered and died down again before the oak leaves overhead have expanded to their full breadth.

The forest offers the best and clearest example of the way in which all green things live in harmonious communities. Not that there is no struggle; far from it. The struggle is a desperate one—individual against individual and species against species, as it has been from the beginning and will be to the end for all living things—but those individuals and species survive which combine strength with adaptability and, having survived, know how to live in harmony with their neighbours, enjoying each his due share of sunlight and warmth, rain and the cool dew and the inexhaustible, ever-renewed riches of the earth. Sometimes it will happen that the dominant member in the community—and every community has its dominant—will grow so thickly together that no other species can compete against it, but in nature this seldom occurs for even the thickest natural beechwood has its open bays and inlets up which flood the bluebell tides in May. It is not until man takes a hand that we get the rectangular blocks of funereal firs which harbour no living thing but a spray or two of the irrepressible blackberry and livid caps of the toadstools which feed on decay. And even these plantations, if the trees are allowed to grow beyond the size of pit-props and are well thinned, will harbour bluebells once again after the lapse of forty or fifty springs.

In the woods, of course, it is the trees which are the dominants and all other plants must adapt their lives to the trees' annual rhythm. Below the forest roof of boughs comes a layer of shrubs—hazel, hawthorn, buckthorn, blackthorn, spindle and spurge laurel—and these, too, like the herbs must blossom early if they are to get the full benefit of the

light. Next come the flowering plants and ferns, and, last of all, the mosses and liverworts and other such lowly growths whose light needs are small. All these green things use the sunlight in the inverse order of their stature: first, the mosses and liverworts which are green all the year round; then the herbs which put out their leaves in earliest spring; after them the shrubs whose foliage does not expand till the leaves of the lowlier plants have fully developed; and lastly, when all have had a share of light, the over-arching trees. Underground, the soil is layered in the same way: first comes the topmost inch or so through which the mosses and fungi weave their microscopic threads; then a layer for the shallow-rooting flowering plants—yellow pimpernel, ground ivy and the woodland grasses; below this again are packed the uncountable bluebell bulbs and the long rhizomes of bracken; then come the roots of shrubs; and last of all, winding in and out of the rocky subsoil, the great cables which anchor the trees. Every inch of soil is used and its fertility perpetually renewed by the seasonal decay of the surface growth and the autumn fall of the innumerable leaves.

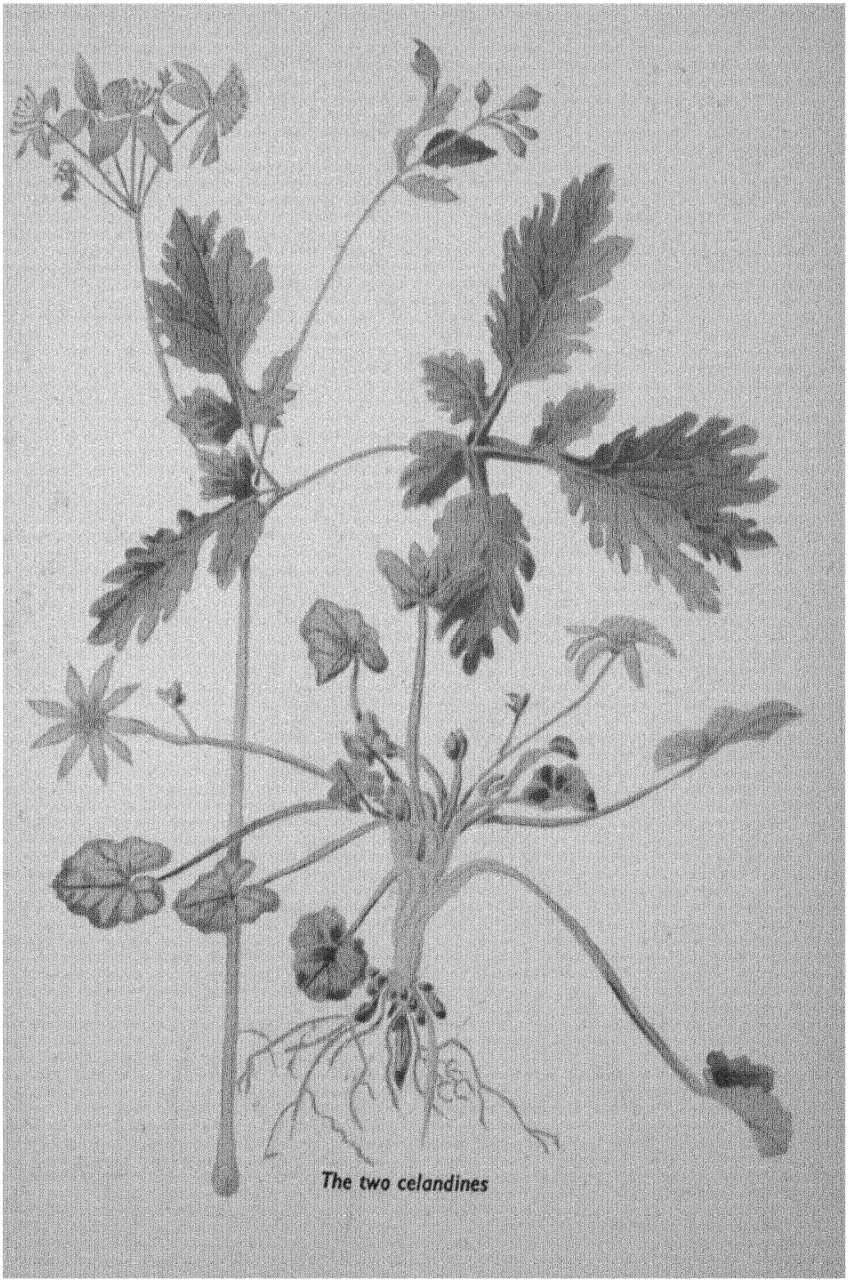
It might be thought that any flower whose seed came by chance to fall on the rich forest soil would flourish there, but, of course, this is not so. A wood carpeted with scarlet poppies would be as remarkable a sight as a fish hunting the hedgerows, for only the flowers of the woods grow in the woods and this by virtue of special adaptations which enable them to do so. They are, for instance, shade lovers who not only do not need but even cannot tolerate the full heat of the sun. They thrive under the drip of trees. Their roots enjoy the cool moisture of the acid leaf mould through which they grow. And, finally, they are conditioned to make their main growth and to flower at the one season of the year when conditions of light and warmth make it possible for them to do so.

It is a fairly recent discovery that one of the chief factors

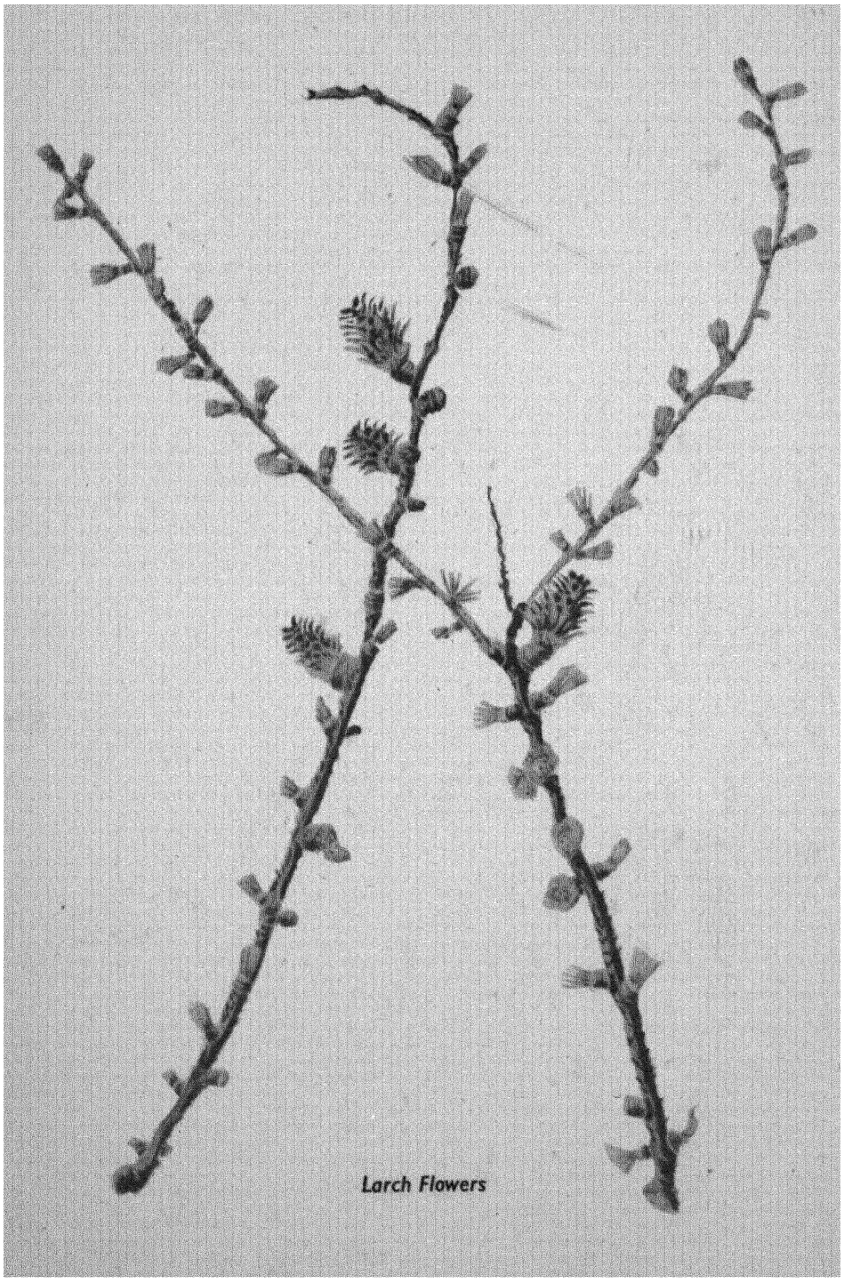
governing the actual flowering time of different plants is the amount of light—or rather, alternation of light and dark—to which they have previously been subjected. All plants, it seems, can be divided into three classes. First, the short-day plants which, before they flower, must have lived through a span of days and nights when the periods of light did not exceed twelve hours at a stretch; the hours of darkness and rest for some are as important as the hours of light. These are the flowers of spring and autumn. Second, the long-day plants whose pre-flowering periods of light must exceed sixteen hours. These are the summer blossomers. And third, those species like groundsel, chickweed and red dead nettle which flower indifferently at any season of the year. Our woodland herbs belong to the first category and it is by virtue of this adaptation more than any other that they are members of the forest community.

Other plants, for quite other reasons, are members of one or more of the remaining great natural or man-made associations into which botanists divide the flora of this country. Working from the sea coast inland, the chief natural communities are: maritime, coastal, aquatic, marsh, bog, grassland, heath, woodland and mountain. And the artificial are: arable, man-made grassland, garden and orchard, plantation and, lastly, wasteland or ruderal.

There are four main factors which influence the constitution and development of these communities. The first and most obvious is climate. It is this mainly which causes the flora of Greenland to be quite different from that, say, of the Amazonian forests. Temperature, altitude, rainfall, wind-force and the amount and strength of sunlight are all included in it. Even in these small islands it plays a great part, for the west is wetter and warmer than the east; the mountain tops are cooler, windier and wetter than the valleys, and even one side of a valley may differ from the other in being sunnier or more sheltered. The second important factor is the constitution of the soil which depends largely on



The two celandines



Larch Flowers

the geological formation of the rocks beneath it. Above limestone and chalk it will tend to be alkaline, except where the calcium carbonate has been leached out of the soil by rain, or where pockets of clay occur, or where layers of sand or peat have been superimposed upon the basic rock. Above sandstone, Bagshot sand and greensand it will be acid. On the first type of soil, for reasons not yet fully understood by botanists, will grow the lime-lovers, the calcicoles, such as box, wild clematis and rock rose, and on the second, the lime-haters, or calcifuges, such as heather, broom and bilberry. Other plants will grow indifferently—within limits—on either type of soil, but they, in their turn, may be particular as to the drainage at their roots, some favouring a wet and heavy soil and others a dry and airy one, some thriving in a shallow cranny and others requiring a depth of rich loam beneath them. The third conditioning factor is that of the living creatures of the earth, all of whom, whether herbivores or carnivores, from the caterpillar to the elephant, from the mole to man, are dependent finally for food on the green world of plants. Among these, incomparably the greatest influence is exercised, of course, by man and his grazing beasts. Lastly, the plants themselves affect the communities of which they are members. In the forest, as we have seen, the light-excluding trees rule the lives of all who live below them, and this is but the end result of an unceasing process by which, in the eternal struggle for life, the smaller, weaker and more ephemeral plants tend to be smothered out by the taller, stronger and longer-living ones. A bare patch of ground will be hastily colonised by the frail annuals, but soon these will be ousted by biennial and perennial herbs which will, in turn, be choked by grasses and scrub, among which will soon appear saplings of the secular trees which will, at last, rule all.

Now for a brief review of the communities themselves. In the maritime community grow only those plants which

are able to lead all, or the greater part, of their lives submerged in salt water. Apart from seaweeds which are mainly marine plants and flowerless, only one of the higher flowering plants has been able to make use of this unpromising medium. This is the eelgrass, or *Zostera*, upon which the brent geese and the wigeon feed and which grows on muddy estuaries and flats. Its long, narrow, flaccid leaves rock with the tides and offer no resistance to the tearing water; its protoplasm takes no harm from the salty solution in which it is immersed; it is able to flower under water, its flowers being no more than a petal-less row of anthers and ovaries enclosed in a sheath; and its filamentous pollen grains are of the same specific gravity as the sea so that they neither float nor sink but drift at the level at which they are released and so come in contact with the slender, elongated stigmas on the ovaries. But even *Zostera* is not perfectly adapted to its restless home for every storm tears it adrift from its insufficient anchorage and piles it in rotting heaps along the shore.

Next come the coastal communities of beach, dune, salt marsh and cliff. Here grow the grey-green samphire with its saffron blossoms and aromatic foliage, cushions of pink thrift and white bladder campion, the insignificant sea purslane and the sea spurry, sea grass, red fescue grass and sea rush. On muds and salt marshes you may find the mauve sea aster and amethyst fields of sea lavender, and on the shingle the bizarre horned poppy; and stonecrop and horseshoe vetch, in their season, turn the cliffs golden. Even the dunes, whose desert wastes seem bare of all vegetation but the sharp marram grass, disclose a flower or two on closer view, for in the hollows of the sandhills, wherever a little moisture has collected in spring, the opportunist annuals—mouse-eared chickweed, whitlow grass and the small forget-me-not, called scorpion grass—together with dandelions, and creeping thistles, will have seized the chance to establish their species. The annuals will have grown, flowered and died

before the little dampness in the dune has all been drawn off by the summer sun, and the perennials, as the seedlings outgrow the surface moisture, send down deep roots in search of a more permanent water supply.

Three adversities the coastal plants must guard against. The first is salinity—about their roots in salt marshes, or blown onto their foliage as sea spray on the cliffs, beaches and dunes—and all the inhabitants of these regions are able to withstand it to a greater or lesser degree. The second is the wind which blows unchecked across the sea, and most coastal plants cling close to the ground to evade its damaging and desiccating breath. The third adversity which is closely connected with the second, for it is in part caused by it, is—for all but the marsh flowers—drought. Rain runs quickly off the rocks and through the porous sand and wind evaporates the moisture almost as soon as it falls so that the beaches and cliffs around our coasts, and especially the dune lands, are the nearest approach we have in these islands to a desert habitat. Of the plants of sand beach and rock many are succulent, like samphire, stonecrop and sea aster, and these store water in the cells of stem and leaf to tide them over a dry spell, and others, like sea-pink, have narrow, leathery leaves with thick cuticle, and so cut down transpiration and evaporation to a minimum. The dunes set yet another problem for colonists to solve besides lack of moisture and that is the instability of the ever-shifting sand. Only the marram and its kind with their fast-growing, wide-spreading root systems and their pointed, penetrating shoots which grow upwards as fast as they are buried have found the full solution. Because of this ability to grow in a moving medium these grasses are of the utmost value in reclaiming land from the sea, for their persistent blades form a windbreak which slows down the constant movement and their rootstocks catch and hold the water. As roots and shoots decay they form a little humus which traps more water, and so a little soil is formed in the sheltered hollows, where annuals and deep-

rooted weeds can gain a foothold, and these, in turn, die down and make room for other plants; and so the dune community merges by imperceptible degrees into the community of the sandy heath which has its own flora, adapted to its own arid and acid conditions. Here live all such plants as love a light, acid soil and abhor a chalky one, and the dominants are heather and pine.

By the borders of the sea you may also find the scrub or brushwood communities in their natural state. Most scrubs are created by the hand of man and are formed of neglected hedgerows or are the aftergrowth of a forest felling which will soon revert to woodland. But around the coasts where the winds sweep the low land unchecked, so that no tree can grow, thorny bushes often form belts of impenetrable thicket—blackthorn, hawthorn, gorse, bramble and wild rose—all barbed in their various ways; and to this armature they owe, in part, their survival, for with their thorns, spines and prickles they repel the grazing beasts. All are resistant to the wind and to the evaporation caused by wind.

A second type of scrub is that which grows on the transition land between marsh and dry ground. It is water, now, and no longer wind and drought that is the enemy to be reconciled, and it is only those shrubs and herbs whose roots are tolerant of periodic flooding which can thrive here. Of these the most conspicuous are rushes, alders, osiers, buckthorns and guelder rose.

Where the scrub ends the marsh proper begins with its lush and varied vegetation. Here, again, too much water suffocating the roots is the limiting factor which, because it is permanent and not merely periodic, excludes the shrubs of the scrub belt and thus leaves the field free for those herbs whose roots are specially adapted to absorb the scarce oxygen. This adaptation made, all other conditions are ideal for rapid and sappy growth. Sheltered from the wind on the land side by sloping banks and on the water side by belts of reeds,

unshadowed by tree or shrub from the full enjoyment of the sunshine, with rich, alkaline mud beneath them—for marshes, unlike the acid bogs, have a mineral base and a neutral or alkaline soil—and a never-failing water supply, it is no wonder that here in the marshes grow some of the tallest, handsomest and most showy herbs in all our flora.

Because of this showiness, perhaps, no flowers, except those of the woodlands, were earlier known and named than these. With what an antique charm those old names sound in our ears after the mere descriptive nomenclature of more recently observed plants: fleur-de-luce, the yellow flag which, with the wild rose, was one of the first flowers to be recognisably portrayed in herbals; codlins and cream, or the great hairy willowherb; chameleuce which was the old name for kingcups or marsh marigolds; medewurt, queen of the meadows, or meadow sweet; ragged robin, and that dainty flower which comes with the cuckoo and is called cuckoo flower, milkmaids, or lady's smock; even the unromantic, yet quaint fleabane which was—and is—indeed the bane of fleas. From early spring to late summer these and many others make the marshlands gay.

But bogland is a different matter, for the acidity of the peaty water inhibits nearly all growth, so that the flora is a poor and lowly one. Where the ground is a little drier heather will grow, but in other parts little but sphagnum moss, cotton grass and small rushes. Nevertheless, the bog has its beauty when the yellow asphodel is in bloom, or when the wind wafts the fragrance of sweet gale across a grey-green, sun-drenched expanse. Here, too, grow the predaceous sundews and butterworts who trap flies on their sticky leaves and eat them alive. In this way, it is thought, they supply themselves with the nitrogenous salts which are unobtainable from the swampy ground beneath them.

The true aquatics which live partly or wholly submerged in fresh water are a well-defined community with many special adaptations to their peculiar habitat. First, they must be

buoyant and flexible. Then, they must ensure a sufficient supply of oxygen from surroundings deficient in this necessary element. Then, the problem of photosynthesis, with sunlight diffused through water, must be solved. With such difficulties to contend with the number of species, though not of individuals, in this community is small. In the deepest water grow the pondweeds which have adapted themselves more completely to their environment than any other plant, except the primitive algae, mosses and quillworts. They, like their near relation, the grass wrack of the sea, spend their whole lives completely submerged. Even their flowers, like those of *Zostera*, are borne under water. Their long, flexuous stems, made buoyant by the numerous air spaces among the cells, rise and fall, sway and bend with the movement of the currents. Their multitudinous, narrow leaves, with no stomata and only the thinnest cuticle, present the greatest possible surface to the diffused sunlight. And leaves and stems alike hoard the precious oxygen in the large intercellular spaces in their tissues. No strength is needed in their stems to uphold them, so they dispense with rigid tissue, and their roots are poorly developed for the same reason and, also, because they need never search for water.

Less completely adapted to a watery life are those inhabitants of the shallower parts of ponds and streams, like water crowfoot and water lilies, whose leaves and flowers float upon the surface. They have their underwater foliage, too, thin, narrow, flexible and without stomata, like that of the deep-water pondweeds, but it is the conspicuous surface foliage which takes the eye. These floating leaves are as different as possible from those below the surface and are excellently designed for their purpose which is to spread themselves on the top of the water and trap the maximum of sunlight for the manufacture of food. They are broad with firm edges, slightly upturned, and are borne on long, flexible stalks which enable them to rise and fall with the ripples. They have stomata on their upper surfaces but, to ensure that these

shall not be swamped, the cuticle contains a waxy water-proofing off which all moisture runs. So stable are they that the lacquered moorhen can jerk her way across the lily pads without submerging a single leaf, or even wetting her own feet. The surface-floating flowers of these plants are fertilised, as land plants are, by insects or the wind.

Next, and nearer to the shore again, come the plants which have an aerial portion lifted well above the surface of the water. This may consist only of a flowering stem, as in the water-violet and water-milfoil which use the facilities of the upper air only for fertilisation purposes, or may be composed of flowers and leaves, as in the arrowhead, which plant goes one better than the water lilies in that it has three types of leaf—an aerial one, held vertically and shaped like the barbed head of an arrow, from which it takes its name; an oval, recumbent one, resting upon the surface of the water; and an underwater strap. Amphibious persicaria which may also be found in this zone is, as its name implies, indifferent as to whether it lives in water or on dry land; but it changes its habit with its habitat. If water is its choice it resembles the water lily type, with flaccid stems and broad, floating, waxy leaves; but if land, it becomes a land plant, with stiff stem and smaller and stiffer leaves.

In stagnant ponds and backwaters where no current can rush it away to destruction lives the tiny duckweed. It has no anchorage, but its free-floating rootlet absorbs all that the small plant requires from the surrounding water and, in addition, acts as a keel to steady the tiny leaves when ripples or the wind threaten to overturn them.

The nearer the water-dwellers come to the bank the nearer their form approaches that of the plants of the bank, for all have been derived form terrestrial ancestors and have only in comparatively recent times become adapted to an aquatic life. It is strange that it should be so, for plant life, it is said, like all life, originated in water or ooze and only later spread thence through the swamps to dry land. But

all these primitive forms of life are long since extinct and, even among the fossils of the coal measure and other deposits, the hereditary thread which connects them with the flora of today is hard to follow.

One last natural community must be mentioned—that of the mountains where wind, altitude, moisture and shallow soil condition the flora. Here are to be found the only natural grasslands in the country, composed of low-growing, narrow-leaved grasses such as bents, fescues and matgrass and a meagre handful of flowering plants of which the commonest, perhaps, are rockrose and lady's mantle. Here, too, in pockets of soil among the rocks occur the few alpines—rare, and precious because of their rarity—such as purple and mountain saxifrages, moss campion, wintergreens and cloudberry.

Other grassland communities in these islands are all man-made, from the close-bitten turf of mountain sheep runs and downland, to the rich, flowery meadows and pastures of the lowlands and valleys. All would revert, through scrub, to forest if abandoned by man, but while man is here to cut and trim the hedgerows and re-seed and recondition thinning pastures, and while his beasts are here to graze off the seedling shrubs and trees and so prevent their growth, the grasslands remain, with their abundant, close-packed flora. None can live in the meadows but the strong who can hold his own among his crowding neighbours. Soil is good here, moisture sufficient and sunlight a-plenty, but all must be fought for and woe to the weak or inefficient. The tall, crowding grasses, such as timothy, foxtail, cocksfoot and ryegrass condition all. When these are still short in spring, low-growing rosettes of many leaves can be seen among them—daisies, cowslips and early purple orchids which will flower before the rush begins; marguerites, scabious, thistles, knapweeds, ragworts, docks, sorrels, plantains and hawkweeds innumerable, all gathering in stores for dear life before the coming race for light. As the grass blades

grow the rosettes send up their flowering stems to keep pace with them, pouring in supplies from their bases. Then, as the shadow darkens about their roots, the rosettes can do no more and die down, leaving the work of maintenance to the few leaves on the flowering stem. These are narrower than the basal leaves and upward-slanting, like the grass blades, so as to catch the maximum of sunlight. So they keep level with the flowering grasses, and those that can flower and set their seed before the mower lays them all low will maintain themselves permanently in that meadow, but the others, the late flowerers, must be content to establish strongholds for themselves along the field edge and in the corners where the knife cannot reach them.

Another important man-made community is the arable field. This is the playground of the annuals, for any plant that would grow here must complete its life cycle between one ploughing and the next. Stalks of corn, as most farmers plant the crop, do not make so dense a forest as the grass stems, so that even the low-growing pimpernel which opens only in the sunlight can thrive between them. Here, in the sheltered and sunny aisles, with their shallow roots kept moist by the corn, the fragile ephemerals hasten, hasten to flower and set their seed—poppy, cornflower, speedwell, corncockle, fumitory, heartsease, corn marigold—forming the brightest of red, blue or golden backgrounds to the yellowing grain. It might be wondered how such plants could be so prompt in finding and using—not singly, but in countless myriads—these ideal expanses of rich soil. Most, of course, are sown unwittingly with the corn, and many plants new to this country have, in this way, been introduced —even, so it is said, in pre-Roman times, the now familiar poppy. Others, the less numerous tribes, are sown by the wind and are such first-comers to almost every habitat as annual groundsel which can live through half a dozen generations in a twelvemonth, sending forth its floating seed on every day of the year from January to June and June to

January, and the perennial but quick-maturing dandelions, docks and thistles. Others again, like charlock and plantain may have lain hidden deep in the soil for many years past, waiting for the plough to bring them up to the light and set them growing.

The wild flora of man-made gardens, called 'weeds', is very similar to that of the arable fields, but here the wind-sown annuals and perennials are predominant and the accidental corn-flowers absent. Round about gardens, in orchards, hedgerows and unweeded wastes, and on old walls grow the plants of the ruderal communities. Such noxious weeds as nettles, docks, thistles and acrid-smelling goutweed are apt to predominate and among them will be many flowers of meadow and hedgerow. But the singularity of this community consists in the number of garden escapes here to be found, all experimenting with freedom and either failing in the struggle to survive in the wild, or just maintaining their position, or at last, going forth to conquer new territories. Some that struggle and fail are, in the hedges and orchards, michaelmas daisies, honesty and garden forget-me-nots, and snapdragons on the walls; some that maintain themselves but seem to spread not at all or very slowly are snowdrops, daffodils, winter heliotrope, spotted dead nettle, cultivated stonecrops of several kinds and houseleeks. The conquerors are such as the common brown and gold wall-flowers, red spur valerian, buddleia, leopard's bane and, possibly, the evergreen alkanet, anchusa's near relation, whose flowers of the purest cobalt blue now bloom in every moist southern hedgerow from late spring to winter, but may once have been confined to cottage gardens.

It must not, of course, be thought that these plant communities are static. In this country all, with the possible exception of the mountain associations, are in a constant state of change, and these changes are brought about either by alterations in the external habitat, or by the interference of man and his animals, or by the very plants themselves.

Thus, the underwater beds of *Zostera* may be gradually raised by river silt until they are above the surface of the sea, so that slowly a salt marsh vegetation ousts the grasswrack, and this, in turn, may be drained by man and become a grassland community over which cattle graze. Or the sea may encroach upon the land and reverse the process. In the coastal communities we have seen how the desert dunes are slowly conquered by the marram and settled, at last, by communities of heath and scrub. Marshes my be drained and ponds and rivers silted up, and grasslands, ploughlands, wastes and gardens would not retain their character unchanged for a single year without the interference—for good or ill—of man. And more than this; every community works towards a climax and a mean. The climax in England is deciduous forest, or grassland above tree level, and the mean is a mesophytic vegetation, which is to say, a vegetation which is neither water-loving nor droughty but suited to a temperate climate with sufficient but not excessive moisture. Thus, through the centuries ponds and marshes, silted up by the innumerable dead bodies of the plants, become, by almost imperceptible degrees, dry land supporting a woodland flora; and dunes and heaths, as humus collects and retains the moisture which allows larger trees and shrubs to grow, become at last high forest.

Here at my very door I have had an opportunity to see with my own eyes how quickly communities change and how greatly man may affect that change. The cottage where I live is surrounded by three acres of rocky ground, a sandstone pocket in an area of carboniferous limestone. One acre is meadow, grazed by an old horse. One is a plantation of Douglas fir, sloping sharply north and east. And the last, along the southern face of the plantation and a paradise for adders, is wasteland. The acid soil is so shallow that nowhere can one drive in a pick more than six inches without striking rock or stones, and boulders lie heaped in the plantation and on the waste ground. The whole knoll, forty

years ago, was oak wood interspersed with a few sweet chestnut trees and with an undergrowth of hazel and a ground carpet of bluebells. For as long as anyone could remember this small wood had been untouched except for the cutting of bean sticks from the hazel and the coppicing of the chestnut stools for fencing. Then the whole wood was clear-felled, one acre cleaned of surface boulders and turned into a meadow, and two acres planted with young Douglas firs with a sprinkling of Scots pine and larch. Twenty years ago a fire swept through the southern half of the plantation destroying every tree, and the blackened, rocky patch was abandoned to its own devices. The first plant to establish itself in numbers on the burnt ground after the grasses and the annuals was the bilberry which soon choked out almost every other rival and bore such luscious and plentiful berries that the children of the village would even dare the adders to gather them. Soon, however, bracken found its way in among the bilberry shrubs, and then small birch trees sprang up in all directions and gorse and broom established themselves. There were few flowering herbs or grasses, except in one corner, and one corner only, where bell-heather, hair grass and bedstraw grew. It was a typical heath vegetation. But soon the bracken began the choke out the bilberries and little oak trees made their appearance above the bracken fronds. Bluebells established themselves in small pools of blue in the miniature birch glades. Crab apples, wild roses, blackberries, hawthorns and blackthorns invaded the edges from the neighbouring hedgerows. Buckthorn and mountain ash appeared along the plantation side. Now, today, it is in a fair way to becoming oak forest once more.

Meanwhile the plantation, as the trees grew, has become bare of all vegetation, except in small clearings where the firs have died off for one reason or another, where again bilberries are predominant. A few sprays of ivy creep here and there under the trees, but apart from them the drab carpet of needles is unrelieved by a single green thing.

The meadow, by dint of constant but not heavy grazing and, possibly, some cultivation, has remained a grassland community rich in species. In fact there are few common flowers of the fields, hedgerows and meadows that I cannot lay my hands on in this one small acre, from twayblade, wood sorrel and violets along the wood edge to cowslips, ragwort, knapweed and scabious in the sunny centre.

How different has been the development of these separate acres in the last forty years, yet all would have followed the course of the burnt patch without the interference of man and, even now, without his constant supervision the plantation and the meadow would soon follow the example of the waste and revert to that greenwood which once covered England from the Channel to the Tweed.

Nothing now remains of that primeval forest along whose upper contours above the swamps the Anglo-Saxons trod their devious ridgeways, and through whose wolf-haunted depths the Romans drove their unswerving roads. First, it was cut and cleared for cultivation round the settled villages; then, before the coming of coal, it was felled for fuel and burnt for charcoal with which to smelt iron; then, much of it was turned into coppice with standards which was cut every ten years or so to provide stools of straight rods—of hazel and sweet chestnut for fencing and turnery work, and larger timber for house, cart and ship-building—while ever more and more of it was enclosed and cleared for sheep-walks, pasture and arable. So, gradually, the great forests dwindled and would, perhaps, have vanished altogether a hundred years ago had it not been for the demand for oak for the building of British ships. To this we owe what little woodland remains in such tracts as the New Forest and the Forest of Dean. But now this demand, too, has failed and there is hardly a use any more for the heavy, slow-growing deciduous trees. Their day is past, for they mature too slowly for our frantic, war-torn age and to work them needs patience, time and skill which are all scarce commodities today. Their

place has been taken by the light, quick-maturing conifers introduced from foreign lands whose timber is turned by machinery into all the hundred forms required today, from rafters to newspapers. So, oak, ash, beech, elm and chestnut are relegated more and more to the role of shelters for the stands of foreign conifers from Norway, Japan and North America. But let man's hand be witheld from the forests and in a generation or two the native trees by natural regeneration would have reconquered their old territories.

As this chapter progressed spring has been running on apace and will soon hand on her torch to summer. The wild cherry trees have had their hour of beauty and faded again into the forest and the first radiance of larch and beech is already sobered to a duller green. Even as I wrote of the early celandines those golden blossoms were fading, the lustre of their shining petals dimmed to a pale straw colour; and as I described the abundant and colourful life of the forest floor under the bare boughs every twig put forth green leaves, few and tender and small at first and translucent, but every day growing in size and number and opacity, till now the sunlight is for the trees alone and bees in search of nectar must keep to the open glades, or, guided by the scent of incense, search out the flowering lindens.

Yesterday, to say farewell to the spring, I took a last walk in the woods and rich was my reward, for never have I known such a day nor such a blossoming. My way at first lay across a little stream, green with watercress, brooklime and apium and hedged with giant plants of the poisonous hemlock water dropwort. In a damp corner of the meadow on the further bank grew a miniature forest of field horsetails and I lay down among them for a minute and peered with half-closed eyes down the aisles of stems beneath the whorled branches, hoping thus to capture for an instant the aspect of the primeval jungles which were their first home. For the horsetails are relics of an ancient flora, older than

the conifers and older by many million years than any species of grass, tree or flower that may now grow by their side, and their only modern contemporaries in this country are the clubmosses of heaths and moors.

In the days when life was just emerging from the water, when monstrous amphibians, like giant newts, wallowed and splashed through the deep mud of the swampy forests, when mammals had not yet been evolved and man was still more than 200 million years from creation, the horsetails had their heyday. They and enormous, bushy-headed clubmosses, together with fern-like trees and woody creepers, now long extinct, formed luxuriant jungles in marshy estuaries and along swampy riverbanks. No birds flew among their symmetrical branches, for this was many million years before the first reptile had taken to the air, but creeping insects swarmed already in sunlit clearings, and over oozy pools hawked primitive dragonflies with foot-long, glassy wings.

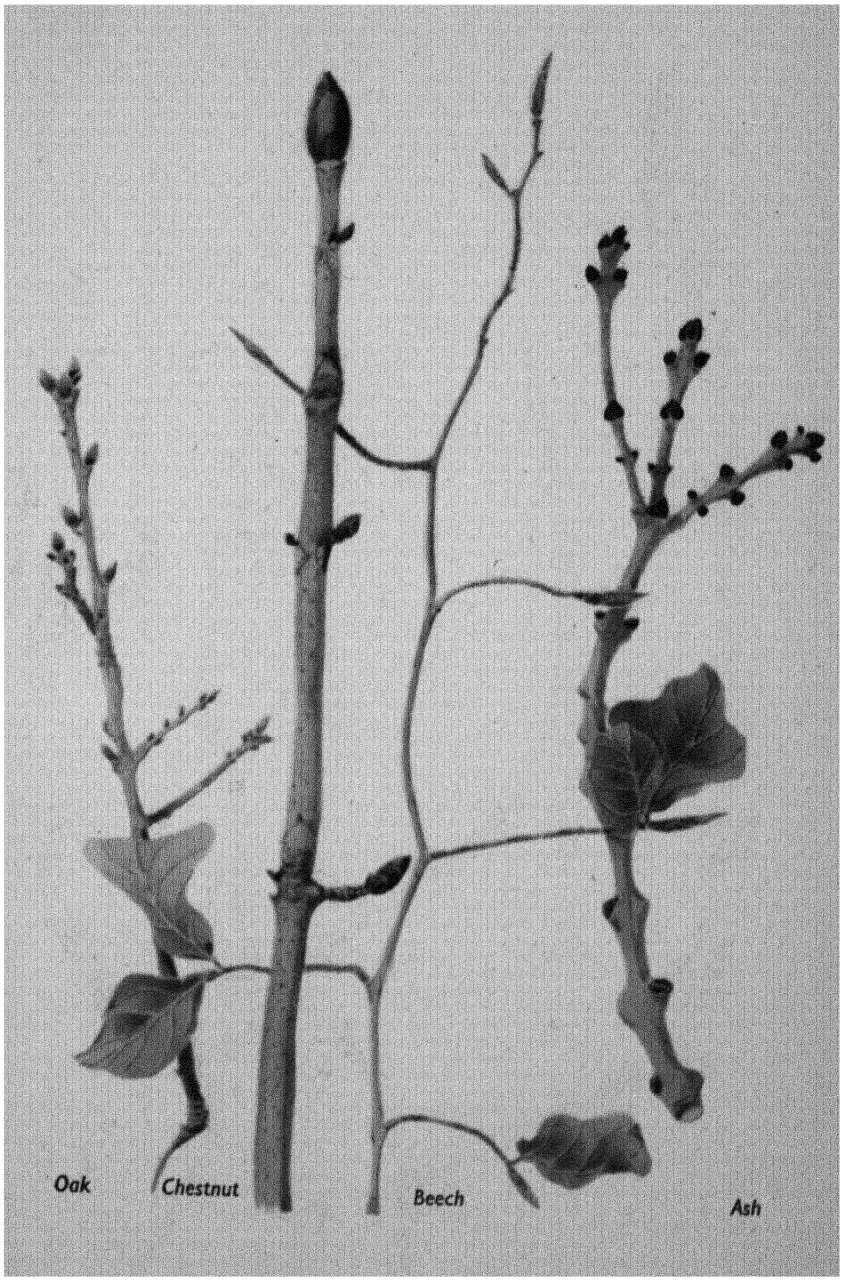
In shape the ancestral horsetails, whose fossilized trunks are known as *Calamites* from their reed (or pipe) -like inner structure, followed a simple and regular pattern: a grooved and jointed bole soared straight upwards from whose nodes sprang whorls of branches, and these, in turn, were clothed in whorls of small leaves, arising also from thickened nodes. The woody trunks and boughs had a hollow pith and were, in addition, traversed by a ring of air canals such as are typical to this day of marsh plants whose roots, smothered in airless ooze, find oxygen hard to come by. There were no flowers or seeds on these trees, for the flowering plant was still only on the threshhold of its evolutionary success, but they reproduced themselves efficiently, though cumbrously, by means of spores produced in cones.

So, for ten million years they grew and multiplied and died, till at last their jungle communities, gradually silted up by the mud of estuaries, or overwhelmed by some seismic convulsion or slow subsidence, lapsed into the ooze and

were fossilized into coal. Some few species escaped extinction and from these are decended our meagre handful of modern horsetails. No more than a dozen species still exist in Britain and all are humble herbs, the largest of them, the great horsetail, being no more than five feet high.

Yet all still exhibit the characters of the giant *Calamites* of the carboniferous forests. The straight, jointed stalks are grooved and ridged and bear whorls of whippy, green branches at the thickened nodes. Though not all are now marsh plants they still preserve the marsh characteristics of a hollow centre and a ring of air canals running up the stem, as can be seen by cutting through a stalk between the nodes. They differ only in their size and in the fact that through the ages they have lost the whorls of leaves that once clothed the branches of their forebears. The only leaves that remain to them have been modified into the membraneous, toothed sheath which surrounds each node, and the leaves' function of food-processing has been taken over by the long, green side-branches.

Spores are still their mode of reproduction, and passing through this meadow earlier in the year, in April, I found the spore-bearing stems of these field horsetails, which appeared like a bed of brown asparagus, ripe for picking; each succulent shoot ended in a cone, corresponding to the asparagus tip. This cone consists of many mushroom-shaped scales, with stalks pointing inwards and hexagonal or pentagonal caps, at first fitting closely together, but later loosening out in order to release the spores, which are borne on their undersides. The wind sows the spores far and wide, but the plants which result from them bear no resemblance to the parent horsestail; they are small, amorphous, green growths, bearing either male or female sexual bodies, and it is only after a female egg cell on one tiny plant has been fertilised by the male sperm from another that a new horsetail is born. This operation requires water, for, though the male sperm is capable of propelling itself towards the female,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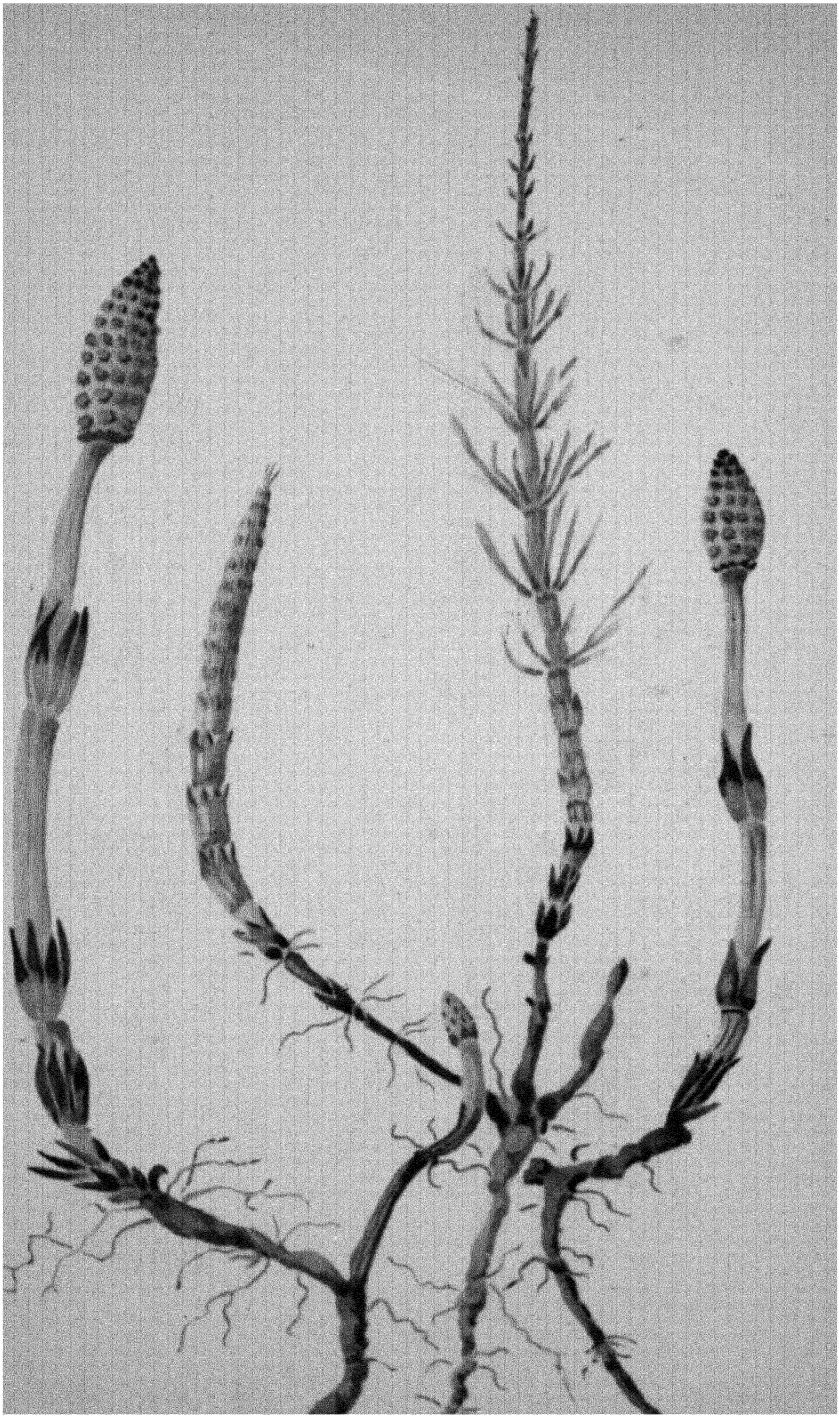


it can only do so through a liquid medium. For the swamp-growing trees of the Palaeozoic Age this roundabout method of reproduction was easy and suitable enough, but for the field horsetail of open pastures, competing against flowers and seeds, it is somewhat out of date.

Seldom is it possible to establish a plant's ancestry so clearly as in these relics of a flowerless age, but thanks to the discovery of coal and of the fossils which it contains, the family tree of the field horsetail can without difficulty be traced back to the Palaeozoic *Calamites*.

Leaving these living fossils, I made my way up a twenty-acre meadow set for hay and starred with innumurable hawkweeds, from whose upper boundary, as I turned to look behind me, I saw the whole valley laid out before me with woods and fields and the burnished river all aglow in the life-giving sunlight. Above me as I stood stretched the boughs of a great wych elm of two hundred years' growth and more, and I paused to remember its flowering in early March when first, along each bare twig, there appeared the dark red baubles of its clustered buds, and these presently, upon a day of sun, burst forth in a haze of pink. From each tiny, four-lobed bell in the many-flowered clusters four stamens sprang, with long, white filaments and large, delicately-balanced, pinkish anthers. One by one the bells opened and the long stamens thrust forth and shed their white pollen to the wind, until at last all had expanded and the balls of blossom seemed veiled in pink tarlatan, but even as the last stamens emerged the first were already withered and the anthers empty of grains. Brief was its flowering, but of an airy grace at variance with the gnarled aspect of the old tree with its harsh and sober foliage.

Above the field I entered the first forest, thirty acres of ancient woodland climbing a rock-strewn slope. This is as natural a forest community as will be found in these islands, for the land was bequeathed, two centuries and more ago,

to the people of the parish, but owing to its remoteness from the present village is never now entered by a human being, except in autumn when the wild pheasants which resort thither to gorge the beechmast and acorns lure out sporting youths with shotguns. But that time is still far distant and on this day there is no sound but the sighing of the breeze and the unending song of a chaffinch in a May tree at the edge of the wood. Once within the trees even these sounds cease and one might imagine oneself in the virgin forest of some undiscovered land. The ground slopes steeply in the wood, and on every hand rise huge boulders clothed in moss, their bases veiled in fronds of male fern and the more delicate lady fern, and their summits crowned with a mat of polypody. Rocky dells are filled with hart's tongue whose smooth, strap-like fronds look, in the dappled sunlight, like the leaves of some outlandish lily and, to foster the illusion, among them grow giant plants of the wild arum. Grey, twisted cables of old man's beard grapple with the blackthorn stems as they fight their way to the light; dog's mercury spreads its dark green mats under the spindly hazels, the insignificant flowers all faded now; an occasional bush of spurge laurel hides green berries under its glossy leaves. The laurels flowered in February—the first blossoms in these woods—and I came on a day of wind and sudden rain slats, which roared through the treetops with the sound of hurricanes, to see their clusters of long, green bells with orange stamens. Some say these flowers are scentless and, indeed, in the cold winter woods they seem so, but a spray brought into the house, or even warmed a little in the hand, will soon give out a fragrance as sweet and strong as that of winter jasmine.

Under an ancient beech tree whose massive, mis-shapen bole looms greyly through the shadow of its own dense foliage, the ground is bare of all greenery, but towards the edge of the circle of darkness a solitary bird's nest orchid raises its parchment spire, and beyond it, where straggling

hazels fight for light, seeding toothwort gleams like ivory against the black forest mould. These two, bird's nest orchid and toothwort, are able to flourish in the shade, for they do not themselves make use of the sunlight but draw its products at second hand. The first is a saprophyte which feeds on decaying leaves, and the second is a colourless parasite on the roots of hazel, wych elm or poplar. Nevertheless, it would seem that toothwort prefers to flower in the light, for its pale lilac blossoms, which turn brown with age, are all withered by the time the forest twilight falls, about the middle of May.

In the very heart of the wood where the shadow is deepest stands a long-abandoned lime kiln, its walls green with moss and riven by forest roots. As I wandered here yesterday, peering about me in the gloom, I nearly set my foot upon a tiny flower and, as I stooped to it, I saw to my surprise that it was a solitary fly orchid. It was strange to find it there in that dark penumbra, this lover of sun-dappled woodland borders on the downs. Some freak of the wind must have blown its dusty seed through the all-but impenetrable thicket which divided this dim recess from the sunny pasture. But, having landed here, it was difficult to see how the seed could have come to germinate and grow, totally without light as it must always have been in the shadow of the old kiln. After examining with wonder the mimic flies—lifelike in colour and shape, even to the two 'antennae' rising from the head—which were its flowers, I left the freakish plant to make good as best it might in its strange home.

And now I tired of the shadows and turned my steps towards the open rides of a neighbouring state forest. Here all was sunshine and colour. The main avenue, kept free of trees for the convenience of the foresters, was like a garden, for the flowers grew, not singly and palely tinted as most summer flowers do, but massed in brilliant patches against the background of the trees. The bluebells were fading, but their place had been taken by beds of purple

bugle, of the colour of the velvet robes of kings, and of yellow archangel with the violet-spotted lip, and of red campion whose luminous pink no water-colour paint can match. Wood spurge, the bracts of whose flowering stems are of the glowing yellow-green of young, sunsplashed leaves, had brought light even to the shadows, and between these taller plants grew a close carpet of yellow pimpernel, ground ivy and dog-violets.

So used are we to the bright colours of the world of plants that we seldom stop to consider what part this tinting plays in the lives of flowers—what are its cause and purpose. Most petal colour comes from pigments, of which the commonest is anthocyanin, dissolved in the liquid of the cells, and the precise hue is determined by the nature of the pigment and its reaction to the cell sap of each particular flower. Some yellow flowers, however, owe their colour to special yellow bodies in the cells, which contain carotin, the pigment which gives a carrot its characteristic hue, and many red flowers and berries are similarly coloured by red bodies in the cells. Petals are coloured in order to attract insects to fertilise the ovules, and the bright tints of berries are designed to attract birds to disperse the resulting seeds. The green of leaves is caused by the all-important chloroplasts in the surface cells, through whose agency a plant is enabled to manufacture food from air and sunlight. The colour of these bodies is green because it is green which traps from the spectrum the rays whose energy makes this process possible. The tints of autumn foliage appear to have no particular purpose—or at least none that has yet been discovered—but are merely the result of chemical reactions brought about during the withering process. The red tint of many young leaves, however, is thought by some to be a protection against the cold.

Besides these surface colours there are many other beautiful tints hidden in the bodies of plants, and in the old days

before the coming of chemical dyes these provided the only dyestuffs. Nearly every hue of the rainbow could be produced from the roots, stems, leaves, flowers or fruits of some plant: red from madder and the roots of tormentil and lady's bedstraw, and from the fresh inner bark of birch; blue from woad (which still grows wild in one district of Britain) and from the berries of elder, bilberry and privet—and, of course, from indigo, but this was an Eastern dye, extracted from certain foreign species of the pea family. Yellow, the commonest dye of all, came from a host of plants: from dyer's rocket, or weld; from heather and ragwort and broom and bramble; from the flowers of gorse and marsh marigold; from buckthorn berries; from crab-apple bark; from the leaves of poplar, plum and willow; from dock roots; and even from nettles. Green was obtained from an infusion of birch leaves, or from larch bark with alum, or from the leaves of lilies-of-the-valley; brown from the green husks of walnuts and from alder, birch and oak bark; purple from deadly nightshade, bryony berries and dandelion roots; and black from acorns. But better, stronger and more enduring than any of these were the dyes obtained from lichens, some of which are still used in the North for the dyeing of Harris tweed, giving the cloth its characteristic odour. So famous were these dyes, which were often blended from several different species of lichen, that they acquired special names, such as Crottle, a brown tweed dye, Cudbear which gave a deep purple colour, and the red or crimson Corcur, called in the Shetlands, Korkalett.

Brighter, though less enduring, than Cudbear and Korkalett were the flowers of this forest glade, and I might have spent the day here in this sunny peace had I not had in view a certain narrow, grassy ride in the heart of the wood where rarer flowers grow than these. Soon I turned off down a shadowy, winding path, quite overarched with hazels and barren of blossoms, but at the edge of the path I saw a clump or two of the gladdon iris and stopped a moment to regret

that I had never seen this flower in bloom. The hazels soon gave way to a black strip of Douglas firs of a size to fell for pit-props. Here not a single green thing grew, except the carefully tended trees, and not a bird's voice was to be heard. But the gentle sighing of the treetops, the mysterious muting of footsteps on the thick carpet of needles and the aromatic scent of the firs gave a mystic—and, as it were, religious—charm to the dark spot, as though this might be some inner sanctuary of the green gods where they rested in silence and solitude.

At the far side of the strip was a small clearing of wet, gravelly ground where the flowers began again, but not in profusion, for the great woodrush had usurped most of the living space; its shining leaves, edged with cottony down, and its brown, lacy flowering heads had their own beauty, enhanced for me by the sudden recollection that its Latin name was *Luzula sylvatica*, which might be translated, 'the woodland glow-worm'; a name given to it, possibly, by someone who had observed that the dew caught among the tiny flowers gleamed like clustered glow-worms in the light of the moon; or suggested, perhaps, by the faint glow of the yellow style and stamens in their dark-brown perianth.

Wood mellick grass grew at the edge of the trees, and tufted hairgrass, and the pendulous woodsedge whose flowering heads, brown and burnt yellow, drooped with an unsurpassable, languorous grace. At one place a bed of the little woodland buttercup, called goldilocks, had established itself. The flowers were nearly over but still formed a patch of brightness under the bushes. Most of the blooms had but one petal instead of their full complement of five, and many had none, but they were not the less bright for that, for the sepals, turning golden for the purpose, had taken on the petals' function. Soon, in the course of evolution, these flowers will dispense with petals altogether, as their near relations the marsh marigold and wood anemone have done.

Beyond the clearing deciduous woods began again and the path ceased, but I knew my way; under an old thorn bush, dragged aslant by an ivy tod; past a great badger sett where the ground was worn bare for many yards around by the badgers' night-wandering feet, and mounds of yellow subsoil were piled before the entrance holes. Now along a badger track for fifty yards or more, and so to my green, grassy ride. At once I began to find the flowers which I had come to see. Where the badger track debouched into the ride, and still under the shadow of the trees, I came upon the first of them—herb paris, that strange lily which takes its name, not from the shepherd of Ida who plunged an ancient civilisation into war, nor from France's capital, but from the symmetry, or 'parity' of its parts. These are in fours (sometimes in fives) or multiples of four: thus, four oval leaves in a whorl some way up the stem; four inner and four outer segments to the perianth of the solitary flower; eight stamens; and four blue carpels, joined to form later in the year a single, bloom-dusted fruit. It is a quaint rather than a beautiful plant, for the spidery flower is all greenish except for the dark navy-blue of the carpels and the pale yellow of the anthers along the stout filaments.

Not far from herb paris, at the edge of the trees, three stems of Solomon's seal curved up from the shadows into the sunlight, but the pairs of creamy bells under the overarching leaves were brown and withered now and the sweet scent faded. A little further and I came upon a compact square of the vivid green, dock-like leaves with flanged stems of bistort, or snakeweed whose pink persicaria-flowers would not expand for another month or more. Here all around me as far as I could see under the trees were innumerable leaves of daffodils, but not a single one of all that host had borne a flower, for the leafy canopy above their heads had become too thick for them. Perhaps the bulbs, by husbanding their resources and confining their spring growth to a few green leaves may survive till the trees are

felled, but I fear that most will dwindle and die before that day.

In the ride itself were colonies of adder's tongue, that unfernlike fern whose single frond, framing the spore-bearing spike, has the appearance of a small, leafless arum with a green spathe and spadix. On every hand grew early purple orchids in mats of brilliant colour, and blue columbines danced in the slight breeze. Then, suddenly, I came on that which I had hoped above all to find—a dozen stately stems of the Martagon lily. The first brown-spotted magenta buds were just cracking open and the petals had not yet turned back to form the turban shape which has caused this lily and all its garden descendants to be called the Turk's cap. But the scent of them was already strong in the shadow where they stood higher than my waist.

The afternoon was waning now, and before making my way homeward I lay down to rest under a sapling sycamore. As I stretched out my arm into the cool grass my hand touched a butterfly orchid and beyond it I saw three more creamy spires; the lower flowers had opened and their immensely elongated spurs stood out from the stem, but the upper flowers were still in greenish bud. And now, as I lay and looked upward at the sycamore leaves outlined against a cloudless sky and listened to their faint rustling in the breeze, and heard the trilling double song of the wood wren, and breathed in the pure evening scent of the orchids, I felt that this, indeed, was what I lived for.

3

Summer Grasslands

IN June more than in any other month occur those timeless moments when all creation, having reached a peak of perfection, seems for an instant to stand still and dream of its own beauty. The past is forgotten, the future is not and never will be, and only the now and here exist. Such eternal instants are unforgettable: their every sound and scent, movement, shape and colour are indelibly imprinted on the memory. This afternoon there occurred one such moment in my neglected garden. Sunlight lay fathoms deep over the unweeded paths and undug beds, and washed in shadowy ripples among the roses and honeysuckle, the rosemary, seringa, laburnums and lilacs which jostle for light under the irrepressible robinias and clamber about the skirts of a great male yew tree; and in the yew tree's heart was a cavern of shade. A wood pigeon crooned in the plantation; a blackcap, hidden in a cypress tree, sang a single snatch of song; in the porch a yellow kitten, bright as a sunbeam leapt at a passing butterfly; and on the compost heap hens, tails cocked skyward, prated companionably to one another as they scratched for insects.

The strong, sweet perfumes of Scotch briar roses and of the crushed leaves of verbena mingled with the resinous tang of firs, hot with sunshine, and the cool, green scent of the tall grass in which I lay. For everywhere the grass was growing; among the flowering shrubs, in the orchard, in the neglected beds, and even in the porch on which the kitten played. Along the low, drystone wall which divides the garden from the pasture it was etched in a plumy frieze against a pale blue sky, and beyond the wall it billowed down in field after field to the glittering river. And, as I watched the

wind ripples rolling down the meadows and thought how brief was the flowering time of the grasses and mourned that with its passing would pass the freshness of the year, suddenly earth seemed to stand still, and in the humming, sun-soaked silence, perfumed by flowers and pines, there echoed the song of the blackcap, the murmur of the dove, the prating of the hens, echoing, echoing, for all time, while the feathery grasses on the wall, refusing the breeze, were suddenly still, immobilised for ever in their delicate grace. It was but a moment—a flash of time—yet an aeon seemed to pass before the birds' voices resumed their living tones and the flowering grasses received the wind once more and swayed under its touch.

Grass, a single syllable, five letters and two of them the same, to form a word which in its associations girdles the earth from east to west and stretches north and south from one region of lifeless ice and snow to another; which runs through all man's history, pasturing the herds of the first nomadic tribes, yielding, under cultivation, food to the primitive villages and security and wealth to the towns; the basis of the rise of civilisations and the proof and symbol of their fall when grass grows again in the streets of their great cities. One word with a thousand moods. Call it tundra and a mossy desolation stretches away on either hand where the snipe and the sandpiper cry in the vast emptiness, their shrill bird's voices swelling and dying in the ceaseless wind. Call it savannah and a new Continent opens, rolling green and blue-green into the western horizon: endless plains where the bison once ranged. Under the name of pampas it lies so flatly between horizon and horizon that a single tree upreared is like a lighthouse to the navigator and, like it, is named and known by all who travel in the featureless expanse. As prairie it becomes a great storehouse—with a stirring history of pioneering adventure behind it—out of which we draw the materials for our daily bread; as veldt, the parched brown hills across which the dogged Dutchman

stubbornly plodded in pursuit of freedom, and whose emblems are the vulture and the springbok; and as steppe, the rolling plain, lush and green in the north and ever more arid to the south, over which the slit-eyed Tartars swept to the conquest of the rich lands of Persia and India. It is high moor where the forests have perished from the mountains and the acid peat denies nourishment to all but grass and moss and heather; and downland where the springy turf covers the chalk and is cropped by the ever-moving, ever-feeding sheep. And turf is another of its names, and alp or pamir in the mountains, and in the valley it is called meadow, and glade in the forest. Put it down by the sea to bind the windblown sands and dune is its name, or links when it has gained a solid footing. Plant it and enclose it in a field and it becomes hay and then a paddock, a ley and then a permanent pasture. Leave it unenclosed and it is a common or a green; and tend it with care, cutting it and trimming it and rolling it, and its name is lawn.

Grass has, indeed, many moods and the names of its kinds, also, are innumerable, for among the families of green, growing things grass is the fifth largest in species, and every species has a name and a character which gave it that name. Each grass has a flower as distinctive to its kind as may blossom to the hawthorn or the heather bell to the ling; but its flower is called a spikelet and in place of sepals and petals are green, chaffy glumes, lodicules and a palea. The stamens and the stigmas are like those of other flowering plants, except that they lean far out of the glumes which protected their ripening and so catch every least breath of the wind which fertilises them. The broad, two-lobed anthers balance so delicately on their hair-thin filaments that a quiver in the air will shake them and send the pollen flying down the air currents, and the diaphanous stigmas wave their tiny plumes to catch the flying pollen as it passes. So do all grasses, but no two species among them arrange their spikelets according to the same pattern. Some, like the

reed, are embellished with silky hairs; some arrange their flowering heads into broad, loose panicles, as bents do and quaking grass; and some, like timothy and foxtail, stand stiffly up with their spikelets packed into tight cylinders round the central stem. According to their fashion so are they named.

Many of their names are world famous and known to everyone: as, bamboo which will grow as tall and thick as a forest tree and, indeed, forms many a forest in Siam, India and Malaya; sugar cane and rice, maize and millet, wheat, barley, oats and rye, all too familiar to need more than the briefest passing mention; and esparto from which paper is made; and sorghum which includes many different species of which Kaffir corn and the sugar cane of China are two. Less famous is the roosa grass of India out of which a perfume was once made, and lemon grass whose essential oil formed one of the ingredients of nard. As their usefulness to man decreases so their names are less well known, but the farmer of this country knows the stiff timothy and ryegrass and the lumpy cocksfoot, for he sows these in his meadows when he re-seeds his grassland; all make good, bulky hay for his beasts. And in old pastures he will know the silky spikes of foxtail and the fragrant sweet vernal grass which scents the meadows at haysel, and, perhaps, the delicate, panicled fiorin and the meadow grasses. If he is a mountain man he will know and value the fine-leaved fescue which is the main nourishment of his sheep. Flote grass and meadow fescue he may know by sight—though possibly not by name—as the grasses after which his cattle stray on to swampy ground and reach for through streamside fences. Every farmer and many gardeners know and execrate the couch grass, or twitch, whose white, proliferating roots penetrate everywhere, sucking all nourishment from the soil, strangling the precious plants of cultivation, forcing their gimlet tips through almost any obstruction and, when broken up, renewing themselves like hydras from every smallest

piece of broken rootlet which falls back into the earth. Reeds everyone knows and their use as thatch, and marram grass which, by binding the moving sand dunes with its consolidating roots, keeps the sea at bay. But it has been long forgotten that crested dog's tail, whose thin stems stand about the pastures rejected by the cattle, was once valued by man for the very quality for which it is despised by the beasts, that is, for the toughness of its stems from which straw plait was once made. An even better straw for this purpose was that of the yellow oat, but who now knows this golden grass by sight or name?

Thus the tale of the commonly known native grasses is nearly told save for a few whose peculiarities have brought them to the notice of the casual passer-by: quaking grass whose flat, red-brown spikelets cause it to quiver in the wind; wall barley whose bearded heads, as all children know, are able, by the aid of the spikes on their long awns, to hoist themselves up a sleeve from wrist to shoulder; and the dry, sapless Yorkshire fog whose leaves, stems and panicles are all so thickly furred with a white down that they look as though they had been powdered like the hair of a Regency beau and are velvety to the touch.

Several thousand names could still be listed of the multitudinous grasses of the earth, grasses whose only use to man is that they cover and preserve and enrich the soil. They are as nearly anonymous as a thing may be whose name is known only to a handful of botanists and a few students, but bring a single one out of its anonymity and track it down and see it flowering and it will almost certainly be beautiful and worth the effort of knowing. Nothing could be more useless than the barren brome, but its name is a poem and its form drooping grace itself. Tufted hair grass has leaves so harsh that no beast will touch them, but it is worth going out of the way to see a plant of it growing under trees with its small, silvery spikelets, on foot-long, spreading panicles, shining in the dappled sunlight. Brown bents on a

marsh and wavy hair grass on heathy ground rival each other in airy charm; and even the ubiquitous false oat of field, ditch, waste ground and hedgerow has a fine, plumy grace at flowering time. And so the list could go on with never a word of disparagement save for darnel, the naughty weed of the Bible, there called tares. Of all the grasses in the world this is the only one that is suspected of poisonous properties and thus ousts couch from the position of black sheep of the family, for couch has the saving grace of making passable fodder at a pinch.

Grass, there is enough comprised in that word to make the study of a lifetime and then not be at an end of the knowledge of its history and habits, shapes, uses and beauties. It forms the many-stitched, many-toned background to almost every one of summer's floral tapestries; in field, hedgerow and marsh, on dune and salting, moor and mountain, by rivers and streams and still waters it grows in one or other of its forms, a green setting to gaudier blooms. To see it in one of its most typical compositions I have only to step ten paces from my door to the meadow where the old horse grazes. He is full-fed, the old horse, and crops no more than a mouthful here and there to while away the time till evening—just sufficient to keep the grass from growing into hay but not enough to discourage the flowers. The cowslips and early purple orchids are all faded now, as are the bluebells, primroses, white violets and wood sorrel which grow where the meadow borders the wood, but the dog violets, on whose leaves the small, spiny caterpillars of the fritillaries feed, are still in bloom, here and there, and spotted orchids are in bud, while the centre of the meadow is gay with buttercups, daisies and tall hawksbeard; with mouse-eared hawkweed whose lemon-yellow dandelion-florets are tipped with scarlet; with the sweet-scented Dutch clover whose nectar-filled tubes provide the hive bees with their second crop of honey to follow upon that which they have but just harvested from the now-fallen apple blossom;

with birds' foot trefoil of the many names—lady's slipper, cocks and hens, eggs and bacon, bird's foot lotus flower—whose dying leaves and stems at times distil the poison, prussic acid, occasionally in such quantities as actually to harm the beasts which feed on them; with hop trefoil and tormentil and creeping thistle and ribwort plantain and many another bloom besides.

Looking at this jostling growth one wonders how all can find sufficient living space, above and below ground, to fulfil their minimum needs. And, indeed, in such a community the struggle is a hard one and it is not surprising to find that, among the crowding company, there are certain parasitic growths which supplement their own supplies by drawing nourishment from the roots of the other plants. Yellow rattle and lousewort, already in flower here in this meadow, and eyebright, cow-wheat and bartsia, which will come into bloom in a little while, are all such parasites. The seeds of these plants germinate in a normal way but soon, as their young roots grow, they touch the roots of neighbouring grasses, and at the point of contact a disc develops which gradually enfolds the root of the host, and from this disc small processes, penetrating to the vascular tissues, suck up thence water and salts. Eyebright, yellow rattle, lousewort and bartsia, and cow-wheat which grows in woods, can all develop alone even to setting their seed, but their root systems are naturally poor and they grow more lustily with a supplementary supply of nourishment.

These plants represent the first stage in parasitism: a second stage is reached by the familiar mistletoe which can only develop in connection with another plant. It has no roots of its own but draws its needs through the peg-like haustoria which it thrusts into the heart of the branch on which it grows. Yet even the mistletoe works a little for its living and is not yet an absolute drone, for it is able to manufacture a certain amount of food for itself through its green leaves and stems. Unlike the meadow parasites, it is

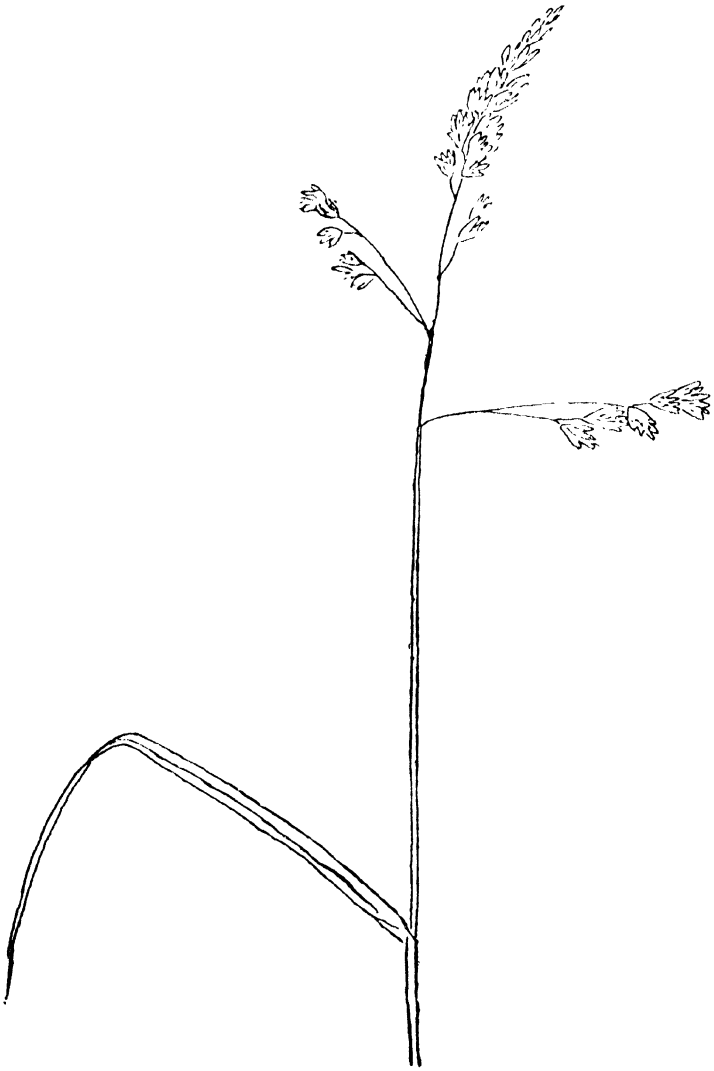
particular as to its host and favours only certain trees—of which oak is the least, and apple and hawthorn the most, common.

The third and last stage in parasitism is reached by two very different types of plant: first, toothwort and the broomrapes which live entirely below ground except at flowering time; and second, dodder which, on the contrary, has no roots or underground system of any kind. Toothwort seeds appear to germinate independently but perish at once if the radicle does not soon meet with a root of hazel, poplar or wych elm. Once in touch, discs develop at the point of contact, from which tiny feelers grow and appear to dissolve their way into the heart of the tree root. The vegetative body of the toothwort consists of colourless, branching, underground stems, set with fleshy, pinkish scales, and sending off many adventitious roots which, like the first radicle, attach themselves by discs to the host. The branch tips turn upwards and, in early spring, force their way with bent heads through the soil, emerging at the surface first as white knobs, like puffballs, then, as the stems lengthen and draw their tips out of the earth behind them, they have the appearance of the bleached, reptilian heads of prehistoric birds. These are the flowering shoots, plated with succulent faintly yellowish scales and terminating in a stout raceme of lilac pink flowers rising from large, white bracts. There is no green colour anywhere, for the plant is a complete parasite. The broomrapes, different species of which grow on the roots of clover, ivy, knapweed and other plants, are very similar to toothwort, but their seeds will not germinate except in actual contact with their chosen host plant and their underground vegetative parts are reduced to a small tuber and the adhesive roots.

Most bizarre of all is the common dodder, whose bunches of small, pink flowers, borne on reddish or yellowish twining stems, may not uncommonly be seen smothering the whins, clover and ling on heathlands. Its tiny seed germi-

Scots Pine
Larch

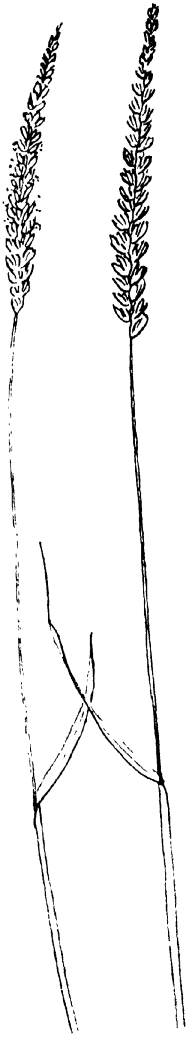
nates on the surface of the ground, but the seedling that emerges takes the form of a single homogeneous, almost colourless thread which is not visibly differentiated in any way into root and shoot. One end of the thread then begins to elongate, the tip rotating as it grows and, as one end lengthens, the other withers, its substance used up by the circling tip. Thus the tiny thread seems to creep along the ground and if, by the time its little store of nourishment is all used up, it has met with no suitable support, it dies away; but if the rotating tip meets with a stem of heather, gorse or clover it wraps itself around it and begins to spiral upwards in a series of tight coils alternating with looser ones. On the inner surfaces of the tighter coils suckers develop with the usual peglike absorbing structures, and on the looser coils flowers are borne. The twining stem possesses no chlorophyll; there is no root, and the small, scale-like leaves are few and as colourless as the stem, so that the plant is entirely dependent on its host. All the apparatus for support and nourishment having been dispensed with, the dodder, with no other work to do, concentrates all its energies on the formation of a mass of flowers and seeds with which to perpetuate its species. It has gone a long way beyond the eyebright and yellow rattle. Too far for its own good, perhaps, for this and the other complete parasites among the flowering plants of this country, despite the drastic simplification of their lives and their concentration on the production of seed, are nowhere very common. It is an event to find a broomrape of any species; toothwort is very local in its occurrence; and even dodder, the commonest of the three, is incomparably less widespread than its hard-working relative, the bindweed. It is only among such lower forms of plant life as the fungi, with their countless wind-borne spores, that parasitism becomes a successful mode of life.



Cock's-foot Grass

COUCH-GRASS RYE-GRASS

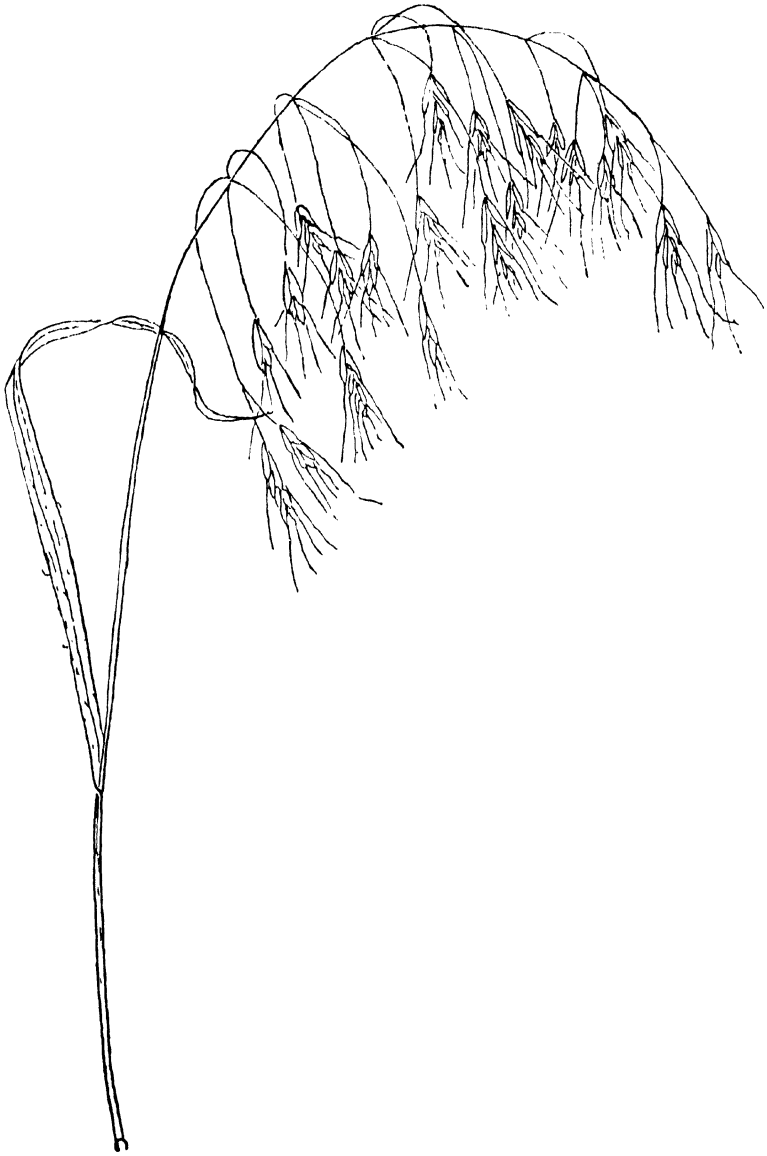
TIMOTHY GRASS



CRESTED DOG'S-TAIL

YORKSHIRE FOG

SWEET VERNAL-GRASS



Barren Brome

False-oat

In the close turf of the meadow the struggle is mainly one for root room, but, in the hedge that runs along one side of the field, light is the scarce commodity for which all plants strive. And here, again, there are some that help themselves at the expense of others. They are not parasites, for they can well nourish themselves; they might rather be described as hangers-on, for by means of twining stems, tendrils, adventitious root, hooks and backward-pointing hairs they fasten themselves to their robuster companions and so drag themselves up to the light. An example of nearly every type of climber, rambler and twiner it to be found in this hedge. Where it joins the plantation there grows a wild cherry tree whose airy blossoming in April, before the leaves expand, it is my delight to watch; but, three years back, an ivy berry found lodgement near its roots—dropped, perhaps, by one of the ringdoves that roost in the wood—and now a sinuous spray of glossy, five-pointed leaves has crept four feet up the cherry's trunk. Unless I uproot the young climber the tree is doomed to be smothered at last by the heavy ivy tod, but this I feel little inclined to do, for I am no meddler in nature's ways and the ivy's life is of no lesser (or greater) account than that of the wild cherry, whose beauty of blossom it can match in beauty of leaf form, and whose red, bitter fruit is no better food for birds than the ivy's purple berries. But with a penknife I have prised away a portion of the spray to see the aerial roots with which it clings so closely to the reddish tree trunk.

A little way into the wood from the cherry tree I was puzzled one summer dusk to smell the strong fragrance of honeysuckle without sign that I could see of the flower itself. But coming again in the morning I soon found it out: a single thin bine of it had laid its spiral round the stem of a young Douglas fir, the thickening of whose bole as it grew had drawn the honeysuckle coils so tight that they had grooved the young stem like the shank of a screw. The ascending bine had put forth no side-branch until it reached the tree-

tops, but there it had spread out and flowered sending out its twilight fragrance to attract the moths. With no other apparatus than the clock-wise twining tip of its main stem it had reached the light twenty feet above its root.

In the field hedge itself brambles maintain themselves by the grappling hooks of their recurved thorns, and goose-grass, which cannot support upright more than six inches of its own weak stem, grows six feet high by the aid of countless, sticky, backward-pointing hairs with which it clings to its stouter neighbours. About the centre of the hedge a plant of white bryony demonstrates the usefulness of tendrils. In this plant the tendrils grow from the axils of the leaves and are at first quite straight, but as soon as the rotating tip comes in contact with a moving, solid body such as a twig in the hedge it twists itself firmly around it. Meanwhile the part of the tendril between the anchored tip and its base in the leaf axil continues for some time to rotate so that soon a loose, elastic coil is formed which, when the wind blows and threatens to tear the tendril from its hold, acts as a spring shock-absorber, expanding and contracting with the gusts. In wild clematis, which does not grow here in this acid soil, the long leaf stalks act as tendrils, and in many of the pea family it is the modified leaflets themselves which perform this function.

In habitats where the light is an even scarcer commodity than in this hedgerow another type of hanger-on is common, and that is the epiphyte. This is a plant which grows actually upon another plant without either giving or receiving any direct benefit, except in so far as it thereby secures for itself a place in the sun. In the teeming equatorial forests this is a common mode of growth, indeed, the herbs and even shrubs of these lightless jungles have all forsaken the forest floor and taken to the treetops where the sun still shines, but in this country, apart from the polypody fern which loves to grow on oak trees, and certain mosses and lichens, there are no true epiphytes. Yet, yesterday by the river bank where

an old pollard willow leans over a side-stream I was reminded of this habit of growth, for out of the midst of the willow's crown of rods grew a hawthorn bush, its roots deep in the black mould which had gathered in the rotted heart of the old tree.

This last week, as one sunny day followed another, sweet with the honeyed breath of June, my steps have turned often to the river, for on its banks and along the green paths leading to it summer's pageant is all displayed. One morning at first light I rose and taking food with me set out to spend the whole day by the water. The sun was still hidden as I left my door and the wooded hills across the valley rose dimly out of a sea of luminous mist which veiled the river and its meads. The sparrow, however, which builds yearly in the cottage eaves was already awake, and a thrush and a hedgesparrow sang from the garden shrubbery. My footprints, as I crossed the lawn, were black on the grass, hoary with summer dew against whose chilling moisture the daisies had closed their flowers and the clovers folded up their leaflets. In a green lane between two hedges, where the still air seemed warm yet with yesterday's sunshine, the flowering grasses were wet with more than dew, for here in this moist, unmoving atmosphere the gushing sap had gathered faster than the normal processes of transpiration and evaporation could disperse it; so that from the tip of almost every blade there hung a crystal drop forced from the over-turgid cells. Many plants besides the grasses—and especially the marsh plants—are equipped with special cells, called hydathodes, at the leaf tips or other nerve endings, to deal with such excess of moisture.

Day broadened as I made my way between the wet hedges; birds woke and sang, though not in the great chorus of May; a cuckoo called and was answered across the valley; the cold tang of dew rose from the earth. Now I could see plainly the shapes and colours of the foison of hedgerow

flowers on either hand. In winter this was a green lane, wide and clear, but now it brimmed with waiste-high vegetation. In a foaming river of hogweed appeared islands of red campion and foxgloves and of evergreen alkanet with flowers as blue as a Madonna's robe, pure cobalt blue as bright and clear as that of any of the flowers of the Borage family to which it belongs—gromwell, forget-me-not, mertensia or borage itself, so famous for the azure intensity of its petals. In open bays between the taller plants grew herb Robert and avens, buttercups, tufted vetch, dandelions, clover and meadow pea, and blue mats of germander speedwell, the loveliest and largest of all the common speedwells, except, perhaps, its alien cousin *Veronica filiformis* which, introduced into this country only a hundred years ago, now grows so thickly in the meadows in May that the grass is hidden under the blue mist of its innumerable nodding flowers. On either hand, elder flowers like clotted cream, white, flat heads of guelder rose and sprays of the incomparable dog-rose leaned from the hedges. But soon, as I descended, I left the lanes behind and took to the meadows, and here the billowing river mist prolonged the night, for the sun had not yet risen over the steep valley brim. So thick was the pearly vapour that had I not known nearly every blade of grass I might well have lost my way, and an extraordinary silence reigned here, broken only by the steady rush of the great river as it swept southward to the sea. As I reached the waterside the sun topped the steep behind me and turning I saw it as a golden glory already high overhead. At the same moment a dove crooned far off in the hanging woods across the river and its gentle notes, falling feathers of sound, floated softly downwards through the illuminated mist. A little breeze arose then, and swirled the dark vapours and freed from their burden the rosy heads of the reed-grasses, bowed down with diamond drops, and set the willow leaves whispering. Almost in a moment the mist had gone from the meadow, though it lingered a little, steaming, on the river, until the

sun and the breeze between them harried it from there also.

As the sun warmed the cold earth and dispersed the chilly condensations of the night, the plants awoke and started their new day, and it was possible to watch their awakening. As the dew evaporated, the clovers slowly expanded their trifoliate leaves, parting the two lateral leaflets that had spent the night joined like praying hands, and lifting the third leaflet that formed a pent over them. The daisies—the day's eyes—little by little bent back their pink-tipped outer florets and opened their yellow hearts to the sun. The meadow grasses, as the hot beams lightened their burden of moisture, lifted their dew-matted heads and shook out their delicate lacework, and those whose spikelets had reached maturity burst suddenly into flower. First, the round, bronze discs of quaking grass thrust forth their trembling anthers; then, cocksfoot and sweet vernal grass, opening wide their spikelets, seemed to veil their heads in a gauze of pollen—palest yellow, shot with pastel pink and lavender and grey. Along the upper hedge away from the river the little yellow cinquefoil lifted the petals with which it had guarded its fragile stamens from the chill dew, and herb Robert raised its drooping flowers, while a plant of stork's bill opened brief buds whose petals would all be shed by noon. At the waterside an early blooming white convolvulus that had twined about a stem of budding tansy shook out its crumpled bells; on light, warm night its wide trumpets will stare nightlong at the moon, but mist and dark had caused it to fold its papery corollas.

These waking movements of the meadow plants and their sleep movements in the evening are as deliberate and regular as our own when we lie down and close our eyes at night or rise and stretch ourselves in the morning, for plants are not as immobile as they are thought to be but are capable of many different motions besides the mere act of growth, motions by means of which they are able to adjust themselves to their environment, or to protect or better them-

selves in a variety of ways. The growing tips of seedlings and of tendrils constantly rotate, as though groping their way in a dark world—a movement botanically called circumnutation—and the track of their growth, if it could be charted, would show an ever-elongating spiral. Roots and shoots do not merely grow in opposite directions but, whatever the position of the plant, the root, reacting positively to the stimulus of gravity will grow downwards into the earth, and the shoot, reacting negatively to the same stimulus, will grow upwards into the air, and each, if diverted from its course, will curve deliberately in the desired direction. Who has not at some time carelessly dropped a weeded dock or dandelion on a garden bed and come upon it again later with its root tip burrowing away underground for dear life and its crown craning upwards towards the sky? It is adjusting itself as best it can to the misfortune of uprooting. If, however, there is some good purpose to be served, the shoot may reverse its normal mode of growth and behave like a root, and the underground system may ignore the stimulus of gravity and go its own way. An example of the first is a blackberry cane which starts life by growing upwards against gravity in the usual manner, but as autumn approaches the long, slender shoot becomes topheavy and bends over in an arc towards the earth. Then, as its growing tip touches the soil, roots develop from it, so that in a very short while a new blackberry plant is established and fresh territory thus conquered. Below the ground, rhizomes, which are botanically underground stems but which perform many of the functions of true roots, behave neither like stems nor roots but grow parallel with the surface of the soil. In some plants, such as Solomon's seal and toothwort, the growing tips of the rhizomes turn in spring towards the surface of the ground and become normal upward-growing stems; in others, such as nettle and dog's mercury, aerial shoots develop along the length of the rhizome. In either case new plants are formed at some distance from the old, and thus

the species spreads and gravity has been ignored to some purpose.

Light, too, stimulates plants to movements of various kinds. Normal shoots grow upward into the light and, as long as this is fairly evenly diffused, will be straight-stemmed and symmetrical; but should the light come to them from one side as it does to geranium plants in a cottage window, they will bend deliberately towards it. Foresters, in order to obtain straight boles, plant young conifers in thick plantations and are in no hurry to thin them, for, in this way, light comes to each tree from directly overhead and draws it straight upward. Not only the whole shoot but also each individual part of it normally seeks the light; the sunflower daily turns its great disc from east to west so that it may keep always in the eye of the sun; the ivy twists its petioles so that its leaves may catch the maximum of light; the meadow saffron, whose seeds have been formed below ground, thrusts its pods up among the June meadow grasses to ripen in the sun and air. However, there are exceptions to this rule too, for the trees of hot, arid lands protect their leaves from the too great and desiccating heat by disposing them vertically rather than horizontally on their branches, and in this country the flowers of ivy-leaved toadflax first seek and then shun the light. At first these tiny mauve and yellow imitations of garden snapdragons crane outwards from the wall on which they grow, but as soon as fertilisation has taken place the flower stems, bearing the ripening seed capsules, start to elongate and curl away from the light; they appear to grope along the face of the wall until they find a dark cranny in which the seed may safely be deposited. Because it is particular about its habitat, preferring vertical walls and other such places where there is good drainage and the minimum of competition from other plants, any more haphazard dispersal of its seed would soon lead to its extinction.

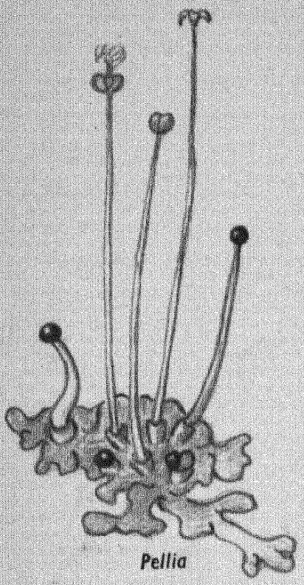
As shoots grow towards the light so roots tend to grow

away from it, though not so markedly, for it is the positive pull of gravity rather than the negative push of light which determines the direction of their growth; except in the case of such creepers as ivy whose aerial roots for obvious reasons grow away from the light and ignore the stimulus of gravity. Roots, however, have two types of movement which are all their own. The first is exhibited by the fine rootlets at the extremities of root systems which tend to grow towards moisture, and the second by the so-called contractile roots. These latter are produced by many corms, bulbs and perennial stocks and their object is to keep the plant at the right depth in the soil, or to draw it down to a certain level. For instance, crocuses produce a new corm every year on top of the old one and, if this process were to continue unchecked year after year, the plant would eventually come right out of the soil; to prevent this each corm as it is formed puts out one or two special roots which grow straight down and anchor themselves securely; when the tips are firmly fixed, the part nearest the corm contracts and so drags the plant down to the level of the old corm. Most bulbs, corms and tubers favour a certain depth at which to grow, and work themselves down to it by means of these contractile roots. As seedlings, of course, they lie very near the surface of the soil, but each year they drag themselves down a little way until at last they reach the level which they prefer; having reached it the contractile roots cease to function. It is in this way that the bluebell descends to its own particular layer of the forest floor, and that the wild arum draws down its corm into the safe, warm earth below frost level. Lastly, the thick tap-roots of such plants as dandelions, docks and cow parsley are often themselves contractile, and this, in their case, has the effect of dragging down the stock so that the new season's rosette of leaves, which has been produced on top of the old one, is once more in close contact with the soil.

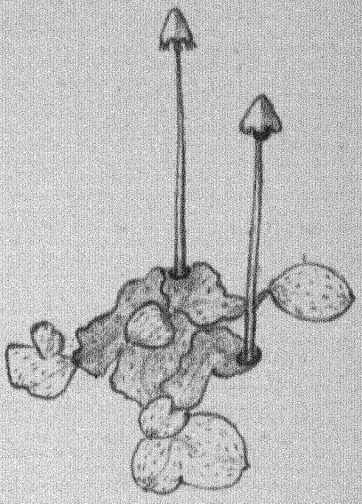
Touch, or friction, is yet another stimulus to movement in plants. It is this which seals the fate of flies blundering

on to the leaves of the carnivorous sundew; the fly's efforts to escape from the sticky hairs which it has touched stimulate other hairs round the rim of the leaf to bend over towards the entrapped victim and deluge it with a digestive liquid which soon stills its struggles, and it is remarkable that the reaction here takes place at quite some distance from the actual point of contact. Again, it is the stimulus of friction which causes tendrils to start their twining movement when they come in contact with a possible support; a mere touch will not suffice, nor will the buffeting of raindrops, but a steady, or intermittent, rubbing to and fro will soon set them in motion. The pea family is more given to movements of various sorts than almost any other, for, not only is it much addicted to tendrils, but the bases of the leaf-stalks—the so-called pulvini—of many of its members are highly mobile. The runner bean, for instance, which has a thick, cushiony pulvinus at the base of each petiole, daily moves its leaves rhythmically up and down, each leaf pivoting, as it were, on its pulvinus; in the same way clovers fold their leaves at night. These two movements are in response to intensities of light, but one of the most spectacular motions in the vegetable kingdom, which is also exhibited by a member of the pea family, is a response to the stimulus of touch: this is the famous shrinking movement of the sensitive plant. Any jolt or rough touch will cause the leaflets of this plant—which is a species of mimosa—to fold together in pairs and the whole leaf to hang downwards, and often, if the original disturbance is sufficiently violent, the reaction will be communicated to adjacent leaves and even to the whole bush which will thus take on a withered appearance—an appearance which is thought by some botanists to be the object of the reaction as it would tend to protect the plant against the ravages of grazing animals. It was this most spectacular movement that first suggested to early eighteenth century botanists that plants might be, in their own limited way, as 'alive' as animals, an idea that had not occurred to anyone

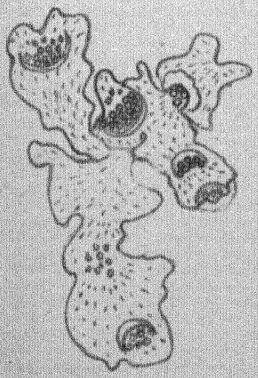
Liverworts



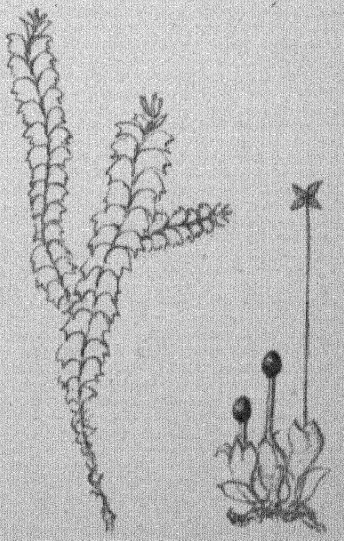
Pellia



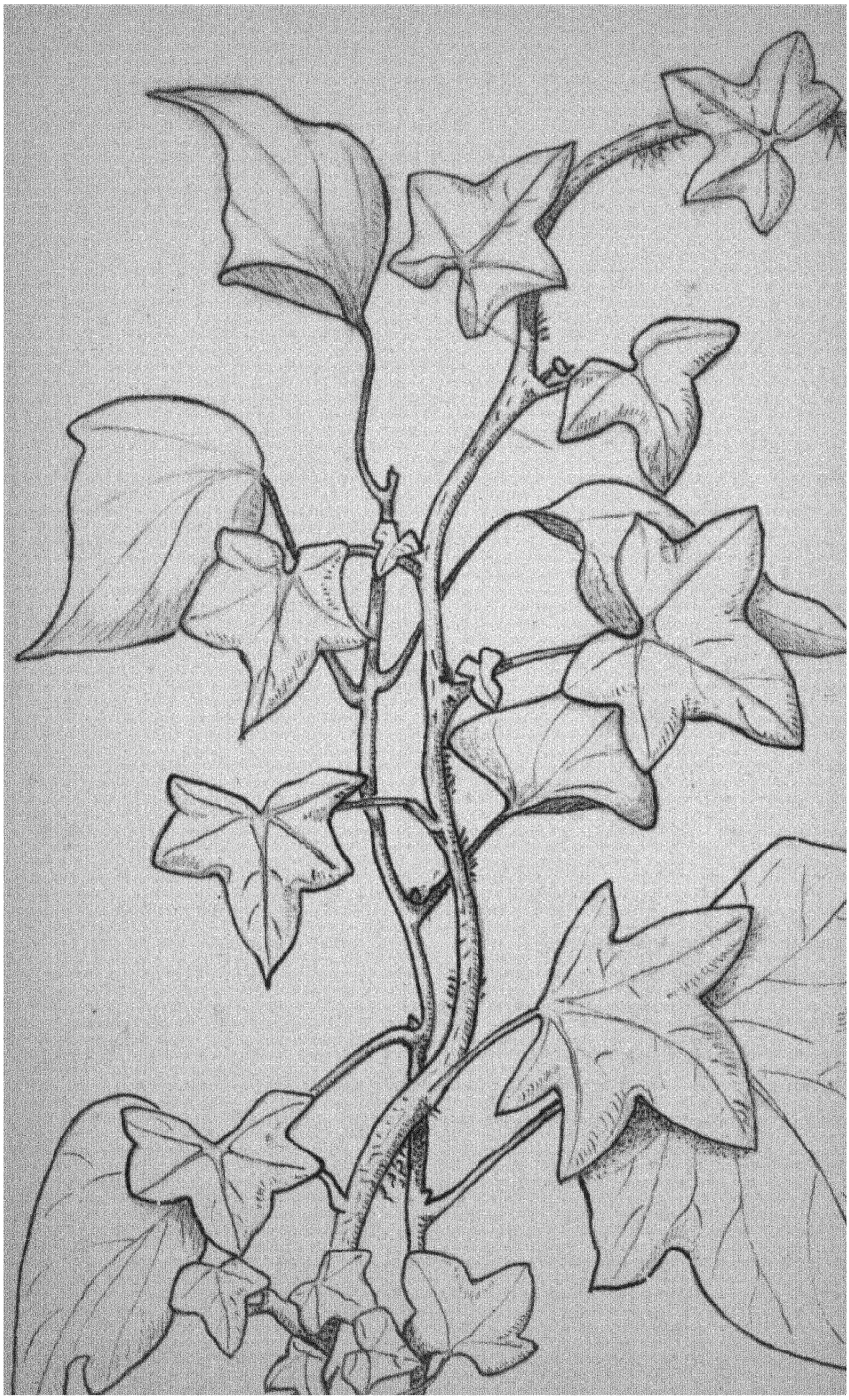
Fegatella conica



Marchantia polymorpha : *gemmae*



Leafy liverwort : *Lophocolea bidentata*



before that date. As long ago as the fourth century B.C., Theophrastus described from first-hand observation the reproductive organs and the seeds of plants but without, apparently, a notion as to their real function, and it was not until the sensitive plants had, two thousand years later roused an interest in the exact nature of the vegetable kingdom as a whole that experiments were made with stamens which established for the first time the sexuality of flowers and the method of their fertilisation.

And so back to the morning meadow and the sleep—or nyctinastic—movements of leaves and flowers. These are mostly designed as protection against the chilling effects of dew. Leaves fold themselves in such a way as to protect their stomata, or breathing pores, from the cold, clogging dewdrops or the chill night air. For instance, clover leaves, which bear stomata chiefly on their upper surfaces, fold their leaflets face to face, while wood sorrel, which has a similarly shaped, trifoliate leaf, but whose stomata mainly occur on the underside of it, droop their leaflets at night so that they are folded back to back. Flowers close their petals or droop their heads at dusk in order to protect their delicate stamens, and their movement is a reaction to the fading light, or it may be to the falling temperature, or to a combination of both. Warmth is a great expander of buds and blossoms, a fact which all who have brought flowers out of the cold into a warm house must have observed for themselves, and it is the sun's warmth rather than the strong light from its rays which probably causes the celandine to open out its stars between April showers and the scarlet pimpernel, or poor man's weatherglass, to expand its red and purple petals as soon as the summer rain clouds have rolled away. Jack-go-to-bed-at-noon, on the other hand, regulates its hours of opening and closing entirely by the intensity of light and no afternoon, however warm and sunshiny, will tempt it to stay awake beyond its self-appointed time.

Here in the meadow, once the mists have melted away, the ever-growing heat and light of a bright June morning have soon expanded every blossom; then, no sooner are they open and ready than the first bees arrive and, with their arrival, the business of the day is well begun. And the business of the day for every green thing in the meadow is no longer merely growth and the accumulation of nourishment but, above all, the fertilisation of a million waiting ovules, the reproduction of each individual and, if possible, the increase of its species.

John Ruskin, who brought to his love of flowers the same half-mad enthusiasm which he bestowed on all his affections from a Turner painting to an adolescent girl, was bitterly cast down to learn that so ethereal a part of creation as a blossom was—no less than an animal—subject to the gross laws of sex. And, having learned the shocking fact, he would not even then admit that the essential end towards which every plant strives is not the production of beautiful blooms but the formation of viable seed with which to perpetuate its kind. Yet, of course, flowers are no more than the intricate apparatus through which plants ensure that their seed shall be set and their species multiply on the face of the earth. In this insistence on the mere factor of survival they are no exceptions to the universal law of living things—a law which human beings with their emphasis until recent times upon the importance of the individual have tended to forget applies also to themselves. Only now, when the very number of our proliferating millions threatens the continuance of our species do we men begin to subordinate the individual to the common good. At present this discipline is applied only in parochial sort, to ensure the survival of one tribe of men against another, but if it is to be effective in the preservation of our kind it must be applied in a wider way; else we shall do as crowded seedlings do, smother each other till none of us remain, or one tribe of us only and that the strongest.

Just as Man by the intensive development of his brain has multiplied, even to excess, in the world, so plants, mainly by the development of their floral parts, have spread far and wide from their first home in the primaeval marshes. Botanists have many theories as to the exact course taken in the evolution of flowering plants, and it is said that sexual reproduction and the seed habit were several times evolved before they achieved the success that they enjoy today. According to one such theory, the general course of events—omitting the many setbacks and fresh starts that must have occurred—was somewhat as follows. The most ancient and primitive plants, it is said, lived wholly or partly submerged in water and had need of this element to carry the motile male cells to the ova. They propagated by spores and their spore-bearing organs differed but little from their vegetative parts. But soon they began to climb onto dry land, and as they advanced new, seed-bearing forms were envolved. Some—the first—were shaped like ferns and others, later, like the sago palm of present-day tropical forests, but all now had definite male and female parts, the female bearing ovules and the male producing pollen with motile male cells which still required moisture—provided now by the breaking down of tissues in the ovule itself—before it could complete the process of fertilisation. These were succeeded by the ancestors of the conifers with still greater differentiation of the floral parts into male and female cones. And now, at last, the pollen was inert and entirely dependent on some outside agent to bring it into contact with the ovule. The marsh having now been long left behind and water, consequently, being no longer available, this agent was, at first, the wind. Meanwhile, somewhere late in the Mesozoic Age, ancestors of our own true flowering plants appeared. Their exact shape is unknown, for, owing to the quick destructibility of their soft bodies, few fossilized parts of them have ever been found, but it is thought

that the first flower consisted of a normal vegetative shoot with upper leaves modified into a whorl of pollen-bearing leaflets, surmounted by another whorl of leaflets bearing ovules. These flowers may have been wind pollinated, or, perhaps, insects had already taken a hand in this work; at any rate, advantage was soon taken of the surer, less haphazard and more economical method of insect pollination and a conspicuous corolla was developed out of the next whorl of leaves below the pollen-bearers to attract the attention of bees, moths and flies. Finally, to protect the now delicate floral parts before they were ready to expand, a still lower whorl became the calyx; the internodes between the whorls being, meanwhile, so shortened as to bring the rings of specialised leaves closely together. According to one theory, that was the evolutionary process, and the earliest flowering plants of which there is any record were members of the water-lily and magnolia families whose present-day representatives have simple flowers arranged according to the above finished pattern—ovules, stamens, petals, sepals, in rings one below the other.

Water, then, was the first fertilising agent, afterwards the wind and, finally, birds and insects; and all four are, of course, still in use today. The algae, mosses and such lower growths need water to carry their spores and, among the higher plants, the pondweeds and grass wrack have, since their return to an underwater life, reverted to this method of conveying their pollen. The primitive conifers, the catkin-bearing trees such as birch, alder, hazel and poplar and many other trees, some few herbs such as nettle, mugwort and plantain, and all the grasses, use the wind. Many tropical plants with bright, stoutly-made flowers are fertilised by birds such as humming birds and honey-suckers. The remaining flowering plants, including the majority of herbs, rely on insects.

Leaving aside the more primitive growths from algae to conifers it is interesting to note how the flowers of the

higher plants—the Angiosperms—are adapted to their chosen method of pollination. Those of the water users are inconspicuous and simplified to the utmost limit, and their pollen has the same specific gravity as the water—salt or fresh—in which the plants grow, so that it neither sinks below, nor rises above, the level of the ovules which it must fertilise. The flowers of the wind users, also, having no insect interest to catch, tend to be dim and much simplified, without petals, scent or nectar. Those of the catkin-bearing trees consist of little more than dull-coloured scales bearing stamens and stigmas which, to minimise self-fertilisation, are arranged in separate male and female inflorescences. The very numerous anthers, grouped together in a long, swaying tassel, release an abundance of fine, light pollen, easily carried by the wind, and the flowers expand early in the year before the broadening leaves of their own and other trees impede the airways. Hazel, alder and birch are typical examples of such catkin-bearers and so inconspicuous are their female flowers that they must be looked for with attention: tiny, scarlet tentacles of hazel, emerging from small, green, gourd-like buds; miniature, maroon-coloured cones of alder with white stigmas creeping out between the scales; emerald green thumbs of birch, indistinguishable in colour from the tuft of budding leaves from which they spring. Not all catkin-bearers, however, are pollinated by the wind and you may know those that are not—like the sallow—by their stiff, upright spires which the breeze cannot oscillate and which provide stable platforms for the bees, by the nectar which they secrete to lure the insects; and by the bright and most visible colour of their pollen: a sallow bush in spring shines out among its dun hazel neighbours like a sun from raincloud.

The nettle's long, green spikes, which hang beneath the upper leaves like the plush fringes of Victorian tablecloths, follow somewhat the same plan as the pendant catkins. The individual flowers which are of two sexes, borne on different

plants, are drab to a degree and simplified to the extent of consisting merely of four small, green sepals and the stamens or stigmas. The wind swaying these plush tassels scatters the light pollen. But the nettle and its nearest relative, the wall pellitory, have, besides, a spring mechanism to help still further in the dispersal of the pollen: their stamens, in the bud, are folded in upon themselves but, as they ripen, spring suddenly outwards and apart, scattering in this abrupt motion the dusty contents of the anthers.

Grasses follow another method again. Instead of pendant tassels they have long, swaying stems which bear the flowering heads into the air currents well above the level of their own leaves and of the surrounding herbage. Here the breezes have free play and, to take advantage of every slightest movement of the air, the anthers of the grass flowers are so delicately balanced on long filaments that a breath will shake them and set the light pollen floating. The anthers of early flowering trees, such as the elm, are made on a similar model, and these trees, like the catkin-bearers, blossom before the leaves have expanded.

Dull-coloured, scentless, nectarless are the wind-flowers, and had the insects never been evolved the palette of spring and summer in temperate lands might have held no tint brighter than the dusty pink of elm flowers or the shadeless white of blossoming sloes; there would, perhaps, have been no scent of honeysuckles in the dusk or fragrance of clovers on sunny afternoons, no beautiful floral shapes of bell and chalice, trumpet and cup, spire and panicle and solitary star to embroider the green background of the leaves and grasses. For colour and shape and scent have all been evolved to attract the pollinating insects. In tropical lands birds, too, have had a hand in things and the brighter colours of the flowers of those countries—and in particular the frequency of red flowers, rare in temperate lands—is directly related to the colour vision of birds, who are blind to blue but can distinguish red and green. For this reason the flowers that

are pollinated by humming birds and honey-suckers tend to be scarlet or crimson, just as the autumn berries in this country, which depend on birds to disperse their seeds, tend to be of the same bird-visible colours. Most insects, on the other hand, cannot tell red from green or black; some are totally colour-blind, distinguishing only intensities of light, but bees, moths and butterflies have been proved to have a well-developed colour sense. Experiments with bees have shown that they can see yellow and blue, and tones of these, but that red and green both appear black to them as they do to a partially colour-blind man. Some butterflies, and notably the common cabbage white, are able to distinguish tones of red—especially pink—and of green, their colour vision thus approximating to that of a normal man. So, the colours of flowers being directly related to the vision of their pollinators, those of temperate lands which are pollinated by insects tend to be either white or yellow, which all insects can distinguish, or some shade of blue or purple, which the bees can see, or pink for the moths and butterflies.

Nectar and pollen are the wares which such flowers have to offer in return for the services of their insect visitors. The first is the common lure, but there are some nectarless flowers which produce pollen in such abundance that they can afford to provide bees with pollen 'bread' and still have sufficient over for fertilisation purposes. These are, in general, large and showy blossoms with pollen-covered anthers well displayed; of such are the wild rose, poppy and rock rose.

The nectar flowers are of many different shapes, sizes, colours and scents according to the special clients which they wish to attract. First come those with shallow cups and the nectar exposed on the surface where it is easily available to all comers. The nectaries are usually within or on the petals, but in the spurges they take the form of green cushions round the highly simplified flower where they have the appearance of succulent, green sepals. The visitors

catered for are the short-tongued flies, beetles and bees, and the predominating colours among such flowers are white and yellow, shades which will appear bright even to the colour-blind *Diptera*. To this class belong all the *Umbelliferae*: cow parsley, angelica, hogweed, hemlock and many more, over whose white, shining platforms of clustered florets small insects can crawl at ease, sipping the nectar and distributing the pollen as they go. A sunshiny summer day will turn a hogweed head into an entomological show-case of small beetles and flies. Next come flowers with nectar concealed in short tubes or behind scales or hairs. Their clients are again flies and short-tongued bees and typical among them are the *Ranunculaceae*—the buttercups, water crowfoot and celandine—which often cover their nectaries, one of which lies at the base of each petal, with a tiny, heart-shaped scale. The shining inner surface of the buttercup's petals are said to mirror these hidden nectaries to visiting insects. The flower colours, again, are mainly white and yellow.

Now the corollas deepen and, in place of a shallow cup, they take the form of a bell or tube with nectar quite hidden at the base where none can reach it but the long-tongued butterflies, moths, bees and hover flies. New colours, blue and purple, appear, to attract the attention of these colour-seeing insects. In this class are heather, thyme and forget-me-not. Next come the flowers which have specialised for the long-tongued, heavy-bodied bees alone. They are the most curiously shaped and colourful of all; many are scented, and shape, colour and scent all play their different parts in ensuring the attention of the bees. They are rich in nectar and include such famous honey flowers as the clovers and wild basil, or calamint, one of whose tubular, lipped blossoms may contain as much as an eighth of an inch of pure nectar at its base; but the sugary liquid is well concealed in hidden nectaries which lie at the bases of long tubes or in spurs and pouches where the short-tongued insects cannot reach it. The foxglove, for instance, and Labiates, like the

honey-rich white dead nettle, store the sweet lure in the tubes of their flowers, the violet and heartsease in a spur behind the petals, and toadflax in a special pouch at the base of the corolla. The flowers of these plants are often two-lipped, the bottom, broader lip providing a landing platform for the visitors. Sometimes, as in members of the pea family, the lower lip takes the form of a winged keel which, pressing up against the standard petal, encloses and hides the stamens, stigmas and nectaries. Only the heavy-bodied bees have weight sufficient to depress the keel—and thus open up the flower—and tongues long enough to reach the nectar within.

So much for form. As for colour, they are of every hue that a bee can distinguish: white, yellow, blue, purple, but especially blue and purple for these are the bees' particular shades. But this is not all; many are patterned in a combination of different colours, and it has been proved experimentally that bees can distinguish such patterns and that they perform the function of a guide to the bee, first, to the species of flower which it desires to visit and second, to the actual location of the nectar which it is seeking. For it appears that individual bees form the habit of visiting certain species of flowers in which experience has taught them that they will find the coveted nectar in good quantity. And also different species of bees have very definite preferences among the flowers on their hunting grounds as anyone may observe for themselves. One cloudless day in June I was drawn by the summer sound of foraging bees to an untended corner of my cottage garden. Here, on a hot slope where the shallow soil barely covers the underlying rock, garden strawberries, abandoning their comfortable quarters in the cultivated bed, have established themselves in such profusion as to provide annually my main crop of berries. Where the rock slab ends the soil is deeper and alkanet, foxgloves, hogweed and buttercups from a thick and colourful hedge. This wild patch is always a favourite haunt of bees and this day I noticed that they were of three species, namely, hive

bees, great black and orange bumble bees and a very small brown bee, smaller than a housefly. The first visited the blue alkanet exclusively and never glanced at any other flower. The bumble bees went straight to the foxglove spires and laboriously bumbled in and out of each one of the long, purple bells. But the little brown bees would have none of these taller plants and confined their attentions to the innumerable strawberry flowers, and many a luscious berry they must have set for me that day. The hogweed heads were visited only by occasional flies, and the buttercups were quite neglected by flies and bees alike—and, indeed, I believe that these flowers in spite of the netaries mirrored by their burnished petals are not a favourite with insects of any sort.

In the rainbow medley of a summer meadow the bees' first guide from afar is the general colour of the corolla, or, occasionally, of other parts of the flower modified for this purpose, such as the blue, white or pink sepals of the milkwort. On nearer view they will recognise their particular species by the patterning of contrasting colours, and, on alighting on the petals, the disposition of the pattern will show the actual position of the nectaries. Such patternings, which take the form of rings, spots, patches and lines of contrasting colours, are therefore often called nectar guides, and the shades that compose them are such as are most visible to the semi-colour-blind bee. Speaking in bee colours and remembering that these insects see both red and green as black, the commonest combinations are blue and yellow, white and blue, and white and yellow, and somewhat less common are white/black, blue/black and yellow/black. Tones of the same colour are also sometimes used to form patterns. It is one of the pleasures of meadow prowling to examine each encountered blossom under a pocket lens and note the patternings. Forget-me-nots provide an example of the commonest colour scheme: blue corolla to attract attention from afar, and yellow eye to indicate where the nectar

lies. Wood sorrel, if you examine the apparently pure white bells, will reveal a patterning of purple veins leading down to the base of each petal where a stain of brilliant yellow marks the position of the nectary. Many white flowers have yellow centres, sometimes provided simply by the pollen-covered stamens and sometimes by the tinge of the petals themselves, as in water crowfoot, heartsease and eyebright. The last two also provide an example of black on white, for both have hair-thin, jet black lines pointing the way to their hearts. Bearing in mind the bee's eye view, purple loosestrife with its magenta petals striped with red provides an example of the black/blue colour scheme—blue petals, black stripes, to the bee. For black/yellow examples we must again remember the bee's beholding eye: the standard of the bird's foot trefoil is striped with red and that of the meadow pea with dark green—both black to the bee. One of the most beautiful examples of tones of the same colour is the corolla of germander speedwell with its royal blue curving lines on the paler petals and dark blue stamens at the heart.

Not content with colour alone, many flowers have evolved as a further attraction strong, individual scent, and it has been proved that this scent is as useful as petal colour as a guide to bees, and especially to hive bees who have a highly developed sense of smell and for whom it performs a quite special function. It appears that when nectar is scarce certain scouts are sent out from the hive to prospect for the precious liquid and on their return, if they have found a plentiful supply, these scouts, dancing on the comb, convey the news of their find to their hive mates through the scent of their bodies which are still redolent of the blooms which they have just visited. Other workers, noting the particular perfume, now set forth and, hunting by scent, soon find the coveted nectar.

Other connoisseurs of perfume are the night-haunting moths whose special blossoms form the next class of insect-pollinated plants. These flowers are, like bee flowers, modi-

fied in various ways to suit their clients. They cater for hovering moths who need no sturdy landing platform, so corollas may be regular and flat, or else long and slender with a tube or spur so deep that only a moth's long tongue, uncurled, can reach its sweet base. In colour they are pale so that in the dusk they will be visible to the night-fliers, and their flowers often do not expand fully till evening. And, above all, many are scented with a fragrance that does not develop till darkness begins to fall. Typical among such flowers are the pale honeysuckle and the white, sweet-scented butterfly orchid with nectar buried deep in tube and spur; and the flat-petalled evening primrose whose flowers gleam through the night like clustered moons, but in the morning, as the dew dries on their silken petals (yellow, silken petals, fit for a mandarin's robe) they wilt and fade, their brief life of seduction over. But above their drooping crowns the next blossoms on the spire are ready to take their place and only await the evening to unfurl their long, brown buds.

The last class of pollen-carriers for which certain flowers have specialised is that of the carrion seeking flies. Colour and scent again play their part, but the scent is the scent of corruption and the colour that of decay. The wild arum, or cuckoo pint, is one of these though its odour is slight compared to that of its garden relation, the purple-red snake root, or dragon arum, whose overpowering stench impests the air. These lilies have a lurid beauty, but it seems—against reason—to be the beauty of evil, and their methods of pollination, too, have none of the gay innocence (to human minds) of those of the bright meadow flowers. They deal, not in honey and sunlight and the pleasant hues of life, but in death—the odours and colours of death and the dead bodies of those small flies which, lured by their obscene seductions, find themselves entrapped in the bases of their deep spathes. (To rail against the arum is, I know, against reason, for death has its beauty, too, and its fascination. It is the dark face of life as night is of day, winter of summer, evil of

good: life—death, day—night, summer—winter, good—evil: four wholes composed each of two contrasting facets; take away one facet and the whole is gone, for without the one the other has no meaning.)

The cuckoo pint is constructed on a different plan to any of the flowers mentioned up to now. It consists, not of the usual calyx and corolla, but of a spathe and spadix: the first is the large, green sheath, like a paper poke, out of which rises the purplish tongue which is the spadix. The latter is divided into five sections: first, the purple-red portion which appears framed in the spathe; second, below this, a ring of downward-pointing hairs. These two are modified and sterile flowers. Third, below the hairs, a band of single stamens, followed by, fourth, another ring of smaller hairs and, fifth, below this again, a band of single carpels. The spathe and the upper sterile portion of the spadix, by their colour and by their slight odour of urine, attract small flies which, crawling downwards, become entangled in the sloping hairs. As they struggle to escape from these they fertilise the carpels with pollen brought from another arum flower and, at the same time, by their movements, dislodge the pollen from the stamens above them; well dusted with this, they extricate themselves at last and fly to another flower to repeat the process. In general the method works well, but casualties among the flies are by no means uncommon and one or more of their dead bodies may often be found in the bases of the lily spathes.

Besides the plants which have specialised in certain types of insects for pollination, there are also a few flowers which have carried specialisation to the length of depending for this service on one species of insect only. Many of the orchids have done so; the fly orchid, for instance, depends upon the resemblance of its flower to the resting female of a small solitary wasp, called *Gorytes mystaceus*, to induce the male wasp to alight upon its lip and thus come in contact with

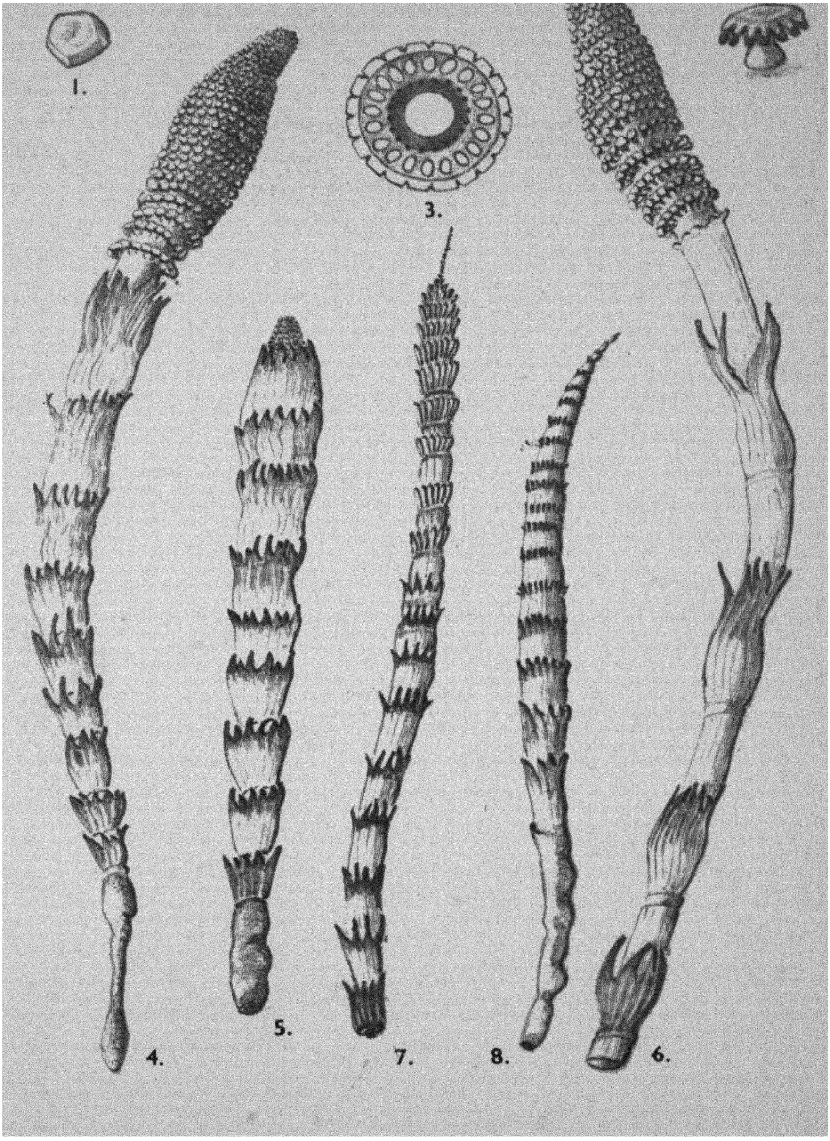
with its sticky pollinia. Another somewhat original method of pollination is that of the familiar ragged robin of the water meadows. Its agent, it appears, is a night-flying moth which visits the flowers, not for nectar or pollen, but in order to lay its eggs in the ovary. To attract a moth with such intentions would appear at first sight to be suicidal on the part of the flower, but it is not so, for the caterpillars that hatch out leave uneaten a sufficient number of the ovules which their mother has helped to fertilise to ensure the survival of their host.

Most fantastic of all is the case of the fig and so fascinating is its story that, although it is not a native plant, some account must be given of its almost incredible ingenuity. The pollinating agent for all figs is some species of wasp and for the fig which I am about to describe—the wild fig of Italy, *Fico sylvatica*—it is a small wasp whose scientific name is *Blastophaga grossorum*. This fig bears annually three generations of unisexual flowers which are borne inside, instead of outside, the floral receptacle at whose apex is a small hole. The first generation of flowers, called the *profichi*, appears in February and consists of a band of male flowers near the mouth of the receptacle and, beyond them, a band of infertile female, or 'gall,' flowers. Before the male flowers are ripe, female wasps of the species *Blastophaga grossorum* crawl through the hole in the apex of the receptacle and lay one egg in each of the gall flowers. Wasp larvae hatch out in the infertile ovules, grow and metamorphose, and, when they have developed into adult wasps, the males gnaw their way through to the females, fertilise them and die, without ever having seen the light of day. Meanwhile the male flowers of the fig have ripened and dust the fertilised female wasps with pollen as these make their way out of the mouth of the receptacle. Now, in May, the second and third generations of fig flowers appear. The second, called the *fichi*, consists solely of normal female flowers which the gravid wasps, while attempting unsuccessfully to lay their eggs in the ovu-

les, fertilise with the pollen from the first generation male flowers; these are the figs which ripen and are edible. The third generation, called *mamme*, consists only of gall flowers. In these the female wasps succeed in laying their eggs and the larvae which hatch out spend the winter in the infertile ovules to emerge as adults in the following February, when the whole cycle is repeated once more.

Many weeks have now passed since the June morning when I watched the meadow's awakening. The flowering grasses are all shorn from the hayfields and the bleached stubbles left by the mower are greening again with the aftermath. Only in hedgerows and field corners and on waste ground the fiorin and brome grasses and false oat bloom still and, among them, late summer flowers—knapweed, ragwort, scabious, St. John's wort, woundwort, betony and many more—have taken the places of the frothing cow parsley and tall foxgloves. The hedges are a uniform dull green broken only here and there by a spray of honeysuckle or a bush of late-blooming field rose whose cool dawn scent, pure petals and dazzling golden heart are refreshment to the senses on hot July days. The vegetation of the riverbank has changed too. In June, when the kingcups and lady's smocks had faded, there was little in bloom on the banks themselves but reed grass, yellow rocket, forget-me-nots, hogweed and a plant or two of creamy meadow rue with its long, tasselled stamens, but now the riverside is gay with massed blooms forming splashes of solid colour such as the summer meadows with their dispersed, pale flowers cannot provide. Tansy, fleabane and yellow loosestrife give the golden hues, with an occasional raft of monkey musk at the water's edge and, on the land side, a drift or two of meadow pea and lush-growing bird's foot trefoil. Purples range from the pale heliotrope of creeping thistle or pinkish mauve of hemp agrimony to the rosy magenta of giant willowherb and royal Tyrian of purple loosestrife. Highlights

of cream and white are formed by thickets of meadow sweet and solitary plants, as tall as shrubs, of hemlock, while the lower levels of the herbage are picked out with the white stars of water stitchwort and the solid heads of yarrow. Blue and red are lacking except for a late-flowering forget-me-not or two, but red's soft dilution, pink, is there, so generously spread that it might be said to form the background colour for the whole rich tapestry. In the river itself and by the water's edge amphibious peachwort forms a shell-pink border and, along the bank which in winter is an almost unbroken strip of glutinous mud, thousands upon thousands of plants of the giant balsam, *Impatiens glandulifera*, have sprung up and stretch away on either hand as far as the eye can see. This flower is sometimes called policeman's helmet, from the shape of its flowers, and sometimes jumping Jack, from the fact that its ripe capsules explode at a touch. I have also heard it called Indian or Japanese balsam; in fact it appears to have no fixed English name although it is more than a hundred years since it was first brought to this country from Kashmir and has now, like the North American Nootka lupin on the Scottish Dee and Tay, established itself along many an English river and canal. No stranger could be more welcome, for it is as handsome a plant as is to be found by the waterside. Its red, grooved stems, hollow and succulent, with swollen nodes, grow six feet high and more, and its glossy, pointed leaves which occur in pairs or in whorls of three have serrated edges and scarlet midribs. Often from the lower nodes of the stems red adventitious roots grow down to the mud to act as additional props and anchors. The large white and pink flowers, an inch and a half long and arranged in loose cymes, hang from their red pedicels like fragile chair-o-planes. The five petals—which look like three—are grouped into a two-lipped corolla, the upper lip being formed by one large petal and the lower by four petals, joined in pairs. The whole is backed by a fat, pink pouch, formed by one of three sepals and ending in a curly, green



Great Horsetail

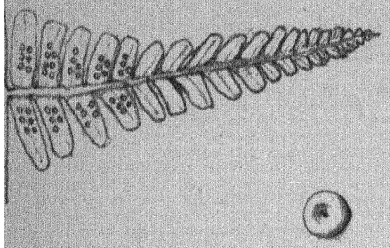
1. *Single sporophyll from above* 2. *Side view of sporophyll showing sporangia*

3. *Cross section of young barren shoot*

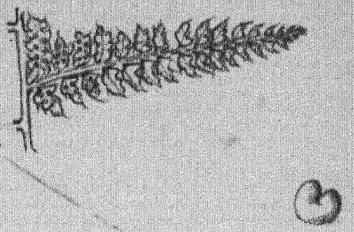
4, 5, 6. *Spore bearing shoots*

7, 8. *Young barren shoots*

Ferns



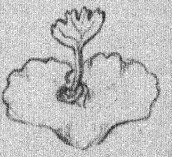
Male Fern : sori



Prickly Shield Fern : sori

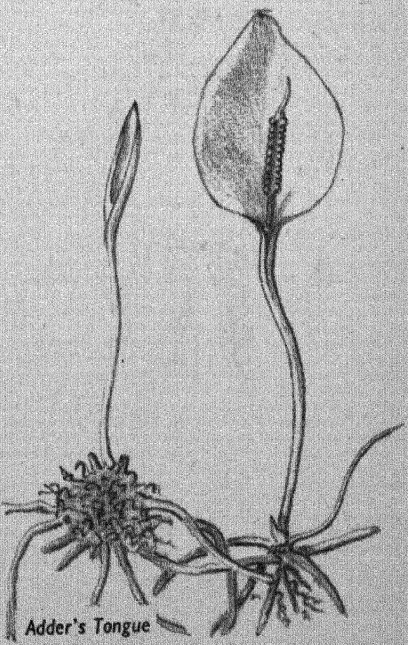
Fern prothallus

Underside



With young fern

Circinate vernation



Adder's Tongue

spur. The anthers of the five short, stout stamens are joined together round the ovary, and both ovary and stamens hang, as it were, from the roof of the flower. The long, slightly pear-shaped capsules are divided longitudinally into five compartments and, when ripe, explode at the slightest touch. From the moment that they come into flower in late July till the first frosts and equinoctial gales cut them down in autumn they continue to open their flowers by ones and twos, so that at all times you may see on any one plant every stage from triangular, purse-like bud to glossy capsule.

As I lay on the riverbank recently in the shade of these giant balsams, inhaling their cool, cucumber scent and watching the bees burrowing in and out of the fat pouches, I noticed a new thing: the joined stamens surrounding the ovary, after three or four visits from the nectar-seeking bees, became bodily detached from the ceiling of the flower and lay, like a tiny, five-pronged tooth, on the lower petals until dislodged thence by the next visitor. The green ovary with its conical style remained, fully exposed now to the pollen brought from neighbouring flowers. Here must be yet another of these floral mechanisms by which plants ensure that their ovules shall be fertilised with pollen from another individual. Cross-pollination, in the majority of plants, produces better seed and a stronger, healthier and more prolific second generation, for which reason the parts of most flowers and the times of their expansion are so arranged as to reduce as far as possible the chance of self-fertilisation. Most flowers are, potentially, self-fertile; that is to say, pollen from their own anthers will, if no cross-pollination has occurred and as a last resort, fertilise their own ovules, but some are so particular as to be sterile to their own pollen—a fact well known, of course, to all fruit growers who take care to plant their orchards with several different varietes of apple, pear, plum or cherry, so that one variety may act as a polleniser for another.

There are three main devices by which self-pollination is

largely avoided and cross-fertilisation made probable. The first of these, and the simplest, is the separation of the male and female parts. Sometimes separation is so complete that the pollen-bearing stamens are produced on one plant and the female flowers upon another. Of such are dog's mercury and the yew tree, which are wind pollinated, and the sallow and red campion, which are both pollinated by insects. Less drastic are those plants which have male and female flowers upon the same plant. If these are insect-pollinated, like the coltsfoot, the probability is that insects visiting the female flowers will have come from a neighbouring individual, but, if they are wind-pollinated, some further device is necessary to prevent the pollen from falling on the stigmas of its own plant. And here the second device comes into play, which is the uneven ripening of anthers and stigmas. In some plants the stigmas become receptive, are pollinated and wither before their own anthers are ripe; in others the anthers ripen first and are empty of pollen before the stigmas have matured. Examples of the first are figwort and plantain, the former pollinated by wasps and the latter by the wind. If you examine a newly expanded figwort bud, it has the appearance of a widely-opened mouth with the tongue—which is the stigma—curved down over the lower lip, while behind it two yellow teeth—the stamens—stick up on either side. At this stage the stigma is receptive of pollen but the anthers have not yet ripened. Look at the same flower a little later and you will see that the stigma has withered and the stamens, now fully ripe, project from the lower lip like two big, buck teeth.

The wind-pollinated plantain follows the same order of ripening. Each plantain head is made up of rings of tighly-packed flowers, each one of which has its normal quota of male and female parts, but all the pale, almost invisible stigmas in each ring of flowers in turn, beginning from the bottom of the spire, emerge together, without their accompanying stamens which will only ripen and protrude when

the stigmas have withered. Thus, though each plantain head bears male and female parts simultaneously, the male—as the flowers open in rings from the bottom up—are always below the female and the anthers in this way avoid dropping pollen on the stigmas of their own plant. Rose-bay willow-herb and ivy are examples of the opposite procedure: both are insect-pollinated and in both the anthers ripen first and shed their pollen before the stigmas become receptive.

A second method of controlling pollination is by the arrangement of parts in such a way that visiting insects will touch the stigmas and anthers in the required order. The shape of the flower itself and the position of the nectar, or other lure, determine the method and direction of the insect's approach, and the styles and stamens are then arranged accordingly. Generally speaking—according to those botanists who consider that elaboration of the floral parts is an indication of evolutionary progress—the more highly evolved the plant, the more complicated and exact will be the arrangement and interaction of its parts with a view to effective cross-pollination. In cup-shaped flowers cross-fertilisation is a fairly haphazard affair, as the pollen deposited by blundering bees and other insects is almost as likely to be from the flower's own anthers as from those of a neighbouring plant. Tubular and irregularly shaped flowers, however, can manage things more exactly. Primrose and purple loosestrife employ a mechanism called heterostyly; that is to say that the flowers on different plants have styles of different length. There are, for instance, two types of primrose flower; one, called the pin-eyed, which has a long style and, short stamens, and the other, the thrum-eyed, which has a short style and long stamens. In the first type the stigma, looking like a pin's head, occupies the throat of the flower, while the stamens reach no further than midway up the corolla tube; in the second type the positions are reversed and the anthers occupy the throat of the flower with the stigma some way below them. The proboscis of a bee, prob-

ing for nectar in a thrum-eyed flower, becomes dusted with pollen at the base, and this pollen can only come in contact with the stigma of a pin-eyed flower—and *vice versa*. Purple loosestrife follows exactly the same method but has three different lengths of style and stamens—together with a special bee, as Charles Darwin discovered, to work the mechanism.

The Labiates, a very highly evolved family which includes the dead nettles, woundwort, calamint, ground ivy, betony and many more, arrange their parts in such a way that their nectar is available only to those insects which are able to work the pollination mechanism. This nectar lies at the bottom of a long tube which generally divides at the throat into two lips; woodsage is exceptional in having but one lip. The two back petals join to form a hood over the stamens and style, and the three front petals spread into a platform with two bosses near the throat to which insects can cling. The space between the two lips is exactly wide enough to accommodate the heads or bodies of such insects as have tongues of sufficient length to reach the nectar at the bottom of the tube. In sipping the nectar the backs of these insects come into contact with the reproductive parts hidden under the hood which then give or receive pollen, according to whether it is the anthers which are ripe at the time of the visit, or the style, for these organs ripen successively, like those of figwort. In order to prevent such insects as are not big enough to work the mechanism from creeping down the tube to steal the nectar, the throat of each flower is often barricaded with fine hairs which are no bar to legitimate visitors but entangle the smaller fry.

Many members of the pea family have yet more intricate mechanisms. The shape of the flowers is exactly adapted to attract and accommodate the bees which are the only species of insect heavy enough—and intelligent enough—to work their mechanism. A conspicuous standard catches the bee's eye, often with nectar lines to show the exact place to probe,

and a convenient platform, formed by the two wing petals, is provided for it to alight upon and is placed over the keel in the exact position where the bee's weight will work the explosive or piston mechanism of pollination. The keel consists of two petals, face to face, and more or less joined along their lower edge. It is situated immediately under the wing petals and conceals the ten stamens and the style. These latter are in close contact with one another but, as the stigma is usually either self-sterile or only becomes receptive when it has been rubbed by the body of a bee, this proximity of style and stamens does not bring about self-fertilisation. The pollen from the anthers is often shed in advance into the tip of the keel whence, when the keel is depressed by the insect's weight, it is either pumped, brushed or suddenly exploded on to the bee's abdomen and even on to its back as well. The exact type of mechanism varies with each species, and some provide nectar and others only pollen for their visitors.

Broom is one of the pollen providers, and I well remember a morning in early June when I stood for long before a blazing bush of it watching certain tiny dark bees of a species unknown to me packing their pollen baskets with yellow grains and, in the process, fertilising the flowers. Each bee, after she had alighted on the wings of a newly-opened blossom, thrust her way through the tightly-closed throat of the flower and, as she did so, the keel appeared to explode, showering upon her a golden largesse for which she scrambled like a beggar for pennies. Busily she gathered in the yellow grains which lay scattered on the wing petals and carefully she combed the dusted hairs of her abdomen, packing the whole golden treasure into the already bulging pollen baskets on her legs. But the grains on her back and head she could not reach and they remained to fertilise another flower; for in the act of explosion the long, curved style concealed with the pollen in the keel of the broom flower is thrust suddenly upwards and, arching over the insect which has

alighted on the wings, hits it a light, sharp blow on the back; the stigma, which is non-receptive to its own pollen, thus coming in contact with pollen from the previous flower visited. The explosive mechanism once operated, the parts of the flower do not return to their original positions, but style, stamens, keel and wings remain hanging in the disorder in which the explosion has left them until the flower withers.

That it required a certain intelligence to work the broom's complicated mechanism was also clearly demonstrated on that day, for, of all the different species which visited the bush —and many were drawn to that golden blaze—only the small, dark bees became at all expert. Bumble bees were not interested in the wares offered; they were seeking nectar and not pollen and after a brief inspection they soon zoomed off to the white lilacs in the garden. Hive bees, similarly seeking nectar, crawled over flower after flower before they became convinced that there were no sweets here, while their sisters from the hive whose bulging yellow legs proved that their allotted task was pollen-gathering were very slow to find their way about the blossoms. Many, after examining half a dozen exploded and empty flowers, became discouraged and flew away and of those few which chanced upon hitherto unvisited blossoms only three, on that morning, had resolution enough to push their way through the tightly-closed throats.

As the broom is adapted to fertilisation by bees, so honeysuckle is adapted to pollination by moths, and though bees may buzz about its blossoms on hot June evenings they can obtain little satisfaction, for the nectar lure is concealed at the bottom of a tube so long that only a moth's tongue can reach it. No landing platform is provided, for moths hover as they sip. The dull reddish flower buds only begin to expand as evening approaches and as they open they sink slowly from a vertical to a horizontal position, giving out, meanwhile, a strong, sweet scent. As the two lips spread apart they expose the pale, creamy inner surface of the

flowers which glows in the dusk. At this stage the anthers occupy the throat of the flower and the style lies well below them on the lower lip. Hawkmoths, attracted by the sweet odour and guided by the gleam of the expanded petals, hover before the flower, probing the long trumpet for nectar and, as they do so, become dusted with pollen. In the morning, when all pollen has been shed by the anthers, the stamens and the style start to change places, and by evening have reversed their overnight positions. Now hawkmoths fluttering before the flower touch the sticky stigma and leave it dusted with pollen from a newly opened bud. Fertilisation thus accomplished, the petals' attractive function has been fulfilled and their creamy colour darkens slowly to an ochreous brown, while the fragrance weakens and, at last, dies away.

Of all flowering plants the orchids are, perhaps, the most elaborate. They are highly specialised and eccentric in many ways and not least in their pollination arrangements. Their reproductive parts differ from those of all other flowering plants, for all orchids in this country, except the lady's slipper, which is a somewhat primitive member of the family, have but one stamen and this, instead of being free, is joined to the back of the style to form a composite structure known as the column. Further, orchid pollen is not made up of a multitude of microscopic free grains as in other plants, but consists of adhesive masses of grains all joined together to form from two to four balls of pollen which are contained in two pouches, one on either side of the stamen. These balls of pollen are called pollinia and are often stalked, with an adhesive disc at the base by means of which insects are enabled to bear them bodily away. Lastly, the style, instead of rising free in the centre of the flower and terminating in three stigmas, as it does in the flowers of the orchid's nearest relatives, the lilies, forms the front part of the column and terminates, well below the top of the stamen, in two stigmas. The third stigma has been modified into a buffer organ,

known as the rostellum, which is situated between the pollen pouches and the receptive stigmas, and one of whose functions it is to prevent accidental self-fertilisation.

The attractive parts—form, colour, scent—of many orchid flowers are as carefully specialised as the reproductive organs. The flower is always irregular in shape, consisting generally of a lip and two wings, backed by three pseudo-sepals. The lip is often prolonged at the back into a pouch or long spur which contains the nectar or other sweet lure. The column occupies the throat of the flower where it must be encountered by any insect visitor. Colour varies according to the insect catered for, from the creamy white of the moth-luring butterfly orchids, to the strange patterning of the mimic fly orchid.

The actual method of pollination differs in each species but all are ingenious. One of the easiest to observe, and one of the most successful, is that of the early purple orchid. The chief pollinators are the bees for whom the lip of each flower forms a convenient landing platform; the lure is a sweet liquid concealed in the walls of the long spur. Above the mouth of the spur, where the bee's questing head must strike it, stands the column, whose lower half is hollowed out into a little recess about the width of a bee's head. The two stigmas form the viscid walls of this recess and it is overhung by a purse-like structure, full of a sticky liquid, which is part of the rostellum and is called the bursicle. Above this alcove stands the single stamen with its two anther pouches, each containing one pollinium. The pollinia are stalked and each stalk ends in a sticky disc which, to keep it moist till required, lies immersed in the liquid of the bursicle. A bee probing the spur pushes against the bursicle flap and comes in contact with the sticky discs which immediately adhere to her head, so that when she backs out of the flower she draws the pollinia with her. At first these, on their long stalks, stand upright on her head, but after a second or two, they bend forward from their bases till they are lying horizontally;

they are now in exactly the right position to come in contact with the cave-like recess formed by the stigmas of the next flower. The pollinia are big enough to be perfectly visible and it is amusing on a warm day in early May to watch the worried bees attempting to scrape these miniature cannon from their heads—but without success for the sticky liquid on the discs sets hard in a second or two. To see the mechanism in more detail and to watch the levelling of the pollinia cannon, it is only necessary to push a pointed stick or pencil into the throat of an unvisited flower and withdraw it with a pollinium adhering to each side. The pollinia of the greater butterfly orchid whose pollinators are the night moths diverge slightly outwards from the parallel as they bend forward, for the stigmas in this flower are placed one on each side of the column. The rest of the mechanism much resembles that of the early purple orchid with the modifications necessary to accommodate the moth pollinators.

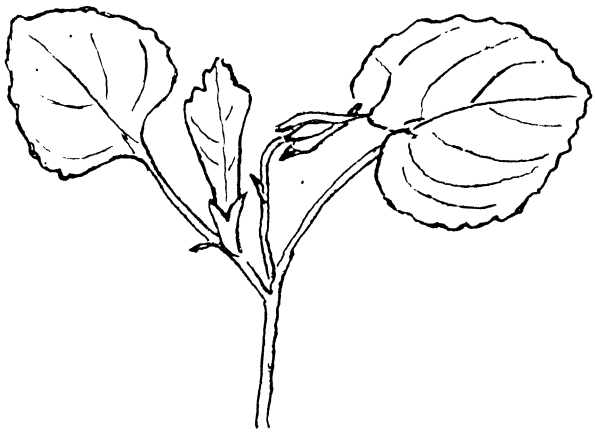
Of all the orchids in this country the early purple is one of the most successful; it is abundant everywhere though its numbers in any one locality vary considerably from year to year owing to the fact that each plant flowers but once and then dies. Its success as compared with other orchids is due, perhaps, partly to the fact that it is not so slow in developing as some—as, for instance, the twayblade which grows for anything up to fourteen years before it flowers; and partly to the fact that it is able to set a very high proportion of its seed. Its pollination arrangements evidently work well: the colour and faint scent of the flowers are attractive to bees which are common insects in April and early May when the orchid flowers; the central spotting of the lip shows the way to the spur whose sweet liquid is a satisfactory lure; the mechanical arrangement of the reproductive parts brings about exactly the required result. Not all orchids, however, are so successful. Many, from over-specialisation, have overreached themselves and are seldom or never pollinated by the insects for whom they must originally have catered.

Either the insects in question have altered their habits or become much scarcer or died out altogether, or, perhaps, through over-refinement the flowers have ceased to be attractive to them. Such orchids in order to survive have been forced to evolve a method whereby self-fertilisation is made possible after the attempted cross-fertilisation has failed. The rostellum, which lies as a buffer between the anthers and the stigmas of orchid flowers and whose original function it was to prevent that which it is now desired to bring about, is the main obstacle to automatic self-fertilisation. The bee orchid, which, for some reason, is seldom visited by insects, overcomes this obstacle and effects pollination by dangling its stalked pollinia over the edge of the rostellum so that these pollen masses sway against the sticky stigmas. After a certain time, if a bee orchid flower has not been visited by any outside agent, the stalks of the pollinia wither and shrink, and as they do so the club-shaped pollen heads are drawn out of the anther pouches and flop over the rostellum, being held in place by the sticky discs which remain immersed in the bursicle.

The helleborines have gone a stage further than the bee orchid towards dispensing altogether with cross-fertilisation. In fact the orchid tribe offers examples of every stage along the evolutionary road from dependence on an outside pollenising agent to complete self-sufficiency in the matter of fertilisation. The least advanced members, such as the broad-leaved and violet helleborines, are still dependent on insect visitors, though the rostellum is already smaller than in most other orchids. In the green-leaved helleborine the rostellum withers in the bud and the flowers are entirely self-fertilised; the pollinia when they are fully ripe swell up into a fluffy mass which wells over the rudimentary rostellum onto the stigmas. In the most advanced—or decadent—members of this group, not only the rostellum but the very column itself withers before the flowers open and, in fact, in the Isle of Wight helleborine the flowers never do open; they have no

need, for the petals no longer have any attractive function. So drastically simplified, indeed, is the helleborine that it is thought to set seed without fertilisation by a pollen male cell—a process known as apomixis.

Self-fertilisation within a much simplified and unexpanded flower, known as cleistogamy, and the process of apomixis are not peculiar to the helleborines, though it is only in these orchids that the two methods of fertilisation are obviously a sign of decadence—of the simplicity, not of primitive ignorance and energy, but of weariness and degeneration—for the helleborines that employ these methods are exceedingly rare and certainly of low vitality. The Dicotyledonous flowers, on the other hand, which practise the same methods, are among the commonest, most pushing and apparently most successful flowering plants in the country. Nevertheless, they, too, are thought by certain students of evolution to be on the downward path towards extinction. The violets, heartsease, wood sorrel and red deadnettle all bear cleistogamic flowers which, in the case of the first three, differ very greatly from the large, showy blooms which take the eye. After the purple dog violets have faded along the



CLEISTOGAMIC FLOWER OF DOG VIOLET

edge of the wood, and when the leafy canopy above them has thickened with the summer growth of the trees, the violet plants put out secret flowers under their broad leaves; they are short-stalked, small and petal-less and remain enclosed in the green sepals, but the hidden stamens drop pollen on the hidden stigma and the flowers set seed as well as or better than, the seductively coloured blooms which the insects visited in May. The wood sorrel and the heartsease—that little pansy of the arable fields—do likewise, while the red deadnettle, or red archangel, independent of the sleeping bees, can set its own seed all winter through in the warm, pink cave of its unexpanded bud.

The dandelion, on the other hand, the hawkweeds and, possibly, the blackberries all practise apomixis. In spite of their bright, attractive heads they have no need of the services of insects. If their petals are cut off, and even their stamens and their styles, the ovules will still ripen into seed. These flowers, too, like those which reproduce vegetatively have discovered the secret of personal immortality; for countless generations their individual protoplasmic streams have flowed, undiluted, undeflected by those of other individuals of their species. They appear to be among the most vital and rapidly evolving of all the flowering plants and are constantly developing new species. Of blackberries alone more than 400 sub-species have recently been listed and almost every district of England supports its own particular hawkweed. Yet nowadays this is thought to be an unhealthy activity which will lead eventually to race suicide.

But now pollen time—mating time for the flowers—is drawing to an end. The wild cherries and strawberries, the raspberries and bilberries have long since shed their petals and offered their bright berries to the birds, and the first blackberries are already ripening; sign that the season of growth has passed its climacteric and is slowly descending towards autumn, the time of fruits. Summer is racing by

with terrifying speed. No birds sing now in the quiet, misty dawns and the cuckoo has long been silent. The swifts have deserted the wide spaces of the air where, cloud-high on midsummer afternoons, they swept and circled, or, in July dusks, fled screaming low across the darkening water meadows. All growth has ceased in the full-foliaged trees, except where an oak or hawthorn, here and there, making a last effort has put out its spring-green and orange, or bronze and crimson, lammas shoots. The flatness of achievement after much striving seems to fill all living things; they have reached the goal which they had set themselves; they can do no more, but the unresting tide of life, having reached its highest point, is already on the ebb. In the valleys, at this time of year, as the eye passes from the seedless heads of the withering grasses to the heavy trees, brooding over their own shadows, the fear of winter—of night, of death—seems to constrict one's heart, like the grasp of a physical hand. During the gentle decline of autumn this paralysing dread is soothed to a sad resignation, and winter's dark endurance is soon lit by the hope, the certainty, of the imminent rebirth of spring. Never again will the dread of the three great Negatives strike with such poignancy as now in the last weeks of summer.

But yesterday on the heath where we went to gather the luscious first-fruits of the blackberry there were no brooding trees, no withered meadow grasses to mar the beauty of the present. From the belt of brambles which was our objective there stretched a gently sloping hill covered with purple heather, now at the height of its flowering. Its honey scent rose like a heat-haze under the sun and was wafted hither and thither—now warm, now cooler—by a little breeze, and the wind as it came and went swelled or diminished the rustling of hare-bell cups, the shrill song of grasshoppers and, among the papery heather blooms, the bourdon of innumerable bees. As I stretched out my hand to gather a low-growing spray of berries I saw just beyond my fingertips an adder

basking on an anthill. It raised an arrogant head and, for a moment as we gazed at each other, I could see its crimson eyes, glinting like rubies in the sun, and in its half-open jaws the white, jagged line of its teeth, set in black gums. Then, slowly it swayed its neck, but before it could fasten its fangs in my hand my companion struck it with a stick and now, all its arrogance gone, half-paralysed, it sank its head and turning made blindly for sanctuary among the blackberry stems. But another blow killed it and at that moment I felt so great a pity for this poisonous creature to whom death had come because of my fear that the sun seemed for a little to lose its warmth and the sky and the heath their bright hues. Nevertheless, the snake and its venomous, proud head and the pathetic humbling of its pride and, more than all, the nightmare slowness of its blind flight and my pity for its helplessness and death give, in memory, point and poignancy to the perfect day, enhancing its colours, deepening its perspectives and preserving for ever in my remembrance each insignificant detail of its course.

When our baskets were, at last, heavy with fruit and our hands dyed with the imperial purple of its juices we made our way towards a stand of pines that stood outlined against the sky on the brow of the hill. In the distance, in that blue, shimmering air, they seemed rather the two-dimensional creation of some scene-painter than living trees, but, as we drew near, their resinous breath and the long sighing of the breeze among their branches endowed them with life. Leaving our baskets in their shade we wandered on towards an area of marshy ground where a small brook had its source.

Here, also, the heather grew, though the waterlogged, peaty soil under it was totally unlike that of the sandy heath behind us. The water of the bog, however, is no more available to the heather than the quick-vanishing moisture of the sands, and the whole plant shows in its narrow leaves and sapless aspect that it is adapted to a droughty habitat. Excess of moisture at the roots of land plants means lack of

oxygen without which the root hairs cannot breathe nor perform their proper function, and, as we have seen already in the winter trees, the reactions to this suffocating excess are the same as those of drought-enduring plants to the actual lack of water—that is, an immediate reduction of all transpiring surfaces and rigid conservation of the available water supply. So, heather is a drought-loving plant that is able, nevertheless, to live in an acid, waterlogged soil that would kill most other land plants, and it owes this adaptability, in part, to the curious fact that it lives its whole life in the closest possible association with a microscopic fungus. Through every cell of the heather—in root, stem, leaf and flower—wind the fungus threads; even the stamens and the ovaries are not free from them, and every ripened seed contains a tiny fragment without which it could not develop and grow. The association is normally one of mutual benefit: the fungus performs the function of root hairs of which heather has none, and thus provides water and salts from the soil and, also, it is thought by some botanists, free nitrogen from the air; while heather affords the fungus a sheltered growing medium and, possibly, also some nourishment in the form of manufactured goods such as sugars and starches. Normally the fungus never fructifies: it remains in abeyance; but let conditions of growth become unfavourable to the heather, let the soil in which it grows become alkaline, for instance, through the addition of lime, or let some disease attack it, and immediately the fungus gets the upper hand, becomes rampant, consumes its host alive, fructifies, and dies.

Thinking of the heather's strange way of life we pursued our way down the little stream, stopping from time to time to admire the innocent colour and the fragile strength—like blown glass—of the harebells, or to tell over the musical names of the mountain flowers—tormentil, asphodel, rock rose, grass of Parnassus—or to note the tiny holes at the bases of bell heather's waxy-pink blooms, where bees had forced an illicit entry to the nectar. At a turn of the stream

we came upon a small bog and, searching the squelching sphagnum moss, our eyes soon picked out the glitter of drops on the leaves of a sundew. Two flies were caught among the oozing hairs—one a mere husk, sucked dry, and the other newly caught, still struggling feebly while the marginal hairs of the leaf curved slowly, inexorably towards it, exuding already the digestive juices by means of which they would extract the proteins from their victim. We stopped to tease the plant a little, first with water drops which it ignored, and then with a withered grass head which caused the teased leaf to start its slow, implacable movement inwards towards the point of stimulus.

Only three kinds of plant in this country have been proved to be carnivores: the sundews, the butterworts and the bladderworts, and, as all are associated with a habitat where nitrogen is hard to come by, it is thought that it is to supply this deficiency that the curious habit has been evolved. Butterwort, which takes its name from its greasy, yellow-green leaves, is common on Scottish bogs and by burnsides and waterfalls where its violet flowers, rising singly from a rosette of pointed leaves with inrolled edges, jewel the treacherous sphagnum or gleam, spray-sprinkled, from some grassy ledge on the wall of a cascade. Its prey for the most part consists of tiny midges which are trapped by the viscous leaves and held fast until the process of digestion is complete.

Both sundew and butterwort have poor root systems; bladderwort has no roots at all. It is a water plant which lives perpetually submerged in the acid waters of northern lochs. Its only aerial part is its flower, but it seldom in these islands succeeds in flowering and is forced to rely on vegetative reproduction for its survival. Its underwater animal trap is formed from the modified segments of some of its much-divided leaves. These segments take the form of small bladders, a tenth of an inch long, closed at the free end by a valve surmounted by a few long, branched hairs. The internal walls of the bladder, which are impermeable to water, are

furnished with four glandular hairs which suck up the water from the interior till the walls collapse on each other like those of a sucked orange. The trap is now set. Presently, some small creature encounters the long, branched hairs on the lid of the bladder and becomes entangled in them. In its struggles to escape it forces the valve ajar and, immediately, a rush of water floods the empty bladder, bearing the creature with it, and the valve closes once more. Soon the victim dies and the bladderwort digests its corpse at leisure, meanwhile setting the trap anew.

Leaving our sundew to deal with its latest catch and continuing our way downstream we came soon to a rocky bluff over which the brook, now running under rowans brilliant with vermilion berries, flung itself in a loud cascade. Without a long detour we could follow it no further, so, climbing a vantage point which gave us a view westward towards the invisible but not far distant sea, we rested in the heather. Before us spread a gently undulating landscape of fields, woods and pastures through which for many miles we could trace the ever-widening waters of our brook. First they slipped invisibly through acres upon acres of the intolerant brake-fern whose greedy, pushing rhizomes and smothering fronds inhibit all other vegetation. Then the brake weakened, grew less sturdily and, at last, gave way to rocky pasture through which the brook's course was marked by a broad belt of marshy land set with clumps of hard rush, like bristles in a worn-out brush. Beyond this poor grazing, arable fields began, bare and straw-coloured where the early oats had already been harvested, a wavering gold for the uncut barley and where the horse hoes had newly cleared the rows of roots and kale, a deep green striped with reddish brown. Saffron yellow patches here and there showed where corn marigolds in their millions had invaded the crops, and a paler yellow meant a resurgence of the long-enduring charlock. In the nearer fields it was possible to distinguish on the headlands white napkins of scentless mayweed and coral-

pink, billowing cushions of the peachwort which country folk call redshanks or lambs' quarters. Drystone walls and an occasional hedgerow chequered this man-made landscape, but the brook took no heed of these and wandered at will from enclosure to enclosure, its meanders marked at first by alders and birches and an occasional gleam of open water, and then by ever denser woods of scrub oak and sycamore until, at last, a spur of rising ground hid it from sight.

With the mind's eye, however, we could follow it still as it broadened into a desolate estuary on whose saltings, among the mauve sea asters and withering thrift, small flocks of curlews and oyster-catchers and restless congregations of great gulls awaited the turning of the tide. Not many weeks before, on a summer expedition, we had followed the last sinuous mile through acres of flowering sea lavender and grey sea purslane, pocked with pools of shining mud which, bare of all vegetation, reflected the sky on their glistening surfaces. At first the same grey muds, silted into banks four feet high, hemmed in the waters of the brook—now grown into a river—but where the sea tides met the current, the river's walls were flattened into greasy plains of ooze where grew miniature forests of marsh samphire whose erect branches seem jointed like wooden toys and have the colour and polish of jade. The jointed appearance is given by the pairs of succulent, almost translucent leaves which, fused together by their margins, form a series of tubes around the stem. Glasswort is another name for this plant, for its tissues, rich in soda, were once much used in glass making. The samphire plains were bounded on the seaward side by banks of shingle through which our stream broke its way at last to the sea, and on the shingle the wild beet grew and cushions of sand spurry and the frosty-leaved horned poppy with the long, curved seed pods which give it its name; its tissue-thin, yellow petals though they are said to last a day are, in fact, so precariously attached that buds that open in the morning are almost always shattered by noon, so that you must go

early in the day to see them in perfect bloom, before the sea breezes have wrought their havoc.

These poppies and the beet were the last outposts of the land vegetation. At their feet the seaweeds began. First, in stagnant pools refreshed only at the highest tides, flourished the green algae—sea lettuce and the gas-inflated tubes of the aptly named *Enteromorpha intestinalis*. Then, clinging to every rock and stone with their tenacious discs, the brown wracks which can survive for long hours out of their native element, the sea. And last, beginning at the level of the ebb and extending seawards to a depth of fifteen fathoms, the tangle weeds—an impenetrable forest of huge fronds, on and among which grow the smaller red seaweeds, the edible dulse, carrageen moss and tough laver. Beyond the fifteen-fathom mark the light is insufficient for the growth of any plant and thereafter the barren sea bed stretches naked under its dark waters.

So, in our mind's eye we traced the course of our stream to its bourne. But now it was evening and the sun, nearing the horizon, had lost the white heat of noon and shone with a red glow as of cooling embers. Above its upper rim, presaging rain, there slowly gathered a quilted cloud, the colour of ripe damsons and, as we rose and turned to retrace our steps, pursuing our antic shadows over the heather, a wind rose at our backs which tattered the damson-coloured cloud and blew out long streamers from its upper edge. The pine trees which sheltered our baskets were groaning already under its pressure, and by the time we reached home and darkness had fallen the wind was full of rain which slatted against the windows and dripped from the gutters. In the night the wind dropped and the beating rain turned to a soundless drizzle, scarcely heavier than mist, so that this morning the valley is hidden in an almost impalpable veil of moisture whose droplets lie like hoar frost on the clover leaves and condense silently on the foliage of the orchard trees. A slight gust from time to time shakes the sodden

boughs, scattering with a sudden burst of sound the collected drops and, here and there, detaching a moon-yellow leaf from the laden plum trees. The orchard paths are slippery already with an autumnal debris.

4

Autumn: Back to the Woods

In our temperate lands the broad annual pattern of growth remains unchanging: a slow undulation rising from the shadowy depths of winter to summer's sunny height, pausing there a moment, then descending again into the shadows. But no two years follow exactly the same course; the spring and autumn slopes are steeper or gentler, darker or brighter according to the season. This year autumn's decline has been like the slow curve of a southward-facing down, illuminated still by the red sun of evening, but stippled and cross-hatched with the multitudinous, thin shadows of its grasses and striped here and there with the denser shade of juniper or thorn bush.

No frost has come as yet to paint almost overnight autumn's flamboyant colours on the woods, though single trees and even single branches have, nevertheless, taken on October tints. The leaves of the ash trees, for instance, that stand apart in the hedgerows have turned the colour of Chartreuse which, in the sunshine, gives the trees an insubstantial grace, as of fluttering fountains of white wine. The drooping boughs of birches are as though floodlit from below where the lower leaves have yellowed to the colour of lamp flames. In the forest, single tongues of fire sweep upwards from the summits of the beech trees, and solitary, blood-red spearheads hang from the boughs of the wild cherries. Some woodland maples have gone further and stand almost bare already among their fallen foliage which lies about their feet like patches of autumn sunshine, the more brilliant in that these are as yet the only leaves to lie on the forest floor.

Such slowly changing tints are the outward sign of the

put out its flowering shoots. These are quite unlike the climbing stems, for, springing straight upwards and outwards from their support, they possess none of those adventitious roots by means of which the main stems cling and climb. The colour of the leaves is paler and yellower than that of the older foliage and their shape, by a gradual transition from the familiar five-pointed outline of the lowest leaves, is heart-shaped or a pointed oval. Moreover, these leaves grow alternately round the stem with none of that twisting of the petiole which ranges those of the climbing stems into two ranks facing the light.

On a sunny day, even if the yellow-green balls of blossom are hidden from sight, they may still be discovered by ear, for they will be alive with honey bees, bumble bees, wasps, drone flies, hover flies and bluebottles, all sipping away for dear life at the abundant nectar which will be their last meal of the year before death or the semi-death of hibernation overtakes them. Butterflies, too, may visit the flowers on their way to and from the Michaelmas daisies, and so intent are all on the feast that you may catch them at will, or with a hand lens held an inch from their enormous eyes watch their probing tongues or note their colours and patternings: the black and orange plush of the great queen bumble bees, the tawny velvet of hive bees, the yellow stripes of the wasp and its imitators, the brown satin of drone flies and the iridescent taffeta of bluebottles and blow flies. Most beautiful of all the casual visitors are the brimstone butterflies which flutter down like falling autumn leaves, coloured sulphur and primrose yellow, like the sere foliage of spindle or garden plum, and marked in the same way with darker veins. An orange-yellow 'eye' marking the centre of each wing, a red thorax and antennae, and delicate crimson pencillings along the front edges of the forewings give them a last touch of beauty.

In spite of the lateness of its flowering there is no commoner plant than ivy, for its abundant nectar draws to it

nearly every pollenising insect still on the wing at this late season and these, as they sip and crawl over the blossoms, set the seed which in 'hungry gap' of early spring will ripen into the black, purple-juiced berries so beloved of wood-pigeon. Just as the flower is nearly unique in autumn and by its singularity attracts the insects it requires for fertilisation, so its fruit, by its uniqueness in spring when other fruits are scarce, attract the birds needed to disperse the seed.

Meadow saffron, too, was once a common plant and abundant in pastures in the south, but so poisonous are its leaves to cattle that it has now been nearly eradicated from its old haunts and, in this district at least, is only to be found in open glades in the woods or in tangled field corners. It is certainly the most beautiful flower of the autumn, much resembling the autumn crocus with which is often confused though that flower does not grow truly wild in this country. Meadow saffron's old popular name of naked ladies seems to suit it well, for its rosy-purple, softly curved buds rise straight from the ground without stalk or foliage. The corm of the plant will always be found to lie just below frost level, and from it springs directly the long, tubular perianth of the flower, which above ground expands into a delicate six-pointed star, three inches across, with an orange-yellow heart, formed of the six large stamens and three styles. The stamens rise from the throat of the flower, but the styles extend down the whole length of the perianth tube till, far underground, they join the ovary which lies almost directly on the corm. So long are these that, after the flower has been pollinated, the pollen tubes take seven or eight weeks to reach the ovules. By this time it is late autumn and over the cold season the ovary, safe from frost at the level of the corm, remains dormant, and only with the first warmth of spring begins to develop and ripen. Then, in May and early June, when all other green things are in bud and bloom, the ripening seed capsules, borne on a long stalk, thrust above

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ground amid a tuft of glossy, strap-shaped leaves. It is these leaves, growing among the June grasses and cut with the hay, that are the chief danger to cattle.

Other late summer and autumn flowers are goldenrod, that yellow aster of the woods, and the umbellate and Savoy hawkweeds whose leafy stalks and late growth distinguish them from the host of their relations. But it is the seeds and fruits, of course, which are the speciality of the season, and particularly those such as hazel nuts and apples which need a long period for development and ripening. Every hedgerow and wood border is full of them and it is they—the crimson hips, the maroon-coloured haws, the yellow and vermilion berries of bryony, the shining, scarlet, massed fruits of the guelder rose, the coral pink and orange spindle berries, the purple sloes—which, together with the turning leaves, give autumn its typical colouring. Spring is clothed in all the higher colours of the spectrum, green and blue and violet, but autumn keeps to the lower ranges of orange and red.

In the vast majority of flowers fertilisation has now taken place: the pollen grain, deposited on the sticky stigma by an insect or the wind, has elongated into a tube whose tip, chemically attracted by the flower's ovary, has grown down towards it, piercing the tissues of the style and nourished on its way by the juices of the cells which it traversed. Entering the ovary this pollen tip has found its way through the micropyle into one of the ovules and there discharged the two male nuclei which it contained. These have fused with the female nuclei in the embryo sac and the young seed has been formed. Thereafter many changes have taken place in the ovule and the containing ovary—changes almost as diverse as the flower species themselves. The ovule has enlarged and contains now, besides the embryo, a certain store of nourishment for the plant to be. A skin, called the testa, has hardened round it whose markings are often sufficient in themselves to identify a species. The testa of petty

spurge, for instance, is finely pitted on the outer side of the seed and marked with two furrows on the inner side; Crucifer seeds have reticulated coverings of different mesh, and chickweed and its relations a testa rough with warts of varying size. The ovule has now become a seed fit for sowing; all activity within it has now died down; it is dormant and, protected by its hard coat, it can lie snugly in the soil throughout the cold season until such time as proper warmth and moisture start it once more into life.

The ovary, which may contain only one seed or many, has changed too, and has ripened into the fruit. Its walls have either become desiccated or have plumped out into a fleshy covering, or they may have divided into two layers, an outer juicy envelope and an inner hard coat round each seed. Dry, many-seeded fruits, which must split open in some way to allow the seeds to escape, are known as capsules. The specialised capsules of the pea family, which open down both sides, are termed pods or legumes, and those of the Crucifers, siliquas or silicules according to size and shape. A capsule splitting down the inside only is called a follicle and a good example of it is the many-seeded carpel of the marsh marigold. The capsule is one of the commonest types of fruit and may open in a variety of ways. In the violet it splits longitudinally into three boat-shaped sections, each containing its quota of tiny seeds. The round capsules of the scarlet pimpernel, which are about the size of a small dried pea, splits around the circumference and the free end, looking with its withered style like a tiny fawn juliet cap, lifts bodily off like the lid of a pan. Chickweeds, campions and many of their relations have capsules which split at the top into a number of small teeth. These remain interlocked until there comes a warm, dry day, suitable for seed sowing, when they open out and allow the contents of the ripened ovary to escape. The poppy's capsule is a most elegant piece of work, shaped a little like a tobacco jar with a decorative lid: the ovary forms the round body of the jar and the eight or

PODS

Legume or pod of Meadow Pea
Siliqua of Wallflower

CAPSULES

Violet
Scarlet Pimpernel
Poppy
Balsam

more flat, stalkless stigmas, raying out from the centre and somewhat overlapping the ovary all round, form the moulded lid. The capsule does not split, but a ring of small holes appears round the sides, just below the lid and between the rays formed by the stigmas. Through these perforations the dust-like seed escapes. The seeds of the harebells, too, escape through tiny pores in the base of the pendant capsule.

Dry fruits which either do not open in any way or else divide into separate carpels, each containing only one seed, are known as nuts if their outer coats are hard and woody, or as achenes if their covering is thin and membraneous. The nuts need no description: hazel nuts, acorns, beech-nuts and sweet chestnuts are all true nuts; the nut itself in each case is the whole fruit, that is, the ripened ovary containing the seed. The hazel's husk, the acorn's cup and the prickly coverings of beech-nuts and sweet chestnuts are extraneous bracts,

modified to protect and hold the ripening fruit. The walnut and the horse chestnut, on the other hand, are not botanically nuts at all; the green, fleshy envelope of the former and the latter's prickly covering do not derive from bracts but are the modified walls of the ovary itself and are, therefore, a true part of the fruit whose outer coat is thus not hard but fleshy.

Among flowering herbs, achenes of a hundred different forms are, perhaps, the commonest type of fruit and each family specialises in its own variety. The four shining nutlets of the Labiates, for instance, are so typical that they constitute the best distinguishing feature between this family and the *Scrophulariaceae* whose flowers, because they, too, are irregular are sometimes confused with those of the two-lipped Labiates; but the fruit of the *Scrophulariaceae* is a capsule. Among the *Compositae* the typical form is an elongated, seed-like fruit surmounted by a crown of silky hairs, called the pappus, such as go to make up the dandelion clocks in June, and so great a likeness is there between certain members of this family that the colour—buff, white or grey—and the form of the pappus are often the main identifying features. Winged fruits such as those of maple, ash and sycamore are also achenes, but of so well-defined a form that they have been given the special name of samaras.

Examples of achenes formed of single-seeded carpels are afforded by the long, dry fruits of many of the wild geraniums whose beak-like shape gives the cranesbills and storksbills their names. The elongated carpels, each containing one seed, break away at the base from the central axis and curl outwards and upwards towards the tip of the beak until eventually they break off altogether and fall, with the seed still attached; the long tip of the carpel sometimes twisted into a species of gimlet which pierces the soil and thus serves to anchor the seed.

The dry fruits of the Umbellate family—the wild parsleys, hogweed, angelica, wild carrot and many more—consist also

of carpellary achenes, two to each fruit, and these achenes bear so close a resemblance to seeds that a microscope is needed to disclose the fact that the outer coat is not the testa but the dried carpel wall. Their form is again typical of their family: most of them are marked on the outer side with a series of prominent ridges which are sometimes expanded into wings and sometimes into rows of spines. Many species, in addition, possess within the seed itself longitudinal channels filled with an oily or resinous substance which appear on the outside as long, brown scars running between the ribs; these are called vittas and are a speciality of the family. The number or modelling of the outer ridges and the presence or absence, distribution and length of the vittas are often the best or, indeed, sometimes the only feature to distinguish one species from another. Even at this season of the year when nothing is left of the white, lacy umbels and ferny foliage but the withered and weightless flowering stems it is possible by examining the fruits to say with certainty that such and such a species grew here. For instance, at this time, on every river and stream bank, in wet hedges and ditches and on waste ground the seeding heads of angelica and hogweed rise stiffly from the sodden herbage and clash together faintly in the wind; to a casual view their buff-coloured panicles of papery discs, borne aloft on stout, ridged stems, are almost indistinguishable, but a single fruit examined under a hand lens soon reveals the identity of the plant from which it came. Each fruit will be seen to consist of two discs—the ripened carpels—at first pressed closely together, but later separating from the base until they both hang free from the tip of a central, hair-thin filament. Hogweed discs are bigger than those of angelica and are of a lighter hay colour; each is surrounded by a narrow, papery border and is marked on the outer face with three or five fine ribs, running from top to bottom; alternating with the ribs and half their length are four scar-like vittas, and on the inner face are two additional vittas, like long, inverted

commas, reaching midway down the disc. The snuff-coloured carpels of angelica hang two by two in the same way as those of hogweed, but the central filament which supports them often itself splits into two yet finer threads, one for each carpel. The discs are less flat than hogweed's and each is bordered with two broad, membraneous wings which bend outwards, while the main body of the carpel, where the seed lies, is slightly curved inwards. Between the wings, three prominent, light-coloured ribs run from top to bottom of the outer face with four dark vittas between, and two long, dark vittas stripe the centre of the inner face.

Two other members of this family which are much alike are cow parsley and hedge parsley, and these two are often confused with one another, although the former is the earliest of all the umbelliferous plants to flower and the latter does not bloom till late summer. Their fruits at once distinguish them, for those of cow parsley, shaped like elongated flasks, are smooth, black and shining, without visible ribs or vittas, while those of hedge parsley are covered with hooked bristles and have the appearance of small burrs.

The fruit of the ill-omened hemlock, with its waved and crenellated ribs and its deeply scored inner face, serves infallibly to distinguish this slayer of Socrates from its scarcely less poisonous relative, the hemlock water dropwort. Many people appear to confuse these two though the latter is a coarse, ungainly plant which grows in, or at the edge of water, and the former, which prefers a dryer situation, is most graceful in its growth; given elbow room it will attain the height of a small bush, putting out its pale-green, maculate branches with perfect symmetry and clothing them with feathery foliage and delicate, lacy flowers.

But of no member of the *Umbelliferae* can it be more truly said 'by their fruits shall ye know them' than of the wild carrots. Their seeding heads can be picked out afar from among the tangle of herbage in a pasture or dry bank, for after flowering the rays of the umbels bunch together, the

ACHENES OR NUTS

Woundwort Dandelion Carrot
Hogweed Goosegrass Avens
Hazel Lime Sycamore (samara)

APPLE FALSE FRUIT

Swollen receptacle Ovary embedded in receptacle
Ovary (core) Seeds (pips)

long, outer arms bending inwards over the short central rays to form a sort of untidy basket—a habit quite unique in the family. Closer at hand, the individual fruits are as typical as the seeding heads, for they are as prickly as hedgehogs.

Fleshy fruits do not as a rule split open to emit the seed but fall all in one piece. They rely on decay or the beaks or digestions of birds to set their contents free. An exception is the spindle berry which is no berry at all but a capsule. Botanically a berry is a succulent fruit containing one or many seeds. These seeds, with no further covering than their own seed-coats, are embedded in the pulp which, in its turn, is surrounded by the skin of the fruit. Holly, honeysuckle, cuckoo pint, bilberry, the bryonies, white and black, the night shades and a host of other plants, including the tomato, produce berries. Not all fruits, however, which are commonly known as berries are botanically such; many are in

reality drupes. In this form of fruit the original ovary wall has developed into two layers, an outer fleshy envelope, and an inner hard coat surrounding the seed, the whole enclosed in a skin as in the berry. Two of the most obvious and familiar drupes are the sloe and the cherry; both the succulent portion of these fruits and the woody outer coat of the stone have originated from the ovary wall; the kernel inside the stone is the seed. Not all drupes are so obvious as these, for the berry-like haw is, in fact, a drupe with several 'stones;' the walnut is a drupe; and the blackberry is a collection of drupes, each of its succulent pips being a fruit in itself.

Some of the best-known fruits of all, such as the pear, the apple and the strawberry are botanically known as false fruits, because the fleshy and attractive part of them is formed, not from the ovary wall, but from some other part of the flower. In the three fruits mentioned and in the rose hip this part is the receptacle, or floral axis—the tiny disc or cone round which the parts of a flower are arranged. In the case of the strawberry the receptacle has swelled up into a scarlet cushion in which the achenes, or 'pips,' are embedded; in the case of the apple and pear it surrounds the core which is the ovary, containing the seeds; and in the case of the rose hip it has become a succulent, red flask within which are packed the many achenes. The mulberry's false fruit is composed of four fleshy 'petals' surrounding an achene and each mulberry is made up of many achenes just as each blackberry—or raspberry—is made up of many drupes.

The fruits of the more primitive conifers differ from those of the higher flowering plants in having no ovary. The ovules lie naked between the scales of a female cone, with the micropyle pointing inwards, and are there pollinated by wind-borne pollen from a male cone. The typical fruit that develops is the woody fir cone of the pines, larches and firs which consists of a series of overlapping, lignified scales, behind each one of which lie two winged seeds. Fircones are as typical

of their species as are other fruits: those of the Scots pine are short and pointed and covered with bosses formed by the thickened tips of the scales; they always hang downwards. Those of the larch, on the other hand, stand upright and are small, short and rounded. Each scale of a Douglas fir cone bears upon its back a three-pronged bract, while a single long, pointed bract, bent backwards at the tip, decorates the scales of the silver fir cone. Both these latter cones are produced at the ends of branches, but the first hangs down and the second stands erect.

These are all typical coniferous fruits, but the yew tree and the juniper, which are both conifers, bear fruits which have the appearance of berries. That of the juniper, however, in spite of appearances is in reality a small, fleshy cone, with the seeds embedded in the succulent scales; and that of the yew is a single, naked, bottle-green seed lying at the bottom of a waxen, scarlet cup whose function is to attract the birds; this cup is formed from the enormously enlarged 'stalk' of the seed, called an aril. Even here the rudiments of a cone may be seen in the small, yellowish scales at the base of the 'berry'.

Though autumn is pre-eminently the time of fruits, yet there is no month in the year when you may not find some seeds mature and ready for dispersal, for nothing varies more than the time required by different plants to ripen their fruits. The ephemeral annuals can afford no delay and rush through every phase of their short lives, from germination to seed-sowing, with the utmost possible speed. Of perennials, the dandelion takes no more than a day or two to change its golden discs into dandelion clocks; the strawberry ripens in a month or so; the crab apple in six months; and the hazel nut in eight. But the slowest of all to reach maturity are the fir cones: eighteen months must pass before the cone of the Scots pine can open out its scales and release the winged seeds.

Infinite, indeed, in variety are the seeds and fruits of plants, but every variation in form and texture, colour and marking, ripening time and season has a definite meaning and purpose. Each is an adjustment directed to one end—the survival and increase of the species, for in the world of plants, where competition is as fierce as in the world of men, there is no time nor energy to spare for the useless and the whimsical. In particular the struggle of plants for new territories is a bitter one, and millions upon millions of seeds and young seedlings perish in the course of it. And new territories every plant must find, for, if its seeds were merely to fall about its own feet, the resultant seedlings would soon smother one another; dispersal is essential and each seed must take its chance of falling in a place suited to its germination and growth. Being themselves inert and unable by their own efforts to leave the parent plant, they must rely on some outside agent to scatter them, and the sun, the wind, running water, the tides and currents of the sea, mammals, birds and insects all act as carriers for one species or another.

Of these distributors the wind is the most efficient and far-reaching, and many are the devices evolved by plants to help them to make use of its agency. The countless, dustlike seeds of orchids rely on their own lightness to enable them to ride the winds. Poppy and heather whose seeds also are small and light employ a pepper-pot technique: the poppy's castor is formed by the desiccated capsule which, in the act of drying, develops a ring of small perforations round the rim; the heather's by the withered but persistent calyx which still surrounds the seeds. When the wind blows the castors are shaken and the seed scattered.

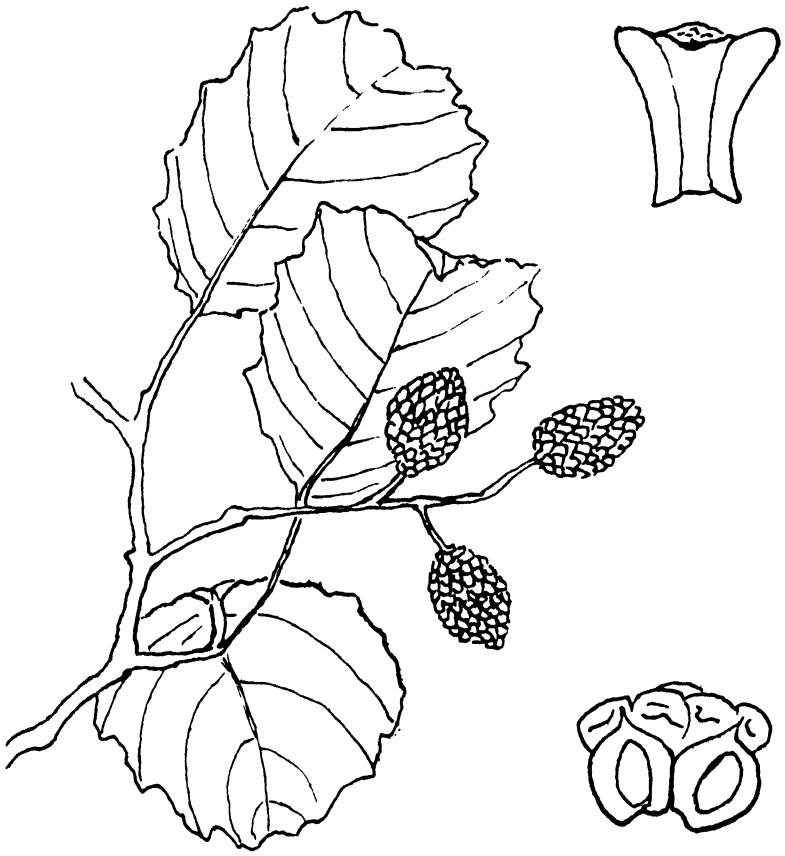
Very popular are vanes or wings of various kinds that will bear up the seed and enable it to glissade down the air currents or float on the gusts. Ash, maple, sycamore and most of the conifers have seeds, each with a single, membraneous vane at one end of it which helps to carry it out of the shadow of the parent tree, and that of the ash tree is, in

addition, twisted like a propeller. Elm and angelica seeds have papery borders for the same purpose. The long, broad bract out of which the sandalwood-scented umbels of the lime flowers grow is another device after the same pattern; it persists after the flowers have faded when it acts as a wing to bear away the cluster of nutlets, and it is amusing on a gusty autumn day to watch these twirling helicopters as the wind catches their curved blades.

Most popular and most effective of all the wind devices is the tuft of fine down such as is favoured by the ubiquitous *Compositae*. This may be no more than a bunch of gossamer filaments such as bear the black, shining seeds of the rosebay willowherb, or fireweed, over treetop and thicket, from clearing to clearing in the forest; or it may take the form of a plume, like a tiny feather, as it does in the seed of old man's beard; or, most successful of all, it may consist of a shaft surmounted by a ring of filaments, as it does in the parachute of the land-grabbing dandelion. There is no more successful plant than the dandelion which is always one of the first-comers to any patch of bare soil, and it owes much of its success to the form of its seed. Its pointed achenes, covered with tiny hooks, and each surmounted by its folded pappus, are tightly packed, points downward, on their launching platform high above the herbage. Here, as the sun dries their filaments, the pappus-parachutes unfurl, rendering the seeds so buoyant that the least breath of a summer's day will lift them out of their shallow sockets and send them floating away over house and hedgerow, river and road till the wind eddy fails and drops them to the earth; now, their heavy, pointed keels force a way for them through the tangled grasses and their tiny hooks anchor them firmly to the new territory.

The white, fluffy hairs on the seeds of willows and willow herbs serve an additional purpose, that of keeping them afloat for a while should they fall into water, till wind or current can drift them to a safe anchorage on the bank.

Here water plays a large part in the dispersal of the seed and, indeed, water is the main distributing agent for a number of marsh and sea plants and for most aquatics, and these show many adaptations to this method of dispersal. The seeds or fruits of such plants can remain under water for long periods without suffering damage; many can float at least for a day or two and some for as long as six months or more, by which time the moving waters of rivers and streams, or the tides and currents of the sea, may have borne them very far from their first home. Seeds of West Indian plants, carried in this way in the warm Gulf Stream, are often washed up on our shores, possibly 'living' still though unable to germinate in our cold climate. The adaptations which permit such seeds to float, or to remain undamaged for long periods in salt or fresh water, are hard to see with the naked eye, for they mostly consist of corky or air-retaining tissues in the seeds themselves, or, in the case of saltwater plants, of the chemical constitution of the protoplasm in the cells. The seed coat of the yellow flag contains corky tissue which protects the seed and makes it buoyant, and the small nutlets of gipsywort are hooped with corky rings; the kingcup's long, waisted seed has a bulbous end whose air-filled tissues keep the seed afloat, and the bogbean's seed coat is similarly filled with air. More visible are the utricles, or loose, air-retaining seed coats, of the sedges and the light, persistent sepals of the water dock—both devices to prevent the seed from sinking too quickly. One of the commonest of the waterside trees, the alder, has seeds wonderfully adapted to the chosen environment of the tree and to dispersal by running water. These seeds are ripened in a miniature cone, two behind each scale, as in the fir cones; each seed is provided with a pair of waterwings which, when the cones open out in autumn and shed their contents on the water, enable it to ride the currents, and each is, in addition, impregnated with a waterproof oil to preserve it from damage through the cold and wet of winter floods.



ALDER

Female catkins. Seed scales: empty (*above*); with two seeds (*below*)

Rain is of small use to flowering plants at seed time, except, perhaps, to wash the fallen seed down to the soil, and ripening operations are slowed down during a wet spell. But the sun, on the other hand, is a general favourite and, besides being the universal ripener, plays an active part in broadcasting the seeds of certain species. Stand on a furzy common on a sunny summer morning, or in a field of ripening vetch, and you will hear the sun at work, cracking the gorse and vetch pods. At each tiny explosion the valves of the bursting pods spring apart, and those of the

vetch twist spirally away from each other, scattering the seed as they do so. Herb Robert and its relations are also mainly dependant on the sun for seed dispersal; the long carpels of the beak-like fruits, each bearing a seed at its base, are hygroscopic and, as the sun dries them out, curl outwards and upwards in a tighter and tighter coil till at last they snap off from the tip of the fruit and are thus jerked away to a little distance from the plant. The interlocking teeth which close the capsules of chickweeds, stitchworts and campions are similarly sensitive to moisture, remaining firmly closed on a damp day, but opening out under the influence of a drying sun to allow the ripe seed to escape.

Balsam is another plant which, like gorse and vetch, spreads its seeds by explosion, but the detonator in this case is not the sun but the surrounding herbage. The slightest contact with its jostling neighbours, when the seeds are ripe, cause the five valves of the capsule to roll suddenly upwards and thus scatter the seed; in addition, the whole capsule is often jerked bodily away, breaking off at the thin neck were the fruit joins the pedicel. Yellow balsam's more picturesque name of touch-me-not, the Kashmir balsam's occasional name of jumping Jack and the Latin name of the genus as a whole, *Impatiens*, all refer to this peculiarity.

After the wind, the birds are the most important seed dispersers, and all plants with succulent fruits depend on them for this service. The colours of such fruits are bright so as to attract the birds, whose vision in this respect is as good as man's, and their flesh is acceptable to a bird's palate. A blackbird on the raspberry canes is merely eating that which was designed for him; it is not he but the human being who keeps him from his natural food who is the thief. The smaller birds eat the fruit piecemeal and scatter the seeds; the bigger ones swallow the berries whole, but the seed itself is passed undigested through the bird and is thus spread far and wide. This process of passing through the digestive tract of a bird is sometimes, if not actually neces-

sary, at least beneficial to the seed concerned. Haws, for instance, germinate better and more quickly if they have been dispersed in this way. On the birds' side, even poisonous fruits, like the yewberry, do them no harm, for the poison is all in the undigested seed of the fruit. The mistletoe is a specialist in bird dispersal: its problem is a tricky one, for, being a parasite on the branches of trees, it would be useless for it to scatter its fruits haphazard on the ground; if it is to survive it must somehow ensure that its seed is planted in the cracks of tree branches where alone it can germinate and grow. The glutinous mistletoe berries—from which birdlime was once made—are the solution to this problem. So viscid are they that the mistle thrushes and other birds which feed on them are compelled from time to time to wipe the sticky flesh off their beaks by stropping them against branches and twigs; in this way the seeds adhering to the flesh are deposited in cracks and crannies of the bark.

Birds may also be the unwitting distributors of many non-succulent fruits, and especially of the seeds of marsh plants which are often carried far afield with the mud on the feet of ducks and waders. This is a commoner mode of dispersal than might be thought and must often account for the rapid appearance of a marsh flora on the banks, for instance, of a newly-dug pond; but it is, of course, quite fortuitous and in no way planned for by the plants in question.

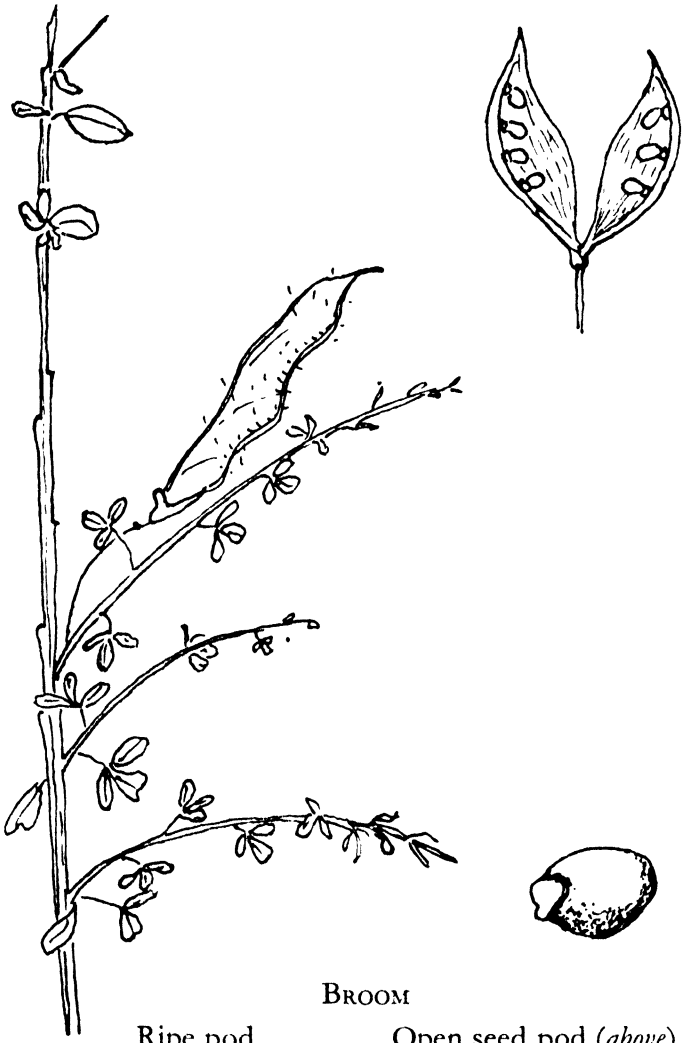
Mammals, too, play their part as distributing agents for certain plants, such as goosegrass, burdock, avens and a host of others. The round seeds of goosegrass, or cleavers, are provided with many tiny hooks with which they cling to the fur of any animal that touches them, and each seed of avens is surmounted by a single large hook which serves the same purpose. In the case of the burdock it is the bracts of the thistle-like flower heads which are furnished with grappling irons. These bracts persist after the flowers have faded, so that a passing animal, caught by the hooks, carries not

one seed but a whole packet with him as he goes and, when he cleans his fur, sows it in some distant place.

Both birds and mammals take a hand in the distribution of those fruits which are commonly called nuts—hazels, chestnuts, beech nuts, acorns and their like—though in this case the nutritious kernels are designed primarily to nourish the young embryo and are only secondarily useful as a method of attracting such distributors as birds, mice and squirrels. Indeed, at first sight it would appear to be a most wasteful method of spreading the species, as the object of birds and mammals in collecting nuts is, naturally, to eat them, and once the kernels are eaten the seed itself cannot germinate. However, in practice it is hardly more wasteful than any other method, for a great number of nuts are dropped by the way or forgotten in winter hoards. At my garden gate stands a great old oak tree, two hundred years old and more, whose boughs every autumn are laden with acorns. As soon as the nuts ripen the jays from the woods across the valley descend upon it—they seem to prefer it to their own home trees—and for a month or more, till the fruit is all shed or collected, I see from my cottage window a constant stream of these birds, acorn in beak, flapping their slow way from the oak tree to their winter hoards in the woods, and many and many an acorn is dropped in the course of the half-mile flight. Grey squirrels, too, visit the tree to stock their drays against winter famine and any sudden movement in the garden will cause them to drop their treasure trove and scamper away.

The last of the distributors are the insects. Many seeds have oily coverings or plump, oily protuberances which are greatly relished by certain insects and especially by ants. These carry such seeds away but often, growing tired of the burden before they reach the nest, they stop and, eating off the tasty portion, abandon the main seed quite unharmed by the wayside. Broom and gorse both have this type of seed: open a ripe broom pod and you will see that each

seedlet has, at the point of its attachment to the pod, a tiny bright yellow cushion—the aril; this is the oily morsel which attracts the ants.



BROOM

Ripe pod

Open seed pod (*above*)
Seed with fleshy aril (*below*)

Seed dispersal is, of course, by no means the only way in which plants increase and extend their ranges. Local gains are made by many other methods. Bracken, nettles, dog's

mercury and many, many more tunnel their way into new territory by means of underground stems which put up fresh shoots and so establish new plants at intervals along their length. Strawberries, ground ivy, creeping buttercup and their like put out runners in all directions which root at the nodes. Blackberries reach out branches which bend over and root at the tips, thus throwing a many-spanned bridge over wasteland and common, each arch a branch and each pier a new blackberry plant. The lesser celandine and wild leek scatter small bulbils instead of seed. Bindweed, couch grass and Canada weed snatch advantage out of adversity and, when they are broken up, develop new plants from the pieces of their shattered roots or branches. Bulbs increase underground by the formation of new bulbs beside the old, and tuberous plants by putting up new shoots from their swollen storage organs. All these are modes of vegetative reproduction, and man has added others which seldom occur in nature, such as layering, budding and the striking of cuttings. All are aimed at the conquest of new territory, but their gains are inch by inch and cannot compare for range with the method of seed dispersal. All can be seen in their fullest operation in autumn, the season of increase.

The conflagration of the woods is now at its height, and the very air seems suffused with a coppery glow reflected by an orange sun from the million turning leaves. Never has autumn been more splendid, for the frosts still delay and the gales are tardy in coming. In many years, each leaf as it turns is whirled away at once by the wild winds, so that the boughs are stripped before they can don their gorgeous robes, but this year the leaves have fallen slowly, drifting down by ones and twos and causing scarcely a gap at first in the full foliaged branches. Each tree has stood for a week or more mantled from crown to trunk in the hue it prefers—for each has its preference—and scanning the forest from afar it is possible to pick out one species from another by its colour alone. Most vivid of all are the wild cherries which

enter now into the second of their seasons of glory; the first was in April when each tree, clothed in white blossom, shone out among the dark boughs of the still-sleeping forest like Persephone herself emerging from the Shades. The blossom fallen, the cherry trees sank back once more into obscurity, their undistinguished leaves merged in the green mosaic of the treetops, but now in October comes their second splendour when their brilliant tones of scarlet and crimson, coral red and rose-madder outdo in richness even the orange-gold of maples and sycamores or the copper and russet of the mighty beeches.

Easy to identify, too, among the mixed woods are the oaks, but for an exactly opposite reason, for their sombre late-summer foliage has scarcely done more as yet than tarnish a little, as though faded by long exposure to the sun. The limes and wych elms have carried the process a little further and stand clothed in varying shades of greenish yellow, and a plantation of larches beside the deciduous forest has turned a uniform lion-tawny colour. In the hedgerows bordering the trees splashes of plum-red proclaim the hawthorns, and of maroon-purple the dogwood shrubs, while here and there a solitary, straggling spindle tree seems to hold the sunlight in its coral-red and orange berries and in its primrose yellow leaves suffused with rosy pink. At my own door, on the burnt ground which has reverted to wilderness, those beautiful weeds, the birches, their silver stems rising from the rufous bracken, are decked with the million spangles of their golden leaves.

In the damp and windless aisles of the forest itself, where the multitude of falling leaves fill the air with the rustling sound of a summer shower, the splendour of the foliage, hidden behind its own shadow, is subdued to no more than a brown glow reflected from the ever-thickening carpet under the trees. What strong colour is here to be seen is provided by the lurid caps of toadstools whose season and place, above all, this is. Brightest of these and hardly to be

missed by any walker in the woods is the fly agaric with its scarlet, white-warted cap and white gills and stem. Its name refers to the fact that its juices were once used for poisoning fly papers, for it is a poisonous member of that genus of ill-repute, the Amanitas, which includes the infamous death cap and vernal toadstools whose likeness to the common mushroom has caused many deaths. Incidentally, a very slight degree of observation on the part of the mushroom picker should suffice to prevent such fatal confusion, for the stems and gills of the Amanitas are always pure white and, moreover, the stem rises from a species of globular cup, characteristic of the genus. A young Amanita toadstool, on its first emergence from the ground, has rather the appearance of a puffball, for it is enclosed—cap, stem and base—in a white envelope, called the volva. As the stem lengthens this envelope is ruptured, the lower half, in the vernal and deathcap toadstools, remaining as a rim around the bulbous base, and the upper half being carried up by the cap with whose expansion it becomes stretched and torn into many pieces. Some of these fragments of volva remain adhering to the cap, and it is these which form the white warts on the fly toadstool. Another distinguishing feature of the Amanitas is the white fringe which hangs from the rim of the expanded cap.

As common and unmistakable in their way as the fly toadstools are the sulphur tufts which grow thickly about the roots of trees or cluster about rotten stumps. Their name sufficiently describes their bright colour which for yellow brilliance can only be rivalled, among toadstools, by certain species of the scaly caps. These latter also generally grow in clusters about decaying roots, but are easily distinguishable from sulphur tufts by their larger size and by the scales covering their caps.

More interesting than the foregoing and found in the same type of location is the honey-coloured toadstool, *Armillaria mellea*. This is one of the worst enemies of forest trees, for,

though the spores germinate only on dead stumps, the weft of fungal threads which results from them is able to force its way into a living tree root and thence penetrate upwards through the sapwood of the trunk, feeding as it grows until the tree is killed. The travelling threads which find their way from the original dead stump to the living root are often compacted into thick, black strands, like bootlaces, and both these and the weft which invades the trunk are luminous, and even impart their luminosity to the wood of the tree which they have killed. Forest dwellers in days gone by were said to use the luminous tinder to light their way through the dark woods at night.

Less brilliant than the fly toadstools and sulphur tufts yet outstanding enough are the Russulas, so called because nearly every member of the genus has some red colour about it. These are, for the most part, sturdy toadstools with white gills, and the brightest of them are the rosy and red russules and the emetic toadstool. The Russulas' chief interest lies in the fact that two species of parasitic fungi use them as hosts, so that if you are fortunate you may at some time behold the unusual spectacle of one toadstool growing upon another. Most of this genus are as unwholesome as they look. And, in this connection, it is interesting to consider what exactly constitutes a 'warning' colour to human beings: a red flower is considered beautiful and a red fruit attractive, but a red fungus causes, often without reason, an instant shudder of distaste or even apprehension; if the death cap were scarlet it would never be eaten. It is not the colour itself, then, that is attractive or repulsive but the associations connected with the coloured object. In this country the mushroom being—quite mistakenly—considered to be the only edible fungus and all others at the best unwholesome and at the worst lethal, the more a toadstool differs in colour, shape and habitat from the beneficent mushroom the more poisonous an aspect it seems to take on.

The lurid Boleti, plentiful at this time in the woods, are a

case in point. Many are, from long experience, considered delicacies on the Continent, but few, I think, would venture to eat them in this country, and their very names, such as for instance, the lurid Boletus and Devil's Own, reflect the aversion with which they are regarded. Nothing in the toadstool world could look less like the mushroom: their gills, instead of being striated, as in the vast majority of toadstools, are spongy, and often of a jaundiced yellow colour, and their fat, bun-like caps, from which they take their popular name of bun toadstools, give them a bloated, unwholesome appearance. Their colours range from the plain bright yellow of the butter Boletus to the variegated hues of the lurid Boletus whose cap is brown and velvety, its gills dark crimson, and its stalk orange, spotted with crimson and streaked with blue. The flesh of the latter, of the Devil's Own and of some other species turns blue when crushed or broken. The caps of many Boleti are covered with a thick brown, yellow or purplish slime which is unpleasant to handle and a great deterrent to would-be toadstool tasters. Many of the species that are so disfigured are, however, greatly esteemed as table delicacies by the connoisseurs of fungus flesh.

So numerous are the species of toadstools that it is impossible here to give even a brief survey of the commoner kinds. All are either saprophytes feeding upon the dead and decaying vegetation of the forest floor, or parasites upon the living tissues of plants and trees. The 'toadstool' itself is, of course, no more than the fruiting body of the organism, the main part of which consists of a weft of fine, colourless threads, one cell thick, ramifying in every direction underground. At the fruiting season, knobs of felted fibres appear on these threads and, elongating and pushing their way through the soil, eventually expand into the familiar umbrella-shaped, spore-bearing structures called toadstools or mushrooms. The spores line the gill plates or, in the spongy-gilled varieties, the honey-comb cavities, and are produced

in such vast quantities that, though individually invisible to the naked eye, in the aggregate they form a thick white or coloured dust. In such species as the associated toadstool, which grows in crowded clumps with one cap overlapping another, the spore dust shed by the higher growing specimens may often be seen lying on the caps below them in dark, radiating bands, corresponding to the gaps between the gills. Toadstool spores are of many colours from white, through pink, mauve, buff, yellow, orange and brown to black, and are not always of the same hue as the gills which produce them. It is amusing, and often necessary for identification, to cut off the stems of mature specimens and, placing the caps gills down on a piece of white paper, to leave them undisturbed overnight. In the morning when the caps are lifted a perfect pattern of the gills will be found beneath them, whose ground-colour, formed by the millions of fallen spores, may often be both unexpected and attractive. Each tiny spore among these millions is capable, under suitable conditions, of giving rise to a new underground web of fungus threads.

Fungi have none of that green colour by the aid of which higher plants manufacture their own food out of earth and air. They have no need of light and can live among the leaf-mould of the densest forests, emerging into the upper air only to consign their spores to the dispersing winds. All are either parasites on living organisms or saprophytes which obtain their sustenance by breaking down the dead tissues of plants and animals. The parasitic fungi are an evil company: they are the cause of mildews, rusts and blights and of many other plant diseases, such as the fatal 'damping off' which destroys so many overwatered seedlings in garden and greenhouse, and the poisonous ergot of rye which has led to many human deaths. They may even attack living animals and it is one of them which causes the fungus disease of salmon, and another, human ringworm. It is they, again, which kill many forest trees, spreading secretly through the living cells

of the trunk, their presence unsuspected till the time comes for them to propagate their unsavoury species, when they erupt from the bark in leathery, spore-bearing brackets or slimy knobs. They are the destroyers of the vegetable kingdom of whom no good can be said.

The saprophytic fungi, on the other hand, do little harm, except when as moulds they taint human food; in fact, their function in nature is a useful and beneficial one, for by disintegrating dead organic tissue they hasten its incorporation into the soil and its transformation into the fertile tilth beloved of plants. The fine fungal threads can penetrate anywhere among matted vegetation, separating fibre from fibre and thus easing the work of those main compostors, the soil bacteria.

Of recent years a new class of saprophytic fungus has been distinguished whose members might be described as would-be parasites which have failed in their attack. These are the mycorrhizal fungi of which the heather's associate, already described, is an example. They are true saprophytes in that they draw their nourishment from decaying vegetable matter in the soil, but they invade with their threads also the living tissues of plants which grow in their neighbourhood. They may confine their penetration to the epidermal cells of the plant's roots, round which, in this case, they form a shaggy, external sheath—most forest trees and many woodland plants are invested in this way—or they may invade the whole root system and even the overground portion of the plant, as they do in heather and some other inhabitants of heath and bogland. The grass, darnel, is said to owe its poisonous properties to a fungus of this sort which inhabits its leaves, stems and flowers. The invaded plants, far from suffering any damage from their attackers, actually derive benefit from them, for many of the fungal threads are digested by the plant's cells and valuable nourishment thus acquired. Only if the green plant is enfeebled in some way and unable to fight back can the invader gain complete

possession. What exact advantage the fungus derives from the struggle has not yet been certainly proved.

The most outstanding examples of plants which benefit by the presence of mycorrhizal fungi are the orchids; in fact, in nature no orchid seed can germinate and grow unless and until it has been invaded by its particular fungus. The reason seems to lie in the very small size of the dust-like orchid seed which can provide but little nourishment for the seedling, and in the long period which elapses before these odd plants are able to put out green leaves and thus manufacture food for themselves. An orchid, it appears, may lead an underground existence for as much as fifteen years before it has accumulated sufficient food and energy to break into leaf and flower, and during all that time it is dependant on its mycorrhizal fungus for sustenance. Once having emerged above ground the orchid may dispense with the services of its associate and produce food-storage tubers or fleshy rhizomes of its own, or it may continue to be partially or wholly dependant on its fungus till the end. Strange, indeed, are the ways of orchids and it is little wonder that many of them are so rare as to be almost extinct.

The forest trees, too, nearly all have their fungus associate, but they are not dependant on it as the orchids are. In their case it is the rootlets only which are invested by the mycorrhizal threads and these do not as a rule penetrate as far as the cortex but form, rather, a matted, woolly, external covering to the roots where they benefit the tree by acting in the capacity of additional root hairs. At this season in the woods the outward and visible signs of the presence of these hidden mycorrhizal threads are to be seen on every hand, for the fruiting bodies of many of the fungal associates are the familiar toadstools already described. Thus, the elegant Boletus is one of the mycorrhizal partners of the larch, and the butter Boletus of the pine. The beech associates with many fungi, including two species of Boletus, *Boletus dysenterica* and *Boletus cyanescens*, and one of the cobweb caps, *Cor-*

tinarius proteus; the fly toadstool is probably the fungal partner of birch; and oak and hazel, too, have their particular toadstool associates.

Yet another shape taken by fungi is that which constitutes the main body, or thallus, of a lichen. Here, again, the fungus lives in close association with another member of the vegetable kingdom, for the complete lichen consists of a compacted weft of fungal threads in whose surface are embedded innumerable green or blue-green algae. The partnership is a mutually beneficial one, the fungal thallus providing a moist and sheltered home for the algae and these, for their part, contributing food, manufactured in their green cells, for the additional nourishment of the fungus. The fungal members of this partnership are of many different species and each is associated with its own appropriate alga to form the various lichens. Though the partners are not normally found apart, closely allied forms of the algal species are able to live a perfectly independent existence. The fungus, on the other hand, though its threads, or hyphae, are able by the secretion of certain solvents to penetrate such unyielding substances as rock and stone and thence extract water and salts, yet cannot, apparently, exist in the absence of its appropriate alga. It can, and frequently does, produce its own independent fructifications which appear like small cups on the thallus, and the spores so produced can even germinate without the help of an algal partner, but the resulting fungus must soon be colonised if it is to survive, and the more usual and more fruitful method of reproduction is a joint affair whereby minute pieces of the thallus, complete with embedded algae, become detached and are blown away by the wind. The powdery appearance on the surface of lichens is caused by these algal-fungal particles, each one of which is capable of producing a new lichen plant under suitable conditions.

Mycorrhiza and lichens are both examples of the peaceful living-together, or symbiosis, of two members of the vege-

table kingdom; a third example is provided by the bacterial nodules on the roots of leguminous plants and of certain other species, such as the alder. These are formed by bacteria of the species *Bacillus radicicola* which are able to fix the free nitrogen of the air. They are abundant in most ordinary soils and find their way through the root hairs into the roots of such plants as vetches, trefoils, peas and beans. Here, making use of the carbohydrates present in the roots, they multiply and form small swellings, and in return for their board and lodging provide their hosts with nitrogen. When their host plant dies they return to the soil, thereby improving its nitrogen content, and it is for this reason that farmers dig in leguminous plants as a green manure on land deficient in nitrogen. For the same reason the roots of peas and beans in a garden should always be left in the soil in autumn and only the dead haulm cleared away.

The woods are the favoured home of another group of plants besides the fungi and that is the ferns. In this country these are but meagre and stunted survivals—with the horsetails and clubmosses—of the gigantic flora of the Carboniferous Age. Then, rising out of low-lying swamps, dense jungles flourished of fern-like Pteridosperms whose stupendous fronds would have weight enough in falling to knock insensible a creature the size of man, and of huge horsetails of the genus *Calamites*, their towering trunks ringed with whorls of branches, and of bushy-headed Lepidodendrons, the tree-sized ancestors of our clubmosses. These forests, drowned by the gradual subsidence of the land or overwhelmed by deltaic sand and mud became fossilized and were turned, possibly by the action of bacteria, into the coalfields of the world. Thus the fuel burning on our hearths today comforts us with the energy of a sun which shone on Paleozoic jungles. Though herbaceous plants existed in Carboniferous times and may even have been commoner than the fossil records indicate, yet that age was thought to have been mainly an age of trees and woody

creepers, whereas in the present era herbs predominate, and ferns, following the prevailing fashion are now all—except the tropical and Australasian tree-ferns and a few other foreign species—small and of a herbaceous habit. The largest you are likely to see in English woods are the omnipresent bracken and the broad buckler fern whose triangular fronds may grow as much as four feet high. Up to recent times you might also have been lucky enough often to find the truly regal royal fern, but the numbers of this fern have of late years been so drastically reduced by the depredations of collectors that you are now only likely to come upon it in a few favoured localities.

Unlike the fungi, our native ferns are not rich in species and a list of the commoner sorts is soon made. First, and commonest of all in woods and shady hedges and by bosky burns are the male fern and the scarcely less common lady fern whose names suggest that at one time they were considered to be the male and female forms of a single species. Their appearance might support this view, for the lady fern is a daintier, lacier and paler version of the coarse, dark male fern; their fronds are about the same size and shape, up to three or four feet long and tapering slightly at the base as well as at the tip, and they rise from their rootstocks in the same elegant whorl, like feathers from the butt of a shuttlecock. They are, however, quite distinct species and modern taxonomists—that is, those who study the structure of plants and 'arrange' them according to their relationships —do not even classify them in the same genus.

Also common in the woods are the broad buckler fern, whose name describes the great breadth at the base of its triangular fronds, and the prickly shield and buckler ferns whose pinnules are tipped with soft, hair-fine prickles. Everywhere on mossy roots, and even on the trunks of trees, grows the polypody, its small, hard fronds with deeply waved edges unmistakable among ferns. Even easier to identify are the simple, strap-shaped fronds of the hart's

tongue which, though perhaps not so common as the foregoing, yet grows in vast colonies in localities which it favours. Its fronds are hard and leathery as, also, are those of another woodland fern, the hard fern, chiefly remarkable for the fact that its simply-divided fronds—not unlike those of polypody but narrower and straighter—are of two kinds: those which bear spores and those which do not. The barren fronds are comparatively broad and green, and fan outwards in a circle from whose centre rise, like a number of eels' backbones, the straight, withered-looking spore-bearers.

Outside the forest, bracken is, of course, the commonest fern and, indeed, the only common one on dry grass and heath lands. Next to the woods, drystone walls and rock crannies are the most favoured fern habitats. Here the polypody again flourishes, together with the delicate yet wiry maidenhair spleenwort whose persistent stems survive the decay of the rest of the frond and then have the appearance of bunches of coarse, black hair springing from a crevice of wall or rock. Its symmetrically arranged, delicate, round pinnae are not unlike those of the rare maidenhair fern—and hence its name—but the latter grows wild only on and about certain sea cliffs in the south-west. Rusty-back, whose name sufficiently describes the rufous, scaly appearance of the underside of its fronds, is common on walls in some districts but rare in others, while the tiny, parsley-leaved wall rue, though often overlooked, flourishes everywhere on such sites. Larger than these and more like the woodland ferns in form is the black spleenwort whose rootstock is often buried deep in a dry wall while its fronds make their devious way to the light through every crack and crevice.

These are the common ferns. There are many others, from the diaphanous filmy ferns of sunless torrents to the holly fern of the mountains, but all are rare or local and none, with the possible exception of the oak fern, once common but now locally rare, is likely to be found in these autumn woods.

Early summer is the time to see the forest ferns in their full glory, for then the coiled buds of the fronds, so different from the straightly-folded buds of flowering plants and one of the most symmetrical and pleasing shapes in nature, are slowly unrolling, straightening first their scaly stipes and then their lowest pinnae and so working gradually upward to the tapered tip. Thus the growing points of the frond are protected and only little by little exposed to the chilling air. As they uncurl their colour deepens from a greyish, frosty green to brightest emerald. This coiling from top to base of the frond in bud is typical of nearly all ferns, whatever their shape and size, and is called botanically circinate vernation, which means no more than coiled bud arrangement. One of the exceptions to this rule is the adder's tongue whose single, simple frond curls longitudinally in bud.

Now, in late October, the fully expanded fronds have darkened to a dull olive green and many are broken or torn or tarnished; much of their grace and beauty has gone; yet for those who do not know one species from another this is the time to study them, for now the backs of many of the fronds are marked with raised circles or lines of white or beige or rusty brown, whose size, position, shape and arrangement are the surest guides to the species. These raised marks are the fruiting bodies, or sori, each of which consists of a collection of minute, spore-bearing capsules, called sporangia, covered as a rule by a papery membrane, known as the indusium. The disposition and shape of the sori is typical for each fern species: those of bracken, for instance, form a continuous ridge round the edge of each frond, following every indentation of the pinnules; those of the hart's tongue are arranged in two series of transverse, parallel bars, one on each side of the main rib, or rachis; and those of the male fern form kidney-shaped dots attached to the midribs of the pinnules. The shape of the indusium, whether it persists or not, and the manner of its attachment to the frond—whether by one edge or by a depression in the

centre—are also important distinguishing features. So similar are the fronds of certain ferns that it is only by noting such minutiae, which often need a pocket lens for proper observation, that the species can be definitely identified. One of the main differences, for instance, between the buckler ferns, to which the male fern belongs, and the shield ferns, such as the prickly shield fern and the holly fern, is that in the latter the indusium is attached by its centre and in the former by a notch in one side.

The sori are usually produced on the backs of the ordinary vegetative fronds but a few ferns, like the hard fern, possess two types of frond, the vegetative and the reproductive, and in some, like the royal fern, the upper part of certain of the vegetative fronds is specially modified for spore-bearing. Typically, each sorus consists of a group of sporangia, which are stalked capsules attached to a placenta, each having an oval, laterally flattened head containing the spores. Reaching three-quarters of the way round the capsule head, starting from the stalk, is a band of single cells, called the annulus, whose inner walls are specially thickened but whose outer wall is thin. Completing the circle from the end of the annulus back to the stalk are a series of broader, thin-walled cells, called the stomium. As the sori ripen, first the indusium shrivels away, exposing the sporangia, and then these in turn dry out. As the annulus loses moisture the thin outer walls of its cells bulge inwards and cause the whole ring to contract until, under the tension, the sporangium ruptures at the weakest point which is the stomium. Now the annulus bends backwards, bearing most of the contents of the sporangium with it, but as the drying process continues and the annulus cells become completely empty of moisture, the tension is suddenly relaxed and the free end of the ring springs forward, catapulting the spores into the air as it does so. So the spores are sown.

Though the above process is not unlike the bursting of a seed capsule, the reproductive methods of ferns are, in re-

ality, quite different from those of flowering plants, for ferns are relics—or rather, modern representatives—of an ancient flora which existed before flowers and seeds were evolved. They increase, as we have seen, by spores which differ from seeds in that they are produced asexually and are not the result of the fusion of a male and female cell, as seeds are, nor do they, like seeds, contain in essence a complete new individual, similar in every particular, except that of size, to the plant which bore them. A germinating fern spore gives rise not to a seedling fern but to a tiny, often heart-shaped growth, called a prothallus. If you examine the dark, moist hollow under the crest of a ferny hedgebank you may sometimes see these quarter-inch scales of green flaking the bare earth of the small landslips which occur in such situations. In other cool, damp places, mosses and liverworts are apt so to hide and camouflage the tiny dark-green hearts that they are hard to pick out. They may also be grown from fern spores sown on moist, sterilised peat under a bellglass, but patience is needed for this as the spores may take months to germinate and the prothalli which eventually emerge grow very slowly. These are the sexual form of the fern and bear male and female cells. The life-cycle of the fern thus consists of two phases: the showy, asexual, spore-bearing phase and the inconspicuous, sexual one. This type of life-cycle, which is common in primitive plants, from algae to horsetails, is called by the botanists alternation of generations, meaning by this that a sexual generation alternates with an asexual one.

Normally, a prothallus is one cell thick at the edges, but thickens at the notch of the heart to a cushion several cells deep. From the thickest part colourless rhizoids penetrate the soil and keep the tiny, green fragment supplied with nourishment. The sexual cells are borne on the underside of the prothallus; the male cells, or antheridia, containing the sperms, on the thinner portion, and the female cells, or archegonia, containing the egg, on the central cushion. Like those of all primitive plants, the sperms—or spermatozoids,

as they are called—of the fern are motile and require water to float them on their fertilising mission. The motive power is furnished by microscopic, lashing whips, or flagella which fringe the pointed end of each coiled spermatozoid, and the thin film of moisture between the spread prothallus and the damp ground provides ocean enough to float them. They find their way by following the stream of malic acid exuded through the neck of the female archegonia, much as salmon, following up the freshwater currents in the salt sea, find their way into the rivers to spawn. From the fusion of the spermatozoid with the egg a new tiny fern plant is born, nourished in its first stages by the prothallus, but eventually becoming independent.

November is drawing to an end and now, indeed, autumn's glory has departed. A fortnight of ceaseless rain, washing all colour from sky and earth, has shattered at last the woodland leaves whose precarious hold has been unable to resist the battering of the unremitting drops. For fourteen days rags of dingy cloud have dragged across the forest wiping it clean of its autumnal tints, and flattened with their trailing fringes the grass and bracken of the pastures, and smudged in windy gusts the river's shining surface. Day by day life and colour ebbed until at last the November landscape seemed no more than a blurred photograph, matt and grey, of many-hued October.

But last night the wind changed to the north-east and turned back the clouds, and the first of the long-awaited frosts froze the raindrops to a white, crytalline powder, limning each twig and grass blade; and after the frost came sunlight to animate the sky and strike sparks from the frost crystals and light up the hedgerow fruits. By noon the sun had melted the rime, but as I made my way upward through rough pastures to the forest I saw that hoar frost still lay in the sodden hollows of the battered bracken where it repeated on the hillside the colour and pattern of the old man's beard

which hung about the fringes of the wood. Not a single leaf lingered on the trees and bushes of scrub and hedgerow, though the bunched keys on the ash trees gave an illusion of withered foliage. Stripped thus of their golden spangles the birches, outlined against an opalescent sky were no less beautiful than in October, but with a beauty of line, now, and of delicate detail rather than of colour; their curved catkins were already formed on the tips of their drooping twigs. In the hedgerows, too, the fall of the mantling leaves had revealed new and more intimate beauties. Each berry by the wayside glowed in the sunshine as with an inner fire which intensified its natural hue so that even from a distance it was easy to distinguish the round, crimson fruits of the field rose from the scarlet dogrose hips, and bryony berries burned like embers. The shoots of dogwood, called the 'bloody twig', were blood-red indeed, and sallow buds, crouched above the scars of their fallen leaves, were ochre yellow; immature catkins were thick on the hazels.

A little breeze blew on the hillside and with a barely audible sigh ruffled the wintergreen blackberry leaves so that their greyish undersides caught the sun in sudden gleams, but in the forest the breeze died among the outermost trees and the absolute stillness was broken only by the occasional harsh scream of a jay. Even a footfall made no sound on the rain-softened leaves which already had taken on the colour of earth. Brown, black and grey were now the hues of the forest, except where a slanting ray of sunlight lit a mossy treetrunk or, glancing along a woodland brook, illuminated a boulder, clothed with brilliant liverworts. Apart from the evergreens and the low-growing wintergreen plants, such as yellow archangel with its silvered leaves, and the dull-hued ground ivy, both of which have already begun to put out their new season's shoots, the mosses and the liverworts provide the sole verdure now in the forest.

Only with the dying-down of the other greenery do these

lowly plants emerge from their obscurity, for so humble are they that during the flowering of the forest they are apt to be dismissed as no more than a dull-green background to showier plants, yet they have their importance in the world of nature, their place in the sequence of creation which begins with the hydrogen atom and ends with man. For they, with the lichens and algae, are the first colonisers of the primeval rock which forms the basis of all soil. When rain and frost and sun have cracked and weathered the barren stone, these lowly growths, whose wind-borne spores wander the world, soon find a lodgement; their tiny, colourless rhizoids are able to extract water and nutrient salts from a medium too hard or too shallow for the roots of other plants, and in the process they still further disintegrate the rock. Their living bodies trap and hold moisture and their decaying substance, mixed with the crumbling rock, form pockets of humus, deep and friable enough to support less primitive plants, and these, dying in their turn, form more humus, until, at last, through the ages, fertile soil is formed, supporting fat pastures where bullocks browse, or nourishing the golden wheat. So, through the alchemy of moss and its humble cousins we are enabled to draw nourishment from a stone. The woodland mosses have few rocks to work upon, but they play their part in the disintegration of dead wood and in the formation of the forest mould.

Few of the mosses have a common name, yet many, like the fronded *Thuidium tamariscinum*, the plushy wall mosses and the symmetrical, bottle-green *Polytrichum commune* are so distinctive and so abundant that one would have thought that some old lover of plants would have christened them, or that countrymen, seeing them daily, would have had occasion at some time to refer to the different species. The nearest approach to a generally known name is sphagnum and this is merely the Latin name recently taken into popular use because this moss has been discovered to have a definite utility for man; the small, living, green cells of its leaves are

arranged in a network round larger, colourless cells which communicate with the exterior of the leaf and thence absorb water, and this absorbent quality of sphagnum has caused it to be used in surgical dressings.

The anonymity of mosses is certainly not due to their lack of distinction or beauty but to the fact that these are on so small a scale that in the days before magnifying glasses and low-power microscopes they were hard to note. One of the chief distinguishing features between different species of moss, and one of the most attractive when magnified, is the stalked spore-capsule, or sporogonium. This, which appears among the green leaves like a seeding flower head, varies in shape and colour according to the species. It may be green, brown, red or orange, and its head round, pear-shaped, cylindrical or oval, in texture smooth or angular or furrowed; it may hold itself erect, or the head may be curved or pendulous; but in general it consists of the same parts, namely, a foot by which it is attached to its parent moss, a stalk, or seta, and the spore-containing head, called the capsule, which is generally covered at first, before it is ripe, by a pointed, membraneous cap, known as the calyptra. The capsule is closed at the free end by a lid below which as a further covering is often stretched a diaphragm, called the peristome. As the capsule ripens, first the calyptra falls off, then the lid blows away and, finally, the peristome diaphragm ruptures and divides—in many species—into a varying number of tiny teeth, called the peristome teeth. These teeth are extremely sensitive to moisture and on a wet day remain in their original position as a covering to the contents of the capsule, but under dry conditions they bend outwards, forming a fringe round the rim of the capsule, and allow the spores to escape. In number they vary from 4 to 64—always in multiples of 4—and are arranged in either a single or a double ring. Under a microscope they are a beautiful sight, for their colour varies from white to red and yellow and they may be decorated with vertical or longitudinal stripes; those

of some species of moss are straight, of others twisted, and of others again cloven into two tongues.

Mosses, like ferns, have an alternation of generations, and the sporogonium is the spore-bearing generation, corresponding to the green, spore-bearing frond of the fern, but, whereas in ferns it is the conspicuous, green, vegetative body that bears the spores, in mosses the conspicuous generation is the sexual one which produces male and female organs among green foliage. Moreover, the two forms of moss are not separate and distinct as they are in ferns, where the prothallus and the fern plant lead quite independant lives, except for a brief period while the prothallus is nourishing the young fern. The spore-bearing form of a moss has no separate existence but grows on the body of the sexual form and is, in fact, a parasite upon it.

A germinating moss spore produces, not a miniature moss plant as a seed would do, but a microscopic green thread, called the protonema, which gradually lengthens and ramifies, some branches creeping over the surface of the ground to form a green weft, and others penetrating into the soil to act as rhizoids. Only when sufficient stores have been gathered from air and earth does a moss protonema begin to form buds, which slowly lengthen and put out leaves until, at last, they take on the forms typical of their species. When enough green growth has been made, and when conditions are suitable, the moss starts the process of reproduction, and it is at this time, which is generally in the early spring, that the beautiful moss 'flowers' appear.

The easiest of these to observe—and even they need to be seen under a pocket lens if they are to be fully appreciated—are the male organs, or antheridia, of the hair mosses, for not only are these mosses of a fair size, but their antheridia are borne on the tips of their upright branches where they have the appearance of the dark heart of a flower surrounded by many pointed petals. The colour of the 'petals' is usually a pale, translucent green, paler than the surrounding foliage,

but it may be brick red as it is in *Polytrichum commune*, or scarlet as it is in that first coloniser of old bonfire sites, *Funaria hygrometrica*. The dark hearts are formed by the antheridia themselves, each one of which contains many spiral spermatozoids, as the male moss cells are called. The female organs, or archegonia, of the hair mosses take the same starlike form as the antheridia, but they are duller and lower growing, and at their hearts are the flask-shaped bodies containing the ova. When they are ripe the antheridia burst open and the microscopic male spermatozoids stream forth and, swimming on the film of moisture on the moss leaves, or in the ocean of a raindrop, make their way to the female archegonia, there to fertilise the ova. Each fertilised egg gives rise to a sporogonium, the capsular alternative form of the moss already described, which is a distinct plant in itself, drawing nourishment from the moss branch, as a parasite might do, by means of its foot, but not structurally connected with it, or developing from its tissues as do the seed capsules of a flowering plant.

Besides this somewhat roundabout and complicated method of reproduction, mosses are much given to reproducing themselves vegetatively by means of small, green buds, called gemmae. These are generally produced at the ends of branches and, breaking off, form new moss plants. Some species of moss, such as the beautiful fern-like *Thuidium tamariscinum*, rarely fruit and rely for propagation almost entirely on this method.

The reproductive cycle of the liverworts is very like that of the mosses, for though the typical flat, or thalloid, liverworts that cover the stones along a brook are so different in appearance from the mosses, yet the two are nearly related, and many of the less-known, though more numerous, species of leafy liverworts, such as *Cephalozias*, show this relationship clearly, for they might well, with their filmy leaflets, be mistaken for mosses. The chief differences to the naked eye are that moss leaves are simple and undivided, though

often toothed, have a prominent midrib, and are arranged spirally round the stem, whereas the leaves of leafy liverworts are often two-lobed, have no central rib and lie flatly in two rows along the stem.

Liverworts, like mosses, have two generations, a leafy, sexual one and a parasitic, spore-bearing one. The male and female organs of the leafy liverworts are borne in the axils of the leaves and at the branch ends, while those of the thalloid forms are borne either on the thalli themselves, where they have the appearance of small pimples, pouches or cups, or else on special stalked outgrowths from the surface of the thallus. The structure, for instance, which bears the female archegonia of *Fegatella conica* and which ripens in early spring at the same time as the moss 'flowers', has the appearance of a small, olive-green toadstool growing out of the ribbon-like body of the liverwort, and the male antheridia of *Marchantia* are borne on a species of leafy parasol, while the archegonia of the same species are produced on the under surface of a stalked star. Both *Fegatella's* toadstool cap and *Marchantia's* star are in contact with the leaf until the ova have been fertilised and only then do their stalks begin to elongate. The sporogonia that develop from the fertilised ova nestle under the cap and star respectively, and there ripen, rupture and shed their spores without ever having themselves grown a long stalk, though they have a short seta attaching them to the archegonium. The purpose of the long stalk is, of course, to carry the sporogonium up into the dry air where it may ripen and scatter its contents to the winds. These two liverworts are somewhat of an exception in this matter as the more usual method is, as with the mosses, for the stalk to be provided by the sporogonium that develops from the archegonium, rather than by the archegonium itself. *Pellia*, like the two foregoing, a very common thalloid liverwort along shady brooks, provides an example of the more usual procedure. Its sporogonia are produced on the thallus lobes, but as they ripen in early spring they suddenly begin to grow

lanky, translucent setae which give them the appearance of long, glass pins with black heads. A colony of these, when the stalks have grown to their full height, look like a patch of mustard and cress which has been grown in the dark. In this species, as in most others, the spores in the black capsules are interspersed with long, hair-like structures, with spiral internal thickening, called elaters, which are peculiar to liverworts. These are fixed to the base of the capsule and, when the capsule ruptures, the elaters writhe this way and that and thus help to eject the spores. In *Pellia* an empty capsule has the appearance of a Zulu head surmounted by a topknot formed by the persistent elaters.

Liverworts, too, like mosses, often reproduce by means of gemmae, and those of *Marchantia polymorpha*, one of the commonest of all thalloid liverworts, are very easy to see in early spring; they are produced in little cups in the thallus where they look for all the world like a number of tiny, green eggs in a nest.

Penetrating deeper among the trees and leaving behind the younger woods of oak and hazel I came at last to the very heart of the forest where a stand of magnificent beeches crowned a limestone bluff that overlooked the river's densely wooded ravine. Here, in May, lilies-of-the-valley carpet the ground, thrusting their pale leaves through the red-brown leaf mould and filling the dells with their fragrance, but now there was no verdure anywhere; even the mosses failed and only the grey boles of the beeches swept majestically upwards, supporting the fountain sprays of their darker boughs. Their shapes, stripped of summer's veiling leaves, were beauty enough. Now, their structure could be seen: the strong, smooth trunks round whose bases the buttressing roots stood out like tendons; the mighty boughs, upheld by woody bosses and springing outwards and upwards at the angle that would best support their weight of summer foliage; the tenting twigs that drooped from the branch ends, sloped in such a

way from crown to base as to guide the raindrops to the root hairs which lay beneath their dripping tips; each detail fitted to resist or use the elements, or to defeat the toppling force of gravity. Their year's activity was at an end and the sap which in the spring and summer had gushed upward through the vessels of the trunk now flowed but sluggishly, for the pumping roots were quiescent and there were no transpiring leaves to draw up by capillarity the watery solutions from the soil. Stripped to the bare bones, but with their stores carefully hoarded and their pointed buds, encased in protective scales, prepared already as starting points for a new season's growth, they waited quietly for the spring.

In the still air they looked eternal, yet at the edge of the bluff one of them had recently fallen and the foresters had already cut the bole from the gaunt, upstanding roots. At the severed end the internal zones of the trunk were exposed to view: first, a dark outer ring, formed by the bark, its perimeter fissured and torn where the pressure of the swelling bole had ruptured it, but lined on the inner side with an unbroken circle of cork. On the continuity and efficiency of this outer covering the tree had depended for protection against the attacks of insects or the insidious entry of the spores of fungi, or of the bacteria of disease and decay. Next to the bark came a thin, brown ring of softer tissue; this was the cortex through whose cells the foodstuffs manufactured by the leaves had travelled to and fro. Then came the main body of the trunk, the wide, pale cylinder of the sapwood through whose woody vessels had flowed water and nutrient salts from the soil. Lastly, at the very heart of the circle a small, brown ring marked the meagre heartwood, a core of dead cells surrounding a black spot which was all that remained of the medulla; this last in the sapling beech had been a spongy pith but was now blackened and hard and dead. From the core faint lines radiated outwards through the sapwood to the cortex, reinforced towards the perimeter by shorter lines; these were the medullary and secondary

rays which traced out one of the regions where the cells had multiplied with the growth of the tree. The other growing region was marked by many shadowy rings which zoned the sapwood like contour lines on a map. Each ring represented a year's growth and had been formed by the large vessels laid down at the beginning of each season to cope with the spring rush of sap. Counting these shadowy rings on the severed bole before me I found that the age of the fallen tree was more than a hundred and fifty years. What had caused it to fall was hard to determine: not old age, for it was hardly as yet even in its prime; nor, apparently, disease, for it seemed perfect in every part. Possibly some subsidence at its roots had upset its equilibrium and November gales had completed its downfall. But for this accident it might have lived another fifty years and come to maturity, to be felled then by the foresters, or, escaping the woodman's axe, it might have reached its natural span of some four hundred years and succumbed at last to old age, hastened by disease.

Nothing varies more than the normal life-span among plants and the causes of death among them are often mysterious. Summer annuals live but a month or two and die as soon as they have flowered; the poorer the soil the sooner they will rush into flower and the sooner they will, consequently, die. But the redwoods of California may live 4000 years. An individual plant of the creeping buttercup may not survive three summers, but it will send out runners which will root and produce other plants, and these, in turn, will send out rooting runners, until the creeping stems resulting from one germinating seed may span a century. Protoplasm itself, it seems, never grows old and may flow with unabated vigour through endless chains of vegetative renewal. Plants die, nevertheless, and not merely through accident and disease, but after an allotted span of weeks or years which is constant for each species and corresponds to the three score years and ten of human life. In annuals and biennials,

they say, death is brought about by an exhaustion of the available food supply, together with a reckless expenditure of stores on the formation of flowers and seeds. Trees, on the other hand, mainly fall victims to bacterial and fungal diseases which find entry through lesions in the bark. But even the Californian redwoods, which are said to be practically immune to such infections, die, nevertheless, at last. The truth is that the mystery of death has no more been solved as yet than the mystery of life.

It was dusk now under the beech trees and a biting cold seeped downward through the treetops heralding a frosty night and confirming that which the grey aspect of the forest had already proclaimed, that autumn was ended and winter upon us. My homeward path lay in a descending slope along a steep valley side, wooded from rim to base. Trees hid the river, except at one point where recent fellings allowed a brief view of the majestic stream as it wound its way far, far below, along the bed of the ravine. Soon the unfelled forest closed in again but, just before the track flattened out along the valley floor, I glimpsed the river once more through thinning trees. Now all the remaining light of the hidden sun seemed concentrated on its surface. Dusk filled the sky and night the forest, but shining day lingered on the water and in the centre of a pool of light, framed by leafless alders, floated two gleaming swans. Mysterious, remote, for ever beyond my understanding they floated serenely there, untroubled by terrors of night and winter and death, at one with the river and the dusk and the black, framing alders; but, because of my humanity which sets me and all human kind apart from the rest of creation, forever severed from me. Yet, we are all of one substance—the sun, the earth, the forest and its flowers, the swans and I—arising from one another in an endless chain: earth with its rocks and water and enveloping air out of an exploded sun; plants out of earth; living creatures out of plants: one substance, transmuted, disintegrated, re-combined into an almost infinite

number of impermanent shapes. All these shapes, from smallest to largest, have their proper place in the panorama of creation, each clearly defined and correctly proportioned in relation to its surroundings—except Man, who looms like an unfocused shadow over the picture, dominating all its parts yet divorced from any intimate connection with them. Only civilised man of all created things is unable to support himself in natural surroundings without the aid of his fellows. So weak is he, so out of touch with the earth and its creatures that a few days naked and alone in the wild will kill him from cold and hunger. Yet, banded into monstrous societies and guided by that intelligence which sets him apart from even his nearest relation in the animal world, he is able to dominate the earth and use and abuse it as he wills. His dominance, however, and the conscious intelligence which brought it about have been paid for with happiness, or at least with that contentment which comes only from an unreflecting accord with the circumstances and surroundings of life and an ignorance of the inevitable coming of death. It may be that the price of knowledge and power has not been too high, that the satisfaction that they bring outweighs the pain. It may be that, pain and pleasure being inseparable, only those creatures which suffer the first are able fully to enjoy the second, and that Man alone of all living things has sensitivity enough to experience the full poignancy of either. But for my part I felt—in the mood of that wintry evening—that most willingly would I, if I might choose, exchange my life, haunted by consciousness, for the serene existence of a swan, or even for the long, dark dream which is the life of the secular trees.

Thinking thus, I returned through the frosty night to the shelter of my cottage where, warming myself before the burning substance of ancient forests and nourishing myself on the powdered seed of a golden grass—both procured and prepared for me by my fellow men—I resigned myself to endure as best I might until the advent of another Spring.

ABSCISS, OR ABSCISSION, LAYER = Layer of specialised cells forming line of weakness along which leaves, twigs and flowers break off when they are shed.

ACHENE = Dry, one-seeded fruit with membraneous outer covering, shed as a whole without splitting.

ADVENTITIOUS = Coming from outside; applied to secondary roots, etc.

ANNULUS = Ring; applied to ring of specialised cells in spore cases of mosses and ferns.

ANTHER = Part of stamen containing pollen.

ANTHERIDIUM A = Organ containing male cells of mosses, liverworts, etc.

ANTHOCYANIN = Red or bluish pigment.

APOMIXIS = Reproduction by seeds produced without sexual fusion.

ARIL = Outgrowth from seed stalk.

ARCHEGONIUM A = Organ containing female cells of mosses, liverworts, etc.

AWN = Bristle.

AXIL = Angle between leaf and stem, or branch and stem, or twig and branch.

BRACT = Modified leaf below flower stalk or flower head.

BULBIL = Small bulb produced on the above-ground portion of a plant.

BURSICLE = Pouch or flap protecting and keeping moist the sticky base of an orchid's pollen apparatus.

CALCICOLE = Chalk (or lime) lover.

CALCIFUGE = Chalk (or lime) hater.

CALYPTRA = Hood, lid, cap; applied to membraneous covering of spore cases of mosses and liverworts.

CALYX = Outermost ring of those modified leaves of which a flower is composed, generally green; the aggregate of the sepals.

CAPSULE = Membraneous envelope or case; applied to dry, many-seeded fruits which split to scatter seed, and to spore cases of mosses, etc.

CAROTIN = Orange pigment which occurs in carrots and gives them their colour.

CARPEL = One of the parts into which a flower's ovary is often divided.

CARPELLARY = Deriving from, or consisting of, a carpel.

CHLOROPHYLL = The green composite pigment which gives leaves their green colour.

CHLOROPLAST = Bodies in the cell sap of plants which contain the above pigment.

CIRCINATE VERNATION = Coiled bud arrangement, as in ferns.

CLADODE = Modified branches having the appearance and performing the function of leaves.

CLEISTOGAMY = Method of reproduction by means of self-fertilisation in an unopened flower.

COLEOPTILE = Sheath protecting the first shoot of certain grasses, etc. from soil friction.

COLUMN = Composite structure bearing male and female reproductive organs in orchid flowers.

CORM = Swollen, underground base of flowering stem, lasting one year only.

COROLLA = Second ring of those modified leaves of which a flower is composed, generally coloured; the aggregate of the petals.

CORTEX = Layer of tissue in stem or root lying immediately below the skin.

COTYLEDON = Seed leaf.

CYME = Type of repeatedly forked flower cluster in which the oldest flowers are at the centre and the youngest round the sides.

DECIDUOUS = Shedding leaves annually.

DICOTYLEDONS = Plants having two seed leaves.

DRUPE = Stone fruit.

ELATER = Filamentous structure in spore case of liverworts which assists in spore dispersal.

EMBRYO SAC = Part of ovule containing egg-cell.

ENDOSPERM = Reserve food substance occurring in some seeds.

ENZYMES = Substances which act as catalysers in the various chemical processes occurring in plants.

EPIPHYTE = Plant growing on another but not drawing nourishment from it.

FILAMENT = Stalk of stamen.

FLAGELLUM A = Lash-like appendage.

FLORAL AXIS = Disc at top of stem from which parts of a flower arise.

FOLLICLE = Dry fruit composed of one of the sections into which an ovary may be divided and splitting down one side when ripe.

GEMMA AE = Small, cellular body in mosses, liverworts, etc., that separates from mother plant and starts fresh one.

GLUME = Chaffy scale, or husk, at base of grass floret.

HAUSTORIA = Suckers through which parasitic plants absorb nourishment from their host.

HETEROSTYLY = Type of pollination mechanism in which the style varies in length in different flowers of the same species.

HYDATHODE = Organ, generally situated on leaf margin or leaf tip, to deal with excess of moisture in plant cells.

HYGROSCOPIC = Sensitive to moisture.

HYPHAE = Extremely fine, branched threads of which a fungus body is composed.

HYPOCOTYL = Stalk below seed leaves.

INDUSIUM = Membrane covering the fruiting bodies of a fern.

INFLORESCENCE = Collective flowers of a plant.

INTERNODE = Part of stem between the points at which leaves spring.

LENTICEL = Breathing pore in woody stem.

LODICULES = Minute scales in grass floret.

MEDULLA = Pith.

MICROPYLE = Minute hole or channel through covering of ovule or seed coat.

MONOCOTYLEDON = Plant having one seed leaf.

MONOPODIAL BRANCHING = Branching system whereby main growth is continued annually through apical bud.

MOTILE = Capable of motion.

MYCORRHIZA = Plant root in association with a fungus.

MYCORRHIZAL FUNGUS = Fungus associated with a plant root.

NECTAR = Sugary liquid produced by plants.
NODE = Point on stem from which leaves spring.
NUT, NUTLET = Dry, one-seeded fruit with hard outer covering, shed as a whole without splitting.
NYCTINASTIC MOVEMENTS = Night, or sleep, movements.
OVARY = Female part of the flower which contains the ovules.
OVULE = Structure containing the egg and developing into the seed after fertilisation.
OVUM A = Egg.
PALEA = Thin, upper bract in grass floret.
PANICLE = Type of branched flower cluster in which the lowest flowers open first.
PAPILLA AE = Short, rounded hair.
PAPPUS = Downy appendage on seeds of thistles, dandelions, etc.
PEDICEL = Stalk bearing a single flower.
PERIANTH = The collective outer covering of a flower consisting of sepals or petals or both.
PERISTOME = Layer of tissue between the lid and the spore cavity of moss spore cases.
PETIOLE = Leaf stalk.
PHOTOSYNTHESIS = Manufacture of food from carbon dioxide and water through the agency of chlorophyll and in the presence of sunlight.
PINNA = The primary division of a fern frond.
PINNULE = The secondary division of a fern frond.
PLACENTA = Part of an ovary to which ovules are attached.
PLUMULE = Primary shoot.
POLLINIUM A = Pollen mass in orchids.
PROTHALLUS = Small plant formed by the germination of a spore and bearing male and female sexual bodies.
PROTONEMA = First filamentous form of mosses and liverworts from which adult form develops.
PROTOPLASM = Semi-fluid, living material of plant cells.
PULVINUS I = Pad, cushion; applied to thickened bases of certain leaf stalks.
RACEME = Collection of stalked individual flowers attached to a central, unbranched stem and opening from the bottom up.

RACHIS = Central main-rib of a divided fern frond.
RADICLE = Primary root.
RECEPTACLE = Disc at top of stem from which the parts of a flower arise.
RHIZOID = Root-like organ.
RHIZOME = Underground stem.
ROSTELLUM = Buffer organ formed by sterile third stigma of an orchid flower and lying between the two operative stigmas and the stamen.
RUDERAL = Of waste land.
SAPROPHYTE = Plant living on dead, organic matter.
SAMARA = Dry, winged fruit (achene).
SEPAL = One segment of the ring of modified leaves forming the outermost whorl of floral parts.
SETA = Stalk of spore case in mosses and liverworts.
SILICULE = Specialised seed pod of the Crucifers if less than 3 times as long as broad.
SILIQUA AE = Specialised seed pod of the Crucifers if 3 times, or more than 3 times as long as broad.
SORUS I = Cluster of fruiting bodies of fern.
SPADIX = Spike of flowers closely arranged round a fleshy axis.
SPATHE = Large, often paddle-shaped, bract or bracts enveloping flower head or spike.
SPERMATOZOID = Motile male sexual cell in mosses, liverworts, etc.
SPIKE = Collection of stalkless flowers arranged round a central unbranched stem and opening from the bottom up.
SPIKELET = Grass flower.
SPORE = Very small, asexual reproductive body.
SPORANGIUM A = Structure containing spores of ferns, fungi, etc.
SPOROGONIUM = Structure bearing spores of mosses, liverworts, etc.
STAMEN = Male, pollen-producing, reproductive organ of flowering plants.
STIGMA = That part of the female reproductive organ of flowering plants which receives pollen.
STIPULE = Scale-like, or leaf-like, appendage at base of leaf stalk.

STIPES = Stalk of fern frond.

STOMA ATA = Breathing pore.

STOMIUM = Point of weakness in wall of a fern's spore case at which the case ruptures when ripe.

STRIATED = Striped, ridged, furrowed or scored.

STYLE = That part of the female reproductive organ of flowering plants which connects the ovary to the stigma.

SYMBIOSIS = Living together in harmless or mutually beneficial partnership.

SYMPODIAL BRANCHING = Branching system whereby the main growth is continued annually through a lateral bud below the apex.

TAXONOMIST = Classifier.

TESTA = Seed coat.

THALLUS = Plant body when not differentiated into leaf, stem, etc., as in ribbon liverworts.

THRUM = Tuft of threads (weaving term) whence:

THRUM-EYED = Applied to those primrose flowers whose stamens, occupying the throat of the flower, have the appearance of ends of thread.

TURGOR = Distention with liquid.

UMBEL = An umbrella-shaped collection of flowers.

UTRICLE = Bag-like structure; applied to the light, air-retaining casings of sedge fruits and to the bladders of bladderwort.

VITTA AE = Oil tubes or resinous canals present in the fruits of some of the *Umbelliferae*.

VOLVA = Envelope or wrapper which encloses certain toadstools before they emerge from the soil.

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