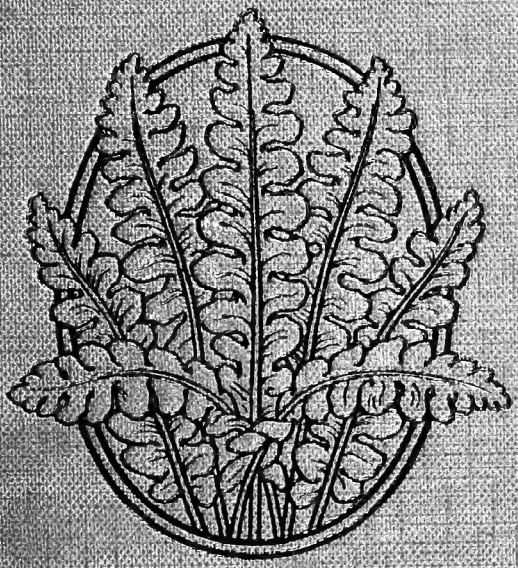
FLOWERLESS PLANTS

HOW AND WHERE THEY GROW



S·LEONARD·BASTIN

BRACKEN IN AUTUMN

Flowerless Plants

How and Where They Grow

By

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With Four Autochrome Plates
and 79 Illustrations from
photographs by the Author

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PREFACE

THERE are few more encouraging signs at the present time than the widespread interest in Nature Study. The age in which we live is an intensely practical one. Whatever our calling may be, it is likely that the majority of us spend most of our time in the keen pursuit of a professional or business career. The crowded days leave little space for that quiet reflection in which alone the spirit can find refreshment. It is surely, then, a matter for congratulation that there is an increasing tendency to turn to the satisfying joys which are waiting for everyone who cares to take up the wonderful book of Nature. Herein the tired man and woman will find an enchanting story, old as the earth itself, and yet ever fresh in its power to charm away the dull cares of a workaday world.

In spite of the large number of Nature Study books which are available at the present time, there are still many subjects which have been scarcely discussed from the ordinary person's point of view. The important division popu-

LIST OF PLATES

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CHAPTER I

A GENERAL SURVEY

In a world which is crowded with allurements it is only natural that, at first, the attention of the observer should be arrested by those things which make the most insistent appeals to the senses. It is not long, however, before the thoughtful individual discovers that the very showy objects are not always the most interesting. The student of plant life is faced with a similar situation. The handsome flowering species will, on account of their striking appearance, always command a lion's share of attention ; but to end one's botanical researches at this point would be to miss some of the most interesting chapters in the wonderful story of the plants.

For proof of this it is only necessary to peep into the life histories of some of the

members of that remarkable group which is collectively known as the "Flowerless Plants." Whilst a limited number of these species are conspicuous in one way or another, by far the majority are of comparatively humble growth and habit. To find out their beauties we must be willing to adopt more patient methods than those which are usually employed in the study of popular botany. Yet it is quite certain that our labours will be amply rewarded. Apart from the actual beauty of the many forms which will come under notice, it would, indeed, be a difficult matter to discover a subject for inquiry which is so full of romance. Indeed, the beginner in the study feels that he has entered such a new and wonderful world that all the marvels which he has ever seen before are cast into the shade.

The flowerless plants played a very important part in the early history of the world, but they have been forced into a second place by the ascendancy of the energetic blossoming species. In many cases the types which we have at the present time are but insignificant representatives of most impressive forerunners. The club mosses and horsetails of to-day are

the descendants of a race which dominated the world during the time when our coal deposits were being formed. At this period, when the horsetails grew into great trees, they were represented by a large number of species. Nowadays in all the world there is only a single genus with, perhaps, thirty named kinds, and the largest tropical sorts could hardly be called trees. So far as the number of species is concerned, the club mosses are much better represented at the present time than the horsetails. Already several hundred kinds have been named, and additions are frequently being made. But there are no very large club mosses in the world to-day. Some tropical species grow into little shrubs a couple of feet high, whilst a few of the rambling examples may be a score or more feet in length. These are not to be compared with the giants of the coal forests. Fossil remains have enabled botanists to state positively that these club mosses were not uncommonly one hundred feet in height.

For some reason, which it is not easy to explain, the ferns, alone amongst the higher flowerless plants, do not seem to have altered

to the same extent, either in number or in general habits. There are thousands of species of ferns in the world to-day, and in some places these form a prominent feature of the vegetation. This is notably the case in New Zealand, where the number of kinds is not only very numerous, but where certain sorts grow to a very large size. Thus the tree ferns may attain a height of forty or even more feet, forming great trunks, from the summit of which the giant fronds shoot out on all sides.

The higher flowerless plants are usually spoken of as the "Vascular Cryptogams," although the latter word is misleading, in that it means a hidden marriage. Nowadays the methods of reproduction are in most cases well understood. These higher flowerless plants have well developed leaves and roots, and a very cursory examination will show that a good deal of woody fibre enters into their composition. In these respects they bear a certain resemblance to the blossoming species. Striking differences are apparent, however, when the reproductive schemes are considered. As will be explained with more detail in succeeding chapters, the method adopted in the higher flowerless plants

consists in the production of spores from which arise independent organisms responsible for the sex elements. These bodies, which are called *prothalli*, are an essential feature in the life history of the ferns, the club mosses and the horsetails. In the case of some vascular cryptogams two kinds of spore are produced, and in such instances it is common to find that two sorts of *prothalli* are developed, each of which bears cells of a distinctive sex character.

Although at first sight the plan of reproduction which is evinced in the flowerless plants may seem to be far removed from that adopted by the species producing blossoms, yet it will be possible to show that the difference is more apparent than real. Indeed, the consideration of the connecting links between the two great sections into which the world of vegetation has been divided is not the least interesting side to a study of the flowerless plants. At the moment it is, perhaps, as well to complete our survey of the remaining groups which follow the highly organised plants to be found amongst the ferns, the club mosses and the horsetails.

It has been seen in the case of the vascular

cryptogams that the plant, prior to any process of fertilisation, gives rise to the spores. When we come to the next group, the mosses, we are faced with a very different state of affairs. Here, the principal growth, the moss plant, is concerned with the question of fertilisation. Sexual bodies are produced on the shoots, and after the union the spores are developed almost in the form of a fruit. Subsequently, by a process of cell extension, the spore develops into a net-work of growth from which arise the moss plants. Coupled with the mosses are the liverworts, plants which are not very well known, save to those who have specially studied them. In many ways the liverworts bear a close resemblance to the mosses, although there are certain points which make a sharp division possible.

At the end of the great list of plant forms are placed the algæ, the lichens, and the fungi. An enormous number of species are grouped together under the term algæ. These range from the showy marine weeds, down to more or less minute water forms which are not at all conspicuous, and may be quite invisible to the naked eye. Many kinds of algæ are able to

get on very well wherever there happens to be a little moisture; even under very dry conditions they will pass into a state of quiescence, from which they are able to awake into full activity with the arrival of damper conditions. A huge number of algæ are of the simplest possible formation, though some, particularly the seaweeds, show signs of a higher formation. Many of these plants attain a great size (actually some of the ocean weeds are almost the biggest plants in the world) and show a division into organs which bear a superficial resemblance, at any rate, to the leaf, root, and stem of the higher plants.

Amid such a range of forms, living under all kinds of conditions, it is no surprise to find that the methods of reproduction show a good deal of variety. In some instances it is possible to recognise a definite sex method of reproduction; in other cases the new individual arises after the emergence of the cell contents from its surrounding wall, whilst a very common mode consists in the mere splitting up of the cells. It is interesting to notice that many species of algæ have more than one method of reproduction available, the particular process

adopted depending to an extent upon the seasons, or the circumstances in which the plant is living.

As a class of plants the lichens will always be of peculiar interest in that they represent an alliance between the algæ and the fungi. Every lichen is composed of a fungus, which we may say is parasitic on a collection of algæ which it embraces. The dual character of these growths deserves a more lengthy treatment than can be accorded in an opening chapter. The chief method of reproduction to be observed in the case of the lichens enables the botanist to classify these plants as true fungi. In the case of those plants which are more commonly spoken of as fungi we are faced with an enormous group, evincing a vast range of form and habit. All these plants have one marked feature: they show no trace of the green matter (chlorophyll) which enables other plants to secure their carbon from the atmosphere. Thus all fungi must live upon some other organism, which may be in either a living or a dead state. In the former instance the plant is, of course, a parasite, whilst in the latter case it is usual to employ the word saprophyte

by way of a description. In the case of some of the smaller kinds of fungi it has been possible to observe a definite sex method of reproduction. But so far as the larger number of fungi which are likely to come under notice are concerned, no trace of any sexual process is to be discovered.

The remaining groups of flowerless plants call for a passing reference, although they are somewhat beyond the scope of the present inquiry. In these days of popular science almost everybody has heard about the bacteria. The place which these minute organisms occupied in the natural order of things was for long in dispute. They have even been classed as animals, but there is no longer any doubt that the bacteria are plants, and it is generally considered that they are related to the fungi. That bacteria play an important part in connection with disease is well known. It is not, perhaps, so generally recognised that many kinds act in a manner which is extremely beneficial to the human race. It is the bacteria which live in the nodules on the roots of bean and pea plants, and so enable these crops to draw upon the vast store of free nitrogen in

the atmosphere. Thus the farmer can improve the quality of his land by growing leguminous plants of one kind or another. As well, it is a species of bacteria which induces the fermentation in yeast—so important a matter in the making of our daily bread. In a general way it is an undoubted fact that different kinds of bacteria play a big part in aiding the decomposition of decaying matter, so that it ultimately assumes the form of pure and wholesome elements.

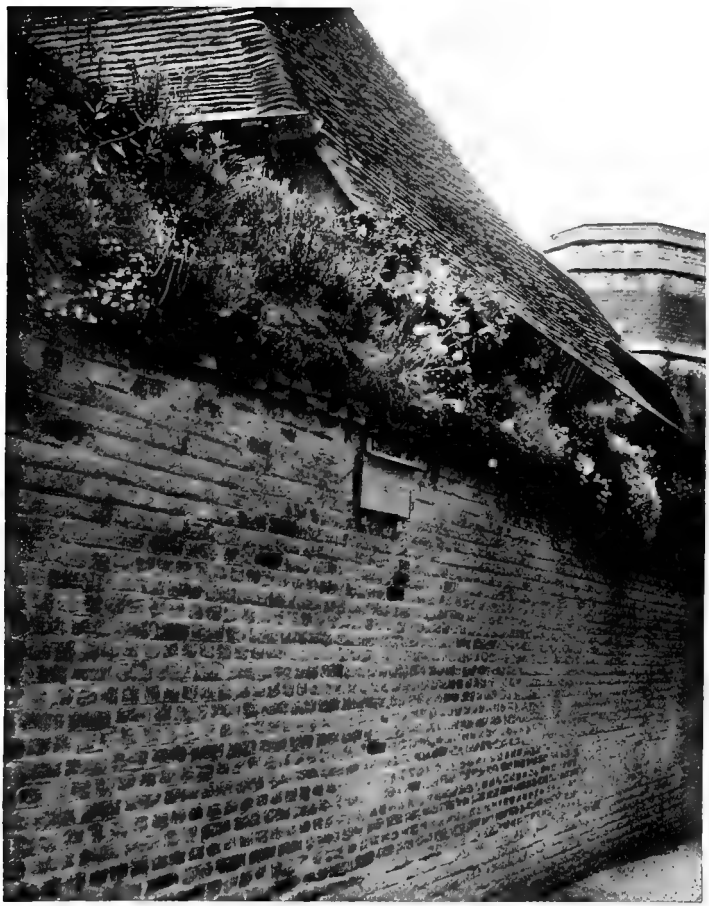
Of the remaining group of organisms it is still a doubtful point as to whether these should be spoken of as plants or animals. During spells of damp weather it is not an uncommon occurrence to see a slimy mass of matter of a yellowish colour spreading over dead wood. This is one of the Myxomycetes, a representative of a very singular group. Various points in the life history of these organisms lead men of science to think that they stand right on the borderland between the animal and the vegetable kingdoms.

There is little doubt that the world owes an immense debt of gratitude to the flowerless plants. We do not know the way in which

life first of all appeared on this earth, but there is good reason for believing that it was evinced in the form of minute plants not unlike the microscopic algæ which abound everywhere at the present time. These, in company with some of the higher types of non-flowering species, such as lichens and mosses, played an important part in preparing the surface of the world for the advanced forms of vegetation. At this far distant period there was nothing in the way of soil as we know it at the present time. The hard, unbroken rocks could give no roothold, and the only kinds of plants which could hope to live would be those of a comparatively simple type.

It is possible to get a very good idea of how the surface of the earth has been rendered suitable for growth of all kinds by studying walls. The new wall which has just been built is absolutely sterile—it is a desert in the truest sense of the word. But it is not very long before vegetation begins to put in an appearance. After a few weeks of rainy weather the bricks and mortar do not look quite so hideously red and white ; a close examination reveals the fact that in places an actual coating of green

slime is present. This is composed of masses of algæ, myriads of which are always floating about in the air ready to settle on any moist position. The growth of the algæ all tends towards the break up of the hard and uninviting surface of the wall, and quite soon mosses and lichens appear upon the scene. Probably the mortar will become outlined with velvety green moss, whilst big patches of grey lichens will spread themselves over the surface of the bricks. These humble plants are able to secure all they need from the air and water, coupled with the small amount of mineral matter which they can absorb from the material of which the wall is constructed. Generations of mosses live and die upon the wall, and eventually in the cracks and crevices there will be quite a nice accumulation of decayed vegetable matter. A gust of wind, or a passing bird, is responsible for the placing of the seed of the first flowering plant to grow up on this world in miniature. Years go by, and as this wall is still left in the hands of Nature, the accumulation of soil from decayed plants may be so considerable that even a small tree is able to establish itself. Thus within the span



A WORLD IN MINIATURE

By breaking up the surface of walls the mosses and lichens prepare the way for more advanced types of vegetation

of a lifetime the desert has been converted into a productive area, crowded with all the evidences of life. This could never have taken place had it not been for those pioneers which were the first to take up a position on this inhospitable region. There is little doubt that, were the botanist confronted with the task of planting a new world, he would call into requisition the humble flowerless plants which must have first of all started the clothing with verdure of the earth on which we live.

It has been hinted that the flowerless plants must now take a second place in any classification of vegetable types. At the present period of the world's history the flowering plants are enormously in the ascendancy. Not only are they the most impressive so far as size and habit are concerned, but the actual number of forms is very large indeed. It is considered likely that for every two species of flowering plants there will not be more than one non-blossoming kind in the world. As the world becomes older it is probable that this disproportion will be even more pronounced. There is small doubt that one of the reasons which is hampering the flowerless plants is the

gradual drying up of the world. It is a fact of supreme importance that the act of fertilisation in the case of practically all the flowerless plants is carried on under water. This moisture may be little more than a film of dew, as will be seen later in the case of the mosses, but the presence of moisture nevertheless remains an essential feature. In the steamy forests of the Coal Age there was an abundance of moisture which is not to be found save in a few tropical jungles at the present time. Hence the area of land which is suitable for a strong race of flowerless plants is steadily decreasing with the ages.

So far as actual numbers are concerned, the fungi and bacteria are vastly a greater group than that of any other flowerless plant, numbering as they do nearly 40,000 known species. The next largest group is that of the algæ, which in their many forms are not far short of 15,000 ; whilst the mosses and liverworts would probably be about half of this number. The lichens, which are still classed as species, albeit each plant is a combination, are to be found in well over 5,000 forms, whilst last of all come the vascular cryptogams (ferns, club mosses

and horsetails) with a membership of less than 4,000. Naturally these figures vary from year to year as fresh species are discovered, and the matter is still further complicated by the fact that there is a tendency in some directions to call many varieties distinct types. Still, on the whole, we may take the figures as approximately correct, in so far as they give an idea of the numerical strength of the various groups.

Although the flowerless plants cannot often be called a predominant feature in any part of the world, yet they show a remarkably wide distribution. They contrive to get far nearer to the Poles than any of the more highly specialised plants. Quite a formidable list of lichens and algæ could be prepared showing those kinds which live right in the Arctic circle, where there is practically snow all the year round. The so-called "red snow," for instance, is due to the presence of certain little algæ which give a singular crimson tinge to the white expanse. Many large and vigorous sea-weeds grow in the Arctic Ocean, where the temperature is never more than a point or so above freezing.

Coming to the other extreme, the fact that flowerless plants are able to withstand high temperatures has ensured their distribution in situations which would be quite impossible for the higher types. Certain lichens are found in abundance growing upon the rocks of deserts. It has been shown that during the heat of the day the temperature of these rocks and the plants which are growing on them may be as high as 200° Fahr. This is, of course, not very far short of boiling point, yet these lichens grow and thrive naturally in these scorching situations. In the hot springs at Carlsbad and elsewhere certain algæ flourish in a temperature which is at least 170° Fahr., and it is said that these enterprising plants have been discovered in situations where the water is even hotter still. It will be realised from such instances that the flowerless plants do not lack in adaptability to general conditions.

It is a singular fact that so few of the flowerless plants are of any very direct benefit to the human race. A certain number of the fungi are edible, but their actual food value is really very small, and they cannot be ranked as important articles of diet. In the same way

certain seaweeds are eaten, but whether they are very nice or nourishing is an open question. A few of the flowerless plants provide fodder for animals. The most important instance is that of the so-called Reindeer Moss—which, by the way, is really a lichen ; this enters largely into the sustenance of the four-footed friends of the Laplanders. Certain kinds of seaweed yield the useful drug iodine, and most of the common sorts when placed on the land act as reasonably good fertilisers. With this paltry list one is almost at an end of the direct benefits which mankind receives from the flowerless plants, apart from the beneficial kinds of bacteria which have already come under notice.

Unhappily, the list of harmful results arising from flowerless plants is much more formidable, though it is chiefly restricted to one group, the fungi. Many of these wreak the most fearful havoc amongst crops, and are known to farmers and gardeners under the names of "rust" and "mildew." One of the most familiar, and at the same time extremely serious, fungus pests is that known as the "Wheat Rust." The life history of this plant is very complicated, and

has, indeed, only been fully described within comparatively recent times. In the summer the fungus appears as rusty streaks on the leaves of wheat, oats and other cereals. Its presence very much checks the development of the plant on which it has forced its attention, and will infinitely affect the yield of grain.

An interesting point in connection with this fungus is that the race is carried on through the winter by means of special resting spores. In the spring these produce smaller spores which, settling on barbery leaves, give rise to the first stage of the fungus. It is in connection with this stage of the parasite's growth that the spores are produced which are able to infect the cereal plants again. There are a good many features in the life history of the Wheat Rust which make the subject one of peculiar interest to botanists.

It has been suggested that the distinction between the higher cryptogams and the flowering plants is not really so marked as appears at first sight. The subject is one of great interest and calls for comment, although it is not possible to do more than indicate the bare outlines of a most fascinating problem. For

the purpose of the study it is necessary to make comparisons between the reproductive schemes of one of the highest flowerless plants, such as a club moss, with the lowest types of flowering species. Some of the most advanced types of club mosses are to be found amongst the genus Selaginella, whilst right at the end of the flowering plants occurs the cone-bearing tribe, usually spoken of as Gymnosperms. Actually, the firs and their allies have many remarkable features which make them very different from ordinary flowering plants. One of the most striking differences between the advanced flowering plant and the members of the cone tribe is to be seen when the female flowers are examined. These are, of course, borne in collections on cones, which are, however, quite distinct from those producing the male flowers. At the time of pollination the ovule is quite naked, there is no stigma, no style, and the pollen grains find an open way right down to the egg cell. This character is a constant one throughout the whole of the gymnosperms, a name which really means plants with naked seeds.

Now, a close comparison between a typical

gymnosperm and an advanced cryptogam, such as Selaginella, shows a remarkable resemblance between the processes of reproduction. In the latter plant two kinds of spores are produced. One sort, of which a large quantity is developed, are known as the microspores, the others, of which there are comparatively few, have been called the megaspores. Now it is an established fact that the microspores in their production and form closely resemble the pollen grains of the cone-bearing plant. As well, there is a remarkable resemblance between the megaspores and their development, and the female organs in the cone tribe.

In the case of the Selaginella the settlement of the spores in a suitable situation is followed by the formation of an independent organism — the *prothallus*. The microspore forms one kind of *prothallus* (in this case rather insignificant) on which the *antheridium*, or the male organ, is borne. The megaspores are responsible for another sort of *prothallus*, on which the female cells are to be discovered. The act of fertilisation is carried on under water, which may be present in the form of dew or rain drops. It consists in

the emergence of the male bodies (*spermatozoids*) from the *antheridium*, and their attraction to the female organs (*archegonia*) of an adjoining *prothallus*. Thus in the case of the Selaginella the process of fertilisation goes on in independent organisms which are leading an existence apart from the parent plant. This may seem to be a very different method from that which is to be noticed in the fir, where there is no obvious formation of *prothalli*. Actually, however, it can be shown that the *prothallus* and its male organ, the *antheridium*, which arises from the microspore, is not really very distinct from the group of cells which are present in the grain of pollen in the cone plant. The *spermatozoids* of the Selaginella may be considered to be equivalent to the generative cells to be observed in the pollen.

In the same way we may compare the *prothallus* of the Selaginella which bears the female organs, the *archegonia*. The *endosperm* (the part which encloses the embryo) of the cone plant may be said to equal the *prothallus* of the Club Moss. The female organs, with the specialised cells which they produce, are almost identical in both plants. So that,

after all, the distinctions between the reproductive schemes of the Selaginella and the cone-bearing plants are actually very slight. It may be argued that there is still a great difficulty to be cleared up in the case of the two plants under consideration; the cone-bearing plant produces seeds, whilst the Selaginella does not.

The development of the seed is a matter which is peculiar to flowering plants, and it is not possible to make any complete comparison between the two species which have been under consideration. In the case of certain plants allied to the Selaginella, and commonly spoken of as "water ferns" (*Azolla*), the manner in which the spores are produced bears certain points of resemblance to the production of a seed.

Recent researches into certain fossil plants have led to the full description of a race of plants which have been called the *Bennettiteæ*. It seems highly probable that these plants represent the intermediate stage between the cryptogams and the flowering plants. In many respects they may be said to have resembled the ferns in habit and character, although, on

ONE OF THE CYCADS (*Cycas revoluta*)

the other hand, they produced seeds somewhat after the manner of the present-day cone-bearing plants. The only living representatives of these plants on the earth at the present time are to be found in the tropical Cycads, plants resembling palms in their general appearance, though actually very distinct in all other ways. One very singular point in connection with these Cycads is that the act of fertilisation is carried out by means of actively moving male cells, exactly resembling the *spermatozoids* which are so common amongst the flowerless plants. This is in direct contrast to the scheme of the flowering plants as a whole, where the generative cells are conveyed to the egg cell by the growth of the process known as the pollen tube. Although a pollen tube is formed in the Cycads, this is only to start the *spermatozoids* on their way ; the final stages of the journey are accomplished by their own activities. In one species of Cycad (*Cycas revoluta*) no attempt is made in the female plant to produce cone or flower. The carpels, or fruit-bearing organs, are developed on singularly leaf-like processes which are strongly suggestive of the spore-bearing fronds of the ferns. The resulting seeds are large and of a

bright red colour. There is now very little doubt that in this Cycad we have an interesting connecting link between the two great sections into which it is possible to divide the majority of modern plants.

A NEW ZEALAND TREE FERN

This example was growing in Cornwall

CHAPTER II

STUDIES IN FERN LIFE

FEW of our native plants call forth such universal admiration as the graceful members of the fern tribe, and it is quite certain that it would be impossible to find subjects which present a more fascinating life history. Early observers were much perplexed as to the manner in which the reproduction of the fern was carried out. In some way they connected the brown scaly substance on the backs of the leaves with the increase of the kind, but of seeds there was none to be found, and the fern plants seemed to arise spontaneously from the soil. Modern research has dispelled most of the mysteries which surround the story of the fern, and we may now follow the marvellous process by which the new plant comes into the world from start to finish. Yet, even though our knowledge on these matters is now fairly complete, a description of the process is much more than a mere recital of facts. Right from the beginning, when the

spore—a tiny speck of life—first of all appears on the scene, until the final unfolding of the mature plant, there is a strong element of romance such as is not by any means always present in a scientific record.

It is not easy to give a decided opinion on the real position of ferns in ancient times. It was formerly considered that a large number of the fossil remains now classed as *Bennettiteæ* were true ferns. As we have seen in the previous chapter, these really represent a very distinct type. When we consider the conditions, atmospheric and otherwise, of the steamy coal forests, it is likely that ferns very similar to those on the earth at the present time were strongly represented. With club mosses and horsetails they must surely have been a leading feature of the vegetation at that period. Many of the non-flowering plants are mere masses of cellular tissue, but the ferns are very striking in their manner of growth. Moreover, as in the case of flowering species, these plants have roots, stems and leaves in a well defined sense. Several of our native ferns grow into large plants which, on account of their size alone, would attract a good deal of

THE MALE FERN (*Nephrodium filix-mas*)

attention. Of these the Bracken, the handsome Royal Fern, and the very common Male Fern are good examples. In some parts of the world, as we have already seen, ferns grow into tall trees with woody trunks.

Even though the group is such a large one, it would seem that the fern tribe have failed to maintain their former standing in the world. This appears to be due to an extent to their apparent inability to adapt themselves to changing conditions. By far the greater number of ferns cannot live save in very moist conditions, atmospheric and otherwise; as we have seen, they throve to perfection in the saturated atmosphere of the Carboniferous Period and formed a dominating race of the peculiar vegetation of the time. Nowadays there are few parts of the world where ferns occupy such a position in the plant life of the country, save, perhaps, in New Zealand, and some islands in the southern seas. Curiously enough, almost the only ferns which are very general in the world at the present time are the few kinds which are not so dependent upon moist conditions. Of this there is no better example than the Bracken Fern, which occurs in Europe,

Asia, parts of America, and throughout the southern hemisphere. Of course, one can hardly say that the species is identical in character throughout the world; slight variations do occur, but to all intents and purposes the plant is the same which grows so abundantly in this country. In Britain we may, of course, find the Bracken equally at home on the open hillside or under the dense shade of the forest trees; in both situations it seems to prosper amazingly.

For the purpose of our study of the life history of the fern we can hardly do better than take an example of the Male Fern (*Nephrodium filix-mas*). This plant is not only a common wild species, but is also very largely to be met with in gardens, a circumstance which does not apply in the case of the Bracken —not an easy subject to cultivate. So familiar are most people with the Male Fern that a detailed description is scarcely necessary. The leaves of the plant are very variable and may very well be four or five inches in height or, in fine examples, as many feet. The stem is thick, and, in the case of old examples which have been left undisturbed for many years,

A COLONY OF LITTLE MALE FERNS

may assume a trunk-like nature. It is covered with a chaffy material, and is also well adorned with the remains of leaf stalks. The Male Fern is deciduous in habit, although its leaves will quite often stand through the winter in sheltered places. If a leaf stalk is pulled away it will be noticed that the roots adhere to its base, and not, as might be expected, to the stump-like stem. As will be seen later, this is a feature which is to be observed in the case of other species of ferns.

An examination of the developing fronds in the month of April is particularly recommended. These have been in preparation for two or three years, and succeeding generations may be discovered inside the circle. How beautifully the opening leaves are coiled, and in what a thorough manner the young growth is protected with the brown chaffy deposit! This doubtless plays a part in preventing loss of heat and moisture. Should the weather be warm the development of these ferns will proceed at a very rapid rate, and if the plant is visited at weekly intervals it will scarcely be recognised from one time to another.

With the maturity of the fronds of the Male

Fern it is noticed that the backs of the leaves are freely covered with brown patches. It is very easy to see that these spots are kidney-shaped, and on examination with a lens it will be found that they represent mere scales covering a number of tiny stalked bodies. This will be clearly seen if a magnifying glass is used, but under a microscope the true nature of the brown patches will be even more plain. The botanist calls each patch on the fern frond a *sorus*, whilst the stalked bodies are known as *sporangia*. Of course, these latter contain the spores by means of which the fern plant is reproduced. As soon as the spores are ripe the covering shrivels up and the spore cases burst open. The sudden opening of the *sporangium* is brought about by reason of the fact that, when ripe, a row of hard cells which occupy about three-quarters of its length acts like a spring, tearing apart the walls of the case. Thus the spores inside are thrown out into the world, and, being very light, float away on the breezes.

A spore, which is infinitely more simple than any seed, has never, perhaps, been better described than as a tiny spot of living matter ;

THE SPORANGIA OF A FERN
An enlarged view showing the little cases which contain the spores

A FERN SPORANGIUM
(Enlarged)

A MUCH ENLARGED SPORANGIUM
In the act of bursting to expel the spores

BABY FERN WITH PROTHALLUS
(Slightly larger than life size)

individually these specks are quite invisible to the naked eye, although collectively they appear like so much dust on a piece of white paper. One is amazed at the gigantic number of spores which each one of our fern fronds will produce. Every *sporangium,* it is computed, will be responsible for, perhaps, fifty spores; each tiny sub-division of the leaf will bear quite this number of *sporangia,* whilst the tapering leaflets at the side of the stalk may carry thirty or forty fertile sub-divisions. Thus every leaflet on the fern frond, bearing spores at all, may produce quite one hundred thousand spores, and the total spore output of each frond must be many millions of spores. Truly a prodigious total! Yet the world is not overrun with Male Ferns, although every spore produced is capable of giving rise to a specimen. Of course, a very large number of the spores are completely lost, owing to the unfavourable situations in which they alight.

The very best thing that can happen to the spore is that it shall settle down in some moist shady place. Here, after an interval, the tiny speck of life begins to develop, not into a mature fern, but into a flat green scale which has been

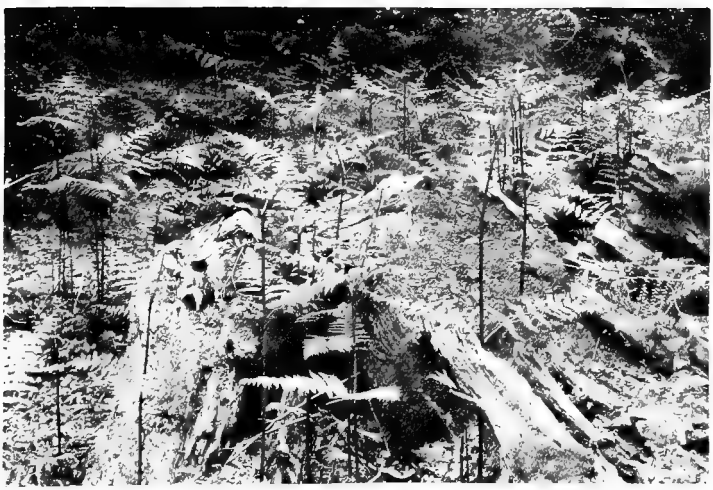
called the *prothallus*. As a rule this process will be about half-an-inch, or something less, in diameter, though it may vary a good deal in the different species of ferns. If we hunt on the moist banks of a hedge round mature fern plants in the autumn, we shall almost certainly find a number of these green scales. An even more easy way to study the development of the *prothallus* will be to secure a packet of spores from some seedsman (or these may be collected from fronds), scatter them on moist soil, and keep the whole surface closely covered with a tumbler. It is advisable to sterilise the soil in the first instance by baking it in an oven in order to check fungus pests. A close examination of the *prothallus* will show that it is secured to the soil by delicate root-hairs, and that it is of a very thin texture, quickly shrivelling on exposure to a dry air.

The succeeding stages in the development of the fern plant cannot be followed with the unaided vision. With a powerful hand-lens, or, better still, of course, a microscope, a close examination of the underside of the *prothallus* will reveal the presence of certain special cells in addition to the root-hairs which have already

THE BRACKEN FERN (*Pteris aquilina*

THE UNDERGROUND STEM OF THE BRACKEN FERN

In the foremost part of the shoot are to be found the buds for two years ahead



THE BRACKEN FERN, SHOWING FRONDS

been mentioned. One group of these, that near the lower part of the *prothallus*, amongst the root-hairs, which in the case of the Male Fern is somewhat heart-shaped, represents the *antheridia*, or male cells. The collection of bodies near the upper portion of the *prothallus* are the *archegonia*, or the female cells of the system. The actual fertilisation of the female organs will take place when there is plenty of moisture surrounding the *prothallus*, such as might be caused by rain or dew. At such times the cells open, and the male organs discharge strange little spirally curved bodies—the *spermatozoids*. These, passing through the watery element, impelled by some motive which has given rise to a great deal of speculation, make their way to the female organs, enter the neck, and so complete the act of fertilisation. It is now generally believed that the explanation of the unerring movements of the male bodies lies in the circumstance that they are attracted towards the female cells on account of a certain substance which is given out from the *archegonia* at this time. As a rule only one *archegonium* on each *prothallus* is fertilised.

It is not very long before the new fern

plant appears on the scene, at first in the form of a tiny bud, relying for its nutriment upon the *prothallus* which bears it. Later on the baby plant starts to send down a root into the soil, a little leaf is sent upwards, and from thenceforward it begins to lead an independent existence. Gradually the *prothallus* withers up, its purpose in life having been fulfilled.

The abundance of the Bracken Fern (*Pteris aquilina*) justifies a few remarks on the life-story of the plant. The general appearance of this fern is well known. The great frond varies much in size, and may well be less than a foot high in exposed places, or as much as three yards in shady situations. The foliage of the Bracken dies down during the winter, and the new shoots usually appear during the month of April. These are a pretty pale green, and quite often are tipped with old gold. The leaf stalks arise from a stout creeping stem, or *rhizome*, which throws out a plentiful amount of fibrous roots, chiefly produced under the leaves. In a sandy place it is not a difficult matter to dig up a portion of the root-stock, and this is worth an examination. The leaf stalks are seen to arise from each side of the stem, and going

THE LADY FERN (*Athyrium filix-fœmina*)

back from the one, or possibly two, leaves which have been produced during the present season, we shall find the remnants of leaf stalks which have served during past years. If the stem is followed up in this direction we shall finally come to a place where it is rotting; as a matter of fact this process of decay is almost keeping pace with the active extensions which are going on at the growing point. Beyond this year's leaf it will be possible to find the buds for next year, and even the season after that. Thus should any accident happen to the developing leaf of the present season there will be another in a fairly advanced state to take its place. The root system of the Bracken is constantly extending, seeing that buds of new stems are continually being produced at the bases of the leaf stalks. This explains the wonderful way in which the fern captures situations. Indeed, it is very likely that, should all the land in the United Kingdom become uncultivated, it would not be many years before the Bracken Fern had claimed the major part for its own.

So complete is the arrangement for the increase of the Bracken Fern by means of its

underground stems that propagation through the agency of spores is uncommon, at any rate in exposed situations. Spores are, however, pretty freely produced in stalked cases which are developed round the edges of the leaflets; these are curved inwards in such a way that a groove is formed. During the late summer the spores are released in great numbers, sufficiently so at times to coat surrounding objects with a brown powder. The subsequent development of the spore consists in the formation of a *prothallus* with sex organs which were observed in the case of the Male Fern. For most people the best chance of watching the development of the new Bracken Fern from the spores consists in growing them on the lines suggested in the case of the Male Fern. It is curious to note that the underground habit of the plant does not at once become apparent. It is only after the production of a number of the leaves that the stem divides into two branches which grow downwards into the soil, whence they never again come up to the light.

A number of species of ferns which are more or less common in Great Britain and Ireland show certain distinguishing features. The Lady

RUE-LEAVED SPLEENWORT (*Asplenium ruta-muraria*)

A typical wall species

Fern (*Athryium filix-fæmina*) bears a general resemblance to the Male Fern, save that it is a paler green and of an altogether more delicate growth. The manner of spore production is on somewhat similar lines to that of the Male Fern, though there are certain small differences. One of the chief of these is that the covering of the spore mass in the *sporangium* is fixed at one side, instead of in the middle, as in the case of the Male Fern.

Many of the ferns are well able to exist in dry situations. The Black Maidenhair Spleenwort (*Asplenium adiantum nigrum*) is a widely distributed species which is always distinctive by reason of its black stalks. This fern seems to be quite happy growing on the top of a wall or in the cleft of a rock. The *sori*, or clusters of *sporangia*, are elongated in shape, and are covered with a very pale green or white scale, during the early stages of development. After a while, however, the spore cases commence to swell, burst through the covering, and fill up the spaces between the clusters, so that eventually the back of the frond may appear to be entirely covered with the deep brown cases. The Rue-leaved Spleenwort (*A. ruta muraria*) is

another species, a common enough kind on walls, but very often overlooked on account of its small size. The root-stock of this plant is often tightly pressed between bricks or pieces of rock, from which arise a number of small fronds, sometimes only an inch or so in length. As in the case of the Black Spleenwort, the spore cases, when becoming ripe, swell up so that the whole underside of the leaf is covered with the brown masses. This very much adds to the appearance of the handsome green leaves.

The Scaly Spleenwort (*A. ceterach*) is remarkable for the manner in which the fronds are protected on the underside with an abundance of rust-coloured scales. There is little doubt that these play a part in protecting the foliage against undue loss of moisture, a danger which is very real in the case of wall plants. As well in dry weather the whole leaf rolls up, so that most people might fancy that the fern was dead. With the coming of moist weather the normal habit of growth is resumed. The spore cases which are clustered on the underside of the leaf have little in the way of a special protecting scale, on account of the abundant covering already mentioned.

MAIDENHAIR SPLEENWORT (*Asplenium Trichomanes*)

THE HART'S-TONGUE (*Scolopendrium vulgare*)
Showing the curious arrangement of the *sori*

It may, perhaps, be well to mention that all these spleenworts vary very much in size according to the situation in which they are growing. On damp walls or rocky hedgerows, where there is an abundance of moisture, the size of the frond is much greater than when the plants are in dry places.

Many species of ferns show a very distinctive manner of producing their spore cases. Everybody is familiar with the common Hart's-tongue (*Scolopendrium vulgare*). The plant is, of course, exceedingly variable (several hundred different kinds have been identified), but its main points are fairly stable. The chief characteristic of the leaf is its undivided form, in outline generally tongue-shaped and tapering to a fine point. The spore cases are usually confined to the upper two-thirds of the back of the leaf, and have been likened to a number of long brown caterpillars. The clusters are placed on the veins of the leaf, and are usually at a distance of about one-eighth of an inch from each other. Each actually consists of two clusters of spores, and is covered when young with a thin white scale. This is, of course, thrown aside when the spore cases ripen.

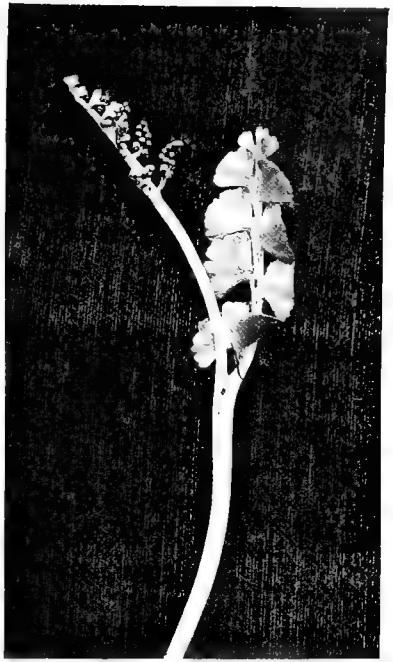
A few species of ferns produce their spores on parts of the leaves which are specially reserved for this purpose, or on altogether different fronds. In the former class must be included the magnificent Royal Fern (*Osmunda regalis*), a plant which, owing to the depredations of trippers, is far less common than was formerly the case. It is still, however, abundant in some of the out-of-the-way parts of the kingdom. In a moist place the Royal Fern may frequently be found with its leaves eight or ten feet in height, and with many of the fronds the upper leaflets are entirely devoted to the business of spore production. On this account the plant is very widely known as "the flowering fern." An examination of the "flowering" portion will show that here the leaflets are very much contracted and bear upon their borders clusters of spore cases, which are usually so abundant as to give to the divisions a uniformly brown appearance. Under a magnifying glass it will be seen that the spore cases are stalked and globular in form.

Two kinds of fern which are not so familiar as they might be if people were only more observant are the Moonwort (*Botrychium*

THE ROYAL FERN (*Osmunda regalis*)

THE BLACK MAIDENHAIR SPLEENWORT

(*Asplenium adiantum-nigrum*)



THE MOONWORT (*Botrychium lunaria*)

lunaria) and the Adder's-tongue (*Ophioglossum vulgatum*). In both these cases the leaves are very decidedly divided into two parts; the business of one portion is that of an ordinary frond, whilst the other section is concerned with spore production. These ferns are chiefly to be found growing amongst grass; the Moonwort seems to prefer a somewhat drier situation than that favoured by the Adder's-tongue. A very careful search will be necessary to find them, however, as they seem to blend to a striking extent with the surrounding vegetation. The frond of the Moonwort usually appears about the month of April, and at a certain distance from the root-stock it divides into two stems, one barren and the other fertile. The barren frond develops into curious sections shaped something like half-moons, whilst in the case of the fertile stalk there are produced divisions bearing clusters of spore cases, which, when ripe, are red brown in colour. The Moonwort sends up but a single leaf each year, and by cutting open the base of the stalk it is possible to discover the frond for the next season, and within this even the leaf for the third year may be discerned.

Much the same kind of thing occurs in the case of the Adder's-tongue. Here, again, we may observe the curious double frond, which is divided into a fertile and a barren portion. The barren portion of the frond is not divided at all, but is of a simple egg-shaped design. The fertile division runs up into a kind of spike, at the upper part of which the spore cases are arranged in a double row. In both these strange ferns the leaves only last for a few months and usually die right down, the nutriment passing into the little root.

In the case of the Hard Fern (*Lomaria spicant*) the fertile fronds are quite distinct from the ordinary leaves. The barren leaves, which vary very much in length according to the amount of moisture which the plant is able to secure, are remarkable for the neat arrangement of the leaflets, not, as at first appears, in opposite pairs, but actually in alternation. The fertile fronds are usually much taller and a good deal more erect in habit. There is a marked contraction of the leaflets, which are really very narrow, and bear on each side of the mid-veins clusters of spore cases. When these are fully ripe, however, they cover in almost the whole

THE HARD FERN (*Lomaria spicant*)

THE ADDER'S TONGUE

(*Ophioglossum vulgatum*)

THE POLYPODY (*Polypodium vulgare*)

One frond is turned so as to show the round *sori*

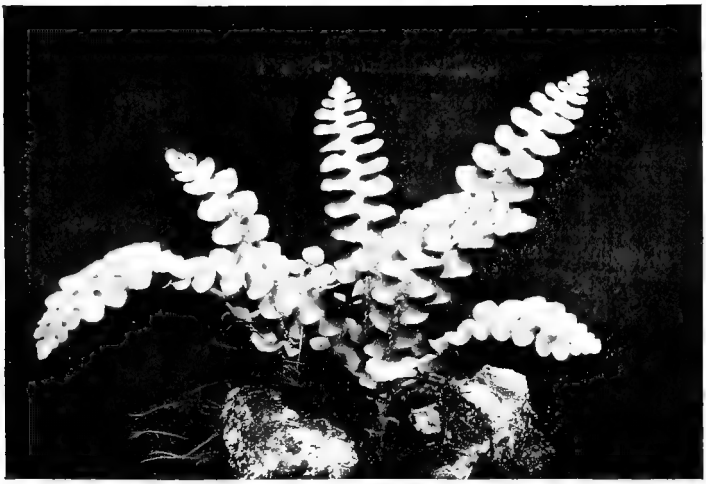
of the underside of the leaflet. In their early days the spore cases are covered with a protecting scale.

After all, it is likely that one of the most familiar ferns is the common Polypody (*Polypodium vulgare*). This plant is very happy in many situations, but it is really most at home on the trunks and branches of old trees, especially oaks. The creeping stem, from which the leaves arise at regular intervals, pushes its way in and out through any leaf mould which may have accumulated. The stem is fleshy, and stands the plant in good stead during very dry weather, when, often enough, the shrivelled appearance of the fronds make it appear that the Polypody is dead. A few showers of rain soon revive the foliage, which is evergreen in habit. The spore cases are chiefly confined to the upper part of the leaf, and these are arranged in clusters on either side of the midrib of the sub-divisions. When in a ripe state the groups are often very closely set, so that a good deal of the back of the frond will appear to be covered with an orange-coloured coating. This often gives a very attractive appearance to the leaves of the Polypody. For its supply of

moisture the Polypody must needs rely to a considerable extent upon that which it can secure from the atmosphere. In some ways, therefore, it strongly resembles the curious epiphytes of the tropical forests.

It may be the good fortune of the traveller in rocky districts to come across one or other of the dainty species of filmy fern. Wherever there are rocks, which from some cause or another are maintained in a moist condition at all times, there one may hopefully look for the Tunbridge Filmy Fern (*Hymenophyllum tunbridgense*) or the One-Sided Filmy Fern (*H. unilaterale*). These ferns are very similar in appearance, the chief distinguishing feature being that in the latter plant the fronds are much narrower than is the case in the first named. One is at once struck by the semi-transparent nature of the little fronds, which rise from wiry rootlets, often so closely interwoven as to form a great mat, which may well be several yards square. The spore cases are borne in cup-shaped scales on the backs of the frond, and should be examined with the aid of a magnifying glass.

All those who really love ferns will resist



THE SCALY SPLEENWORT (*Asplenium ceterach*)
Usually to be found growing on old walls

THE TUNBRIDGE FILMY FERN (*Hymenophyllum Tunbridgense*)

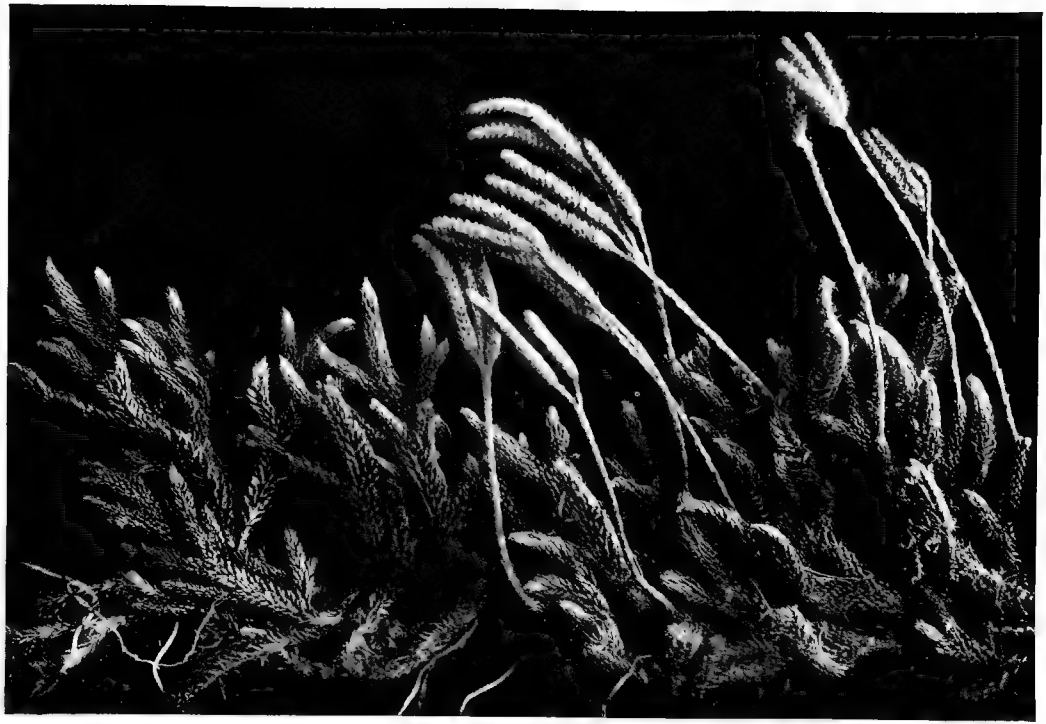
the temptation to tear up masses of the attractive fronds, seeing that these species could never be cultivated in an ordinary garden. Indeed, with all ferns it is a wise rule to refrain from uprooting unless one has a very good place in which to put the specimens. Even then only very small portions should be secured, and if the species is a real rarity, the genuine student will not feel it a sacrifice to leave the plant in its natural home, and take a solemn vow not to reveal its hiding-place to anyone.

CHAPTER III

RELATIVES OF THE FERNS

WHILST there is no doubt that the homely names of many plants are the nicest, it is to be feared that quite often they are misleading. Of this there is perhaps no better instance than the case of the so-called "club mosses," which, of course, are not true mosses at all. Indeed, in their general manner of growth these plants are quite closely allied to the fern tribe, albeit a number of the species bear a superficial resemblance to the mosses. It is interesting, in view of a certain amount of confusion, to indicate in a brief manner the habits of the typical club mosses, so that the observer will be able to decide in a few moments the nature of the plant which has come under his notice. However moss-like these plants may seem at the first glance, a small examination will reveal several distinctive features.

The Common Club Moss (*Lycopodium clavatum*) is sometimes abundant on the moister



THE COMMON CLUB MOSS (*Lycopodium clavatum*)

parts of moors, particularly when the country is rather elevated. The chief characteristic of the species is its creeping stem, which may be traced for a distance of two or three feet. This stem is frequently branched, and now and again the divisions rise upwards in a singularly erect fashion. This habit of growth is a very distinctive feature which will not be readily forgotten. The whole of the stems are very thickly covered with narrow leaves, which are so stiff as to be almost bristle-like. Here and there it will be noticed that certain upright branches are bearing cone-like processes of which a more particular description will be given in a succeeding paragraph. If the recumbent stem of the club moss is pulled up, it will be found that at intervals from the underside real roots are sent down into the soil. These organs are quite absent in the mosses, the only underground processes being certain fibres which play a mechanical part in attaching the plants to the ground.

The study of the club mosses is simplified by reason of the fact that there are comparatively few representatives of this group on the earth at the present time. As we have

already seen, plants not unlike our club mosses played a part in the formation of the coal deposits. These, however, were of enormous size, judging by the fossil remains, and quite unlike the humble representatives which are to be seen nowadays. As has been indicated, the species which is most likely to be met with is the Common Club Moss. This plant is abundant in mountainous districts, but it does not usually occur in the comparatively low-lying lands of the south of England. A species which does grow in moorland districts in the southern counties is *L. inundatum*, and this has been found distributed over the great tract of country forming the New Forest. It also flourishes in some parts of the north of England, though as a moisture-loving plant it rapidly disappears with the drainage of the land.

Certain other species of club moss may be found in the mountainous regions of Scotland and Wales, but most of these are very rare or extremely local. Tourists in Switzerland and other Alpine districts abroad should keep a sharp look out for these interesting plants. In passing, it may be pointed out that there are several kinds of club mosses in common culti-

THE NEW FOREST CLUB MOSS (*Lycopodium inundatum*)

vation in greenhouses, and almost everyone can secure and grow examples for study. The Common Selaginella, which often invades every pot in a fernery, must be familiar to many, although it is quite likely that not a few gardeners would be puzzled to explain to what group the plant belongs. Altogether there are three or four hundred species belonging to this family. A very singular group of club mosses is that which is typified by the Quillwort (*Isoëtes lacustris*). This plant is very common in the northern lakes of these islands, and is found established at the bottom of the pool, where it roots in the mud.

It is only within comparatively recent times that the life story of the club mosses has been understood to any extent. Even now there are many points which are only partially explained. In the case of the *Lycopodium*, it is in the cone-shaped processes that the little spore cases (*sporangia*) are produced. With a magnifying glass these may be distinguished, and they are seen to be kidney-shaped and attached to the upper side of the leaf. The *sporangia* open when their contents are ready for dispersal, and at that time an enormous

number of yellow spores are released. Incidentally, it may be mentioned that the powder formed by the *Lycopodium* spores is highly inflammable, and has been used in the making of fireworks and the production of that effect which is commonly known as "stage lightning." The settlement of the spores on the ground is ultimately followed by germination; the result is the production of an independent body on which the sex cells are developed. The fertilisation is accomplished by the passage of the male bodies, from the special place on the *prothallus* (as the organism is called) where they are produced, to an adjoining egg cell. On the completion of this proceeding there commences a series of changes which result in the development of the perfect plant. The whole process takes a very long time, and some years may elapse before the plant appears on the scene.

Kerner has drawn attention to an interesting fact in connection with one species of club moss —*Lycopodium cernuum*. The first happening in this case after the fertilisation of the egg cell is the production of a plant which does not at first resemble the adult form. Now, this midway style, which ultimately grows into the true

THE ONLY BRITISH SELAGINELLA
(*Selaginella spinosa*)

THE QUILLWORT (*Isoetes lacustris*)

L. cernuum, is very remarkable owing to the fact that it closely resembles the mature form of another club moss, an Australian kind known as *Phylloglossum*. The point is interesting as an instance of the close relationship between many plants which at the present time appear to be diverse species.

In the case of the Selaginella it is noteworthy that two kinds of spores are produced. The *sporangia* are situated in the axils of the leaves and, as a rule, the *microsporangia* are uppermost, and the *megasporangia* are lower down on the shoot. In the former processes a large number of very minute spores are produced, whilst in the latter there are but four of a larger size. With the large spores the *prothallus* is partly formed in the *megasporangium* before being shed. These are responsible for the egg cells. The shedding of the small spores is followed by the formation of an *antheridium*, or male organ. This produces a few *spermatozoids*, those active little bodies whose business in life is to seek out the egg cell and perform the business of fertilisation. In the Water Club Mosses (*Isoētes*) there are again two kinds of spores, and the general manner of procedure is on

very similar lines to that which can be observed in the case of Selaginella. A few of the club mosses have other means of increasing their kind. This consists in the production of small "bulbils," which are of a delicate green colour. These sometimes arise in the place of the *sporangia*, and when they are fully developed fall off and finally give rise to new plants.

For those who wish to study the curious reproductive scheme of the club mosses a quantity of the spores of *Lycopodium* and Selaginella may be scattered on soil which has been sterilised by baking in an oven. The treatment of the soil is necessary by reason of the fact that the *prothalli* of club mosses seem to be peculiarly liable to the attacks of mould fungi. The soil should be in a moist condition at the start, and then, if the pan is covered with a glass shade, little further water will be required. In the case of the Selaginella it is necessary to sow both kinds of spores.

Naturally many of the points in the germination of the spores of club mosses are on an exceedingly small scale and somewhat difficult to follow. To those who are really interested in the subject it may be suggested that an

A TYPICAL HORSETAIL (*Equisetum arvense*)

enormous help to the study will be a microscope of even a low power. With its aid it will be seen that some of the spores are really objects of great beauty, whilst the lenses will reveal many points which could not possibly be observed with the unaided vision.

Another important group of plants which is closely allied to the ferns is the horsetails (*Equisetums*). Like the club mosses, it is generally believed that the early types of horsetails were on a very large scale, and played a big part in the formation of coal deposits. Many of the fossil remains, which bear a more or less striking resemblance to our horsetails, must have been immense trees, perhaps as tall as anything which is on the earth at the present time. It is singular how these comparatively primitive plants have been beaten by the more advanced types. Nowadays there is only one living genus of horsetails, which numbers scarcely more than thirty species. Nevertheless, our native horsetails are very distinctive plants, which almost everyone has noticed from his earliest days.

It may seem a strange thing to say, but if a number of ordinary people went out to hunt

for horsetails, by far the greater number would probably bring back something which was not the plant at all. Quite often the Mare's Tail (*Hippuris vulgaris*) is mistaken for the true *Equisetums*. This plant is sometimes quite common in damp ditches, especially where there is any stagnant water, and superficially it bears a resemblance to the Horsetail. It is, however, a true flowering plant, and if we search at the base of the upper leaves on the stem we shall find the small flowers. In the case of the *Equisetum* these will, of course, never occur, although both plants have the same cylindrical jointed stems.

One of the most abundant of British horsetails is the Field Horsetail (*Equisetum arvense*). The plant grows in damp places almost everywhere, but it is especially common on railway embankments and by the sides of roads. In fields or gardens it is a sign of faulty cultivation, as showing that the land has not been properly drained. It is not an easy plant to eradicate, seeing that its creeping stems burrow in all directions under the surface. In the summer the plant is rather attractive with its upright, rounded stems, from which grow out

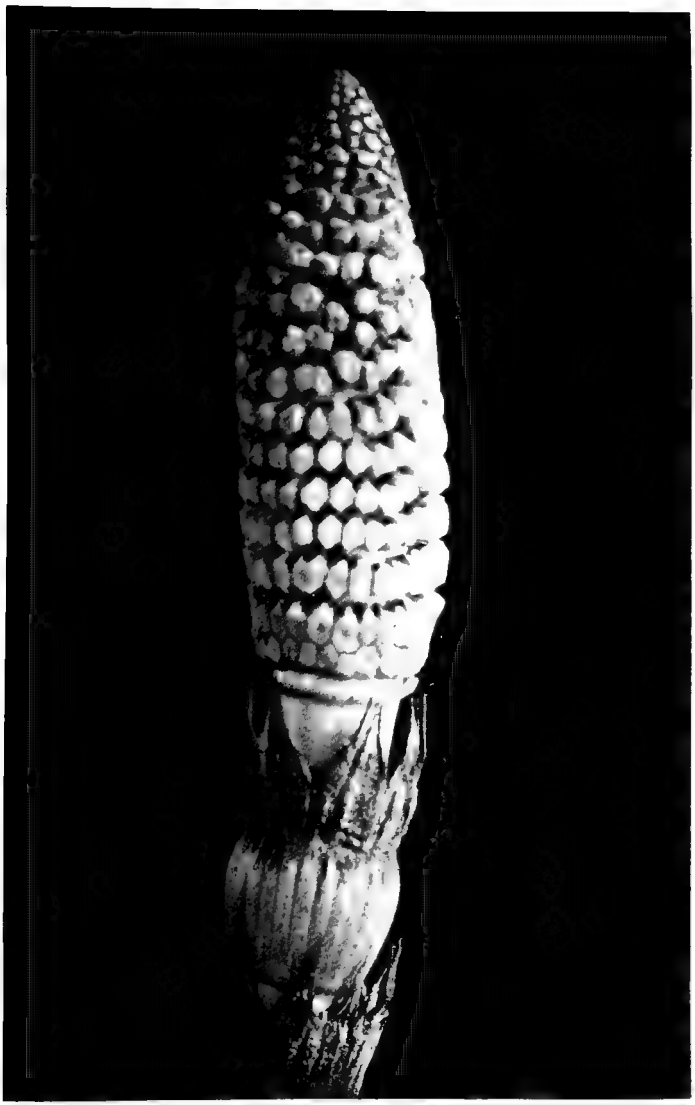
FERTILE SHOOTS OF A TYPICAL HORSETAIL
(*Equisetum maximum*)

circles of long outgrowths which might easily be taken for leaves. For the real leaves, however, we must search round the upper part of the stem joints, where there is a collar-like arrangement with a pointed edge. Actually this collar represents a series of leaves joined together at the base. These are not specially green, and the work which the foliage of most plants carries out is here performed by the stem and the circles of outgrowing branches, which have already been mentioned.

As a whole, it will be noted that the stem of the Horsetail is ribbed, and is very hard to the touch ; this is chiefly due to the large amount of silica which is present as a strengthening material. The stems are hollow to a large extent, save at the joints, where there is a certain amount of solid matter for the strengthening of the plant. These green stems of the Field Horsetail play no part in the reproductive scheme of the plant, other than the securing of food supplies for the extensive system of roots which are below the level of the soil. The fertile shoots are to be found quite early in the season, and in a mild spell may be looked for during the latter part of March. They are

often rather difficult to discover owing to their pale brown colour, which blends with the tone of the ground. Compared with the barren shoots the fertile ones are comparatively short, but they are very sturdy in habit. In character they are quite soft, pale in colour, and have little or no chlorophyll. All the energy which they require arises from the roots, which all through the previous summer store away the food materials elaborated by the green sterile shoots. The shoot is surmounted by a cone, which is composed of compact six-sided patches. As the development proceeds, however, it is seen that these parts separate, so that each patch is found to be borne on the end of a stalk.

On the underside of the scales are borne the spore cases. During a dry day the spores may be shaken out in great quantities on the hand, or, better still, on a piece of white paper. Seeing that these spores are amongst some of the most curious objects in the natural world, they are worth a small description. A few scattered on a glass slide and examined even with a low-power lens will at once arrest the attention of the most indifferent.



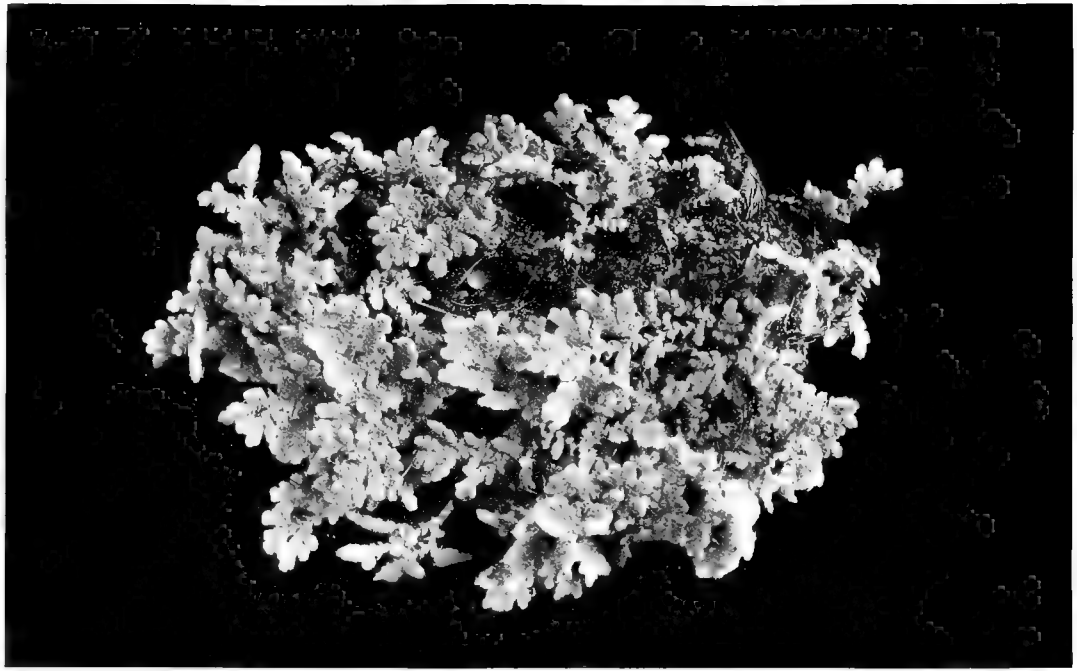
FERTILE SHOOT OF HORSETAIL (*Equisetum maximum*)
Showing the angular scales bearing sporangia

It may be explained that the wall of the *Equisetum* spore is three-layered, and outside of these is a layer which is formed into four long arms. Thus, when magnified, the body resembles a ball with four long clubbed threads attached to it. These are seen to be constantly on the move; even as one watches them through the microscope they are twisting about in a most singular manner, at times being fully extended, and at others wound closely round the spore itself. The constant movement is due to the sensitiveness of the threads to changes in the degrees of moisture in the atmosphere. Blow lightly on the slide, and at once all the spores change their position in response to the damp breath. One purpose served by these active threads seems to lie in the linking up of a number of grains, so that the spores may float about arm in arm, so to speak. They are so light that even an aggregation of them can be wafted by the very lightest breeze. The writer has made several attempts to secure photo-micrographs of *Equisetum* spores, but on account of the continuous movement this has been quite impossible.

Owing to its peculiar method of spore dispersal the *Equisetum* secures a very effective distribution. Though the spores are identical in appearance, yet they mostly give rise to different kinds of *prothalli*, one of which bears the male organs, and the other the female cells. It is thus essential that the two kinds of spores should be in reasonably close contact if a fresh plant is to be the result. In this connection it will be realised that the part played by the threads in linking up a number of the spores is a valuable one.

Besides the Common Horsetail there are three or four species of *Equisetum* which are more or less common. One of the most imposing is certainly the Giant Horsetail (*E. maximum*), which must be looked for in damp ditches, and even growing up through the shallows of stagnant pools. It is not uncommon to find specimens of this plant which may be three or four feet in height. The fertile shoots, as in the case of the Field Horsetail, come up before the ordinary green stems, and are quite short, though very sturdy in appearance.

The Smooth Horsetail and the Marsh Horsetail (*E. limosum* and *E. palustre*) are found in



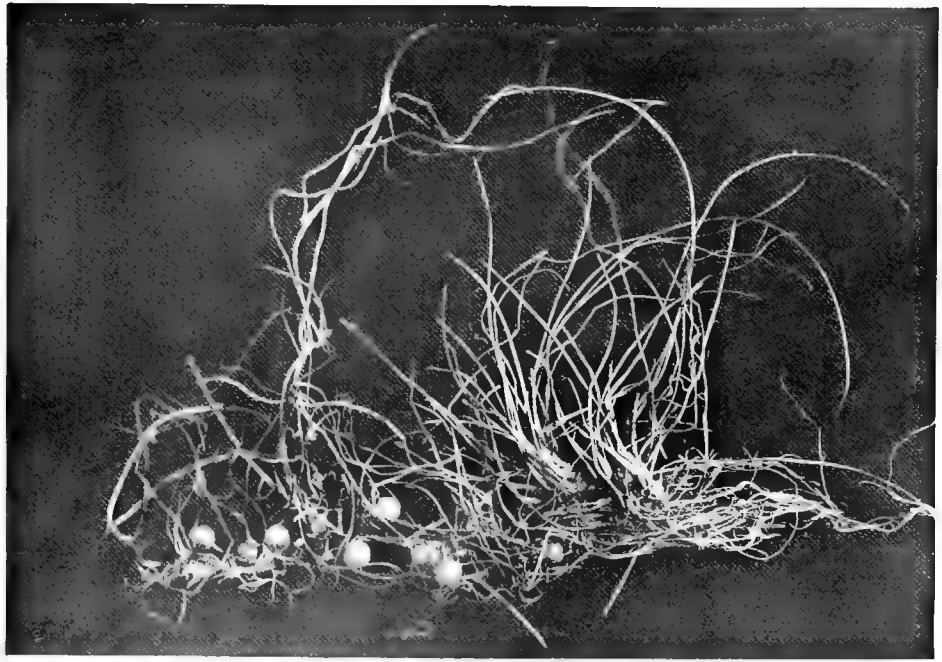
A WATER FERN (*Azolla caroliniana*)

very similar situations to that which is favoured by the giant species. Sowerby tells us that the first-mentioned plant is a very active agent in the changing of pools into swampy places. As soon as the surface water has departed the plant abandons the position for a wetter situation. In both these species the spore-bearing cones are produced on the end of the green branched shoots, and thus the fertilising dust is not matured until well into the summer.

The most graceful of all the horsetails—*E. sylvaticum*—is usually to be found in shaded places where there is a fair amount of moisture. It is rarely more than about fifteen inches in height, and its slender stem is hardly strong enough to maintain it in an upright position ; a fact which rather adds to the general appearance of the plant. A singular feature of this species is that its fertile shoots at first exactly resemble those of the common Field Horsetail. They do not, however, die down when their special business is accomplished, for afterwards they produce green lateral shoots, so that finally it may be difficult to distinguish them from the non-fertile stems.

The fact that these different kinds of horsetails mature their spores at such varied times will make a study of the plants easy, for from April until August it is possible to find cones in maturity, or not far removed from this state. If any attempt is made to grow the spores it is again very important to sterilise the soil, as in the case of the club mosses, by baking. Afterwards scatter the spores as soon as they are secured (they will not keep fresh for long) on the newly-dampened soil, and then at once cover them with a glass shade. A good deal of patience must be exercised, as it is quite likely that the *prothalli* will be somewhat long in appearing.

The remaining relatives of the ferns which call for special notice are certain curious little plants which are more or less aquatic in habit. One of these is not actually a native of Britain, but it has become well established in certain parts of the south of England. This is *Azolla caroliniana*, a plant which is very common in the warmer States of North America, and is also found in Australia, though whether the species is actually indigenous in this continent cannot be positively stated. During the warm



THE PILLWORT (*Pilularia*)

summer weather the *Azolla* grows very rapidly in this country, so that even the native water plants are occasionally overwhelmed by its activities. Sometimes the surface of the pond is completely covered in with the foliage. Underneath the floating leaves there is a large quantity of roots which hang downwards into the water. The plant produces two kinds of spores, those known as megaspores being provided with a floating apparatus and singular hook-like contrivance. The microspores, which are ejected from the spore cases in packages, have certain barbed attachments to which the hooks of the megaspores readily adhere. Thus the formation of the two kinds of *prothalli* which takes place in the water will be soon followed by the blending of the sex elements.

The Pill Wort (*Pilularia globulifera*) is an allied species which grows on the mud bottom of ponds or, on occasion, in swampy situations. This is a singular plant, with needle-like leaves. The spores are produced in cases at the base of narrow leaves. These spore cases are rather complicated as a matter of fact, in that they are divided into several compartments, in which

are produced true *sporangia*. Some of these contain microspores, whilst others produce one megaspore. Fertilisation is accomplished after the formation of the *prothalli* from the two kinds of spores.

CHAPTER IV

MOSSES AND LIVERWORTS

THERE is a tendency nowadays to overlook little things. This is to be deplored, particularly in Nature Study, for many of the small, and somewhat insignificant, forms of life can offer much that is of interest and value. It is perhaps more true of the enormous number of plants which have been grouped together under the term "moss" than of anything else in the botanical world. People admire the pretty green foliage of these lowly plants, but how very few, even of those who pride themselves on some knowledge of living things, have the remotest idea of the habits of life and method of increase of the commonest kinds of mosses. Although the plants themselves are so small, the study of them is really rather a formidable matter, largely on account of the enormous number of species, running into many hundreds in Britain alone, which have been described. It goes without saying that within the limits

of the present chapter it is not possible to do more than give an outline of the usual method of reproduction, and we must remember that in the different kinds this procedure may be considerably varied. Again, out of the large range of kinds it will only be possible to take a very few typical species. Fortunately, the general character and habits of these mosses will give us a good idea of the manner of growth of the group as a whole.

For want of a better term one is led to call the initial processes in the scheme of reproduction in the mosses "flowers." Though to an extent the word is misleading, the term is a good one, in that it at once conveys to the mind of the beginner the fact that he is studying the parts of the plant intimately associated with increase of the kind. Much of the life-story of the mosses is hidden from our unaided vision, but fortunately it is possible to see without the aid of a microscope how the "flowers" of a very common moss are produced. A small pocket lens will be found to be very helpful, however, in the study of mosses.

The Common Hair Moss (*Polytrichum commune*) is at once a very beautiful and an ex-

THE "FLOWERS" OF THE COMMON HAIR MOSS (*Polytrichum*)
(Slightly enlarged)

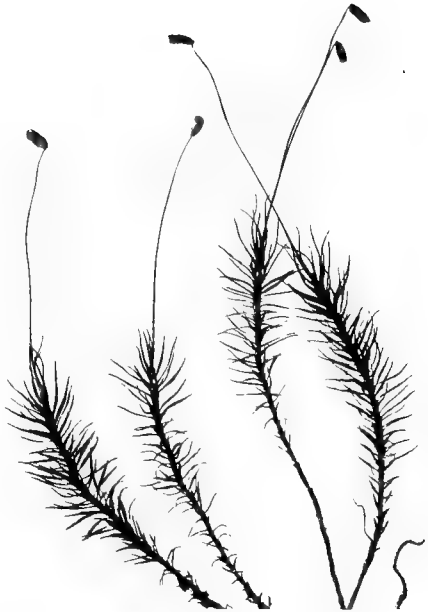
ceedingly abundant species. It chiefly grows on damp and shady banks, or on very moist heaths, and is notable for its habit of living in colonies. These sometimes form big cushions, and in such a condition, where there is plenty of water about, the individual stems may be many inches in length. In the illustration of the Common Hair Moss facing p. 64 the photograph has been slightly enlarged in order to show the processes at the tops of the shoots. These represent the "flowers" of the moss, and as such are worthy of some detailed description.

As a general rule, the Common Hair Moss may be found in bloom nearly all through the winter, and a search amongst any clump of the species will yield a plentiful supply of the material for examination. It is in the curious cup-like formations at the tips of the moss-shoots that the male flower is produced; the female organs are also developed at the summit of the growths, though on distinct shoots. At a certain stage in the development of the "flowers," the *spermatozoids*, emerge from the male organs (*antheridia*), travel towards the female organs (*archegonia*), and enter the egg cell. In a few mosses the two sexes of the

flowers are present on the same shoot, but more often they are, as we have seen in the case of the Hair Moss, on different stems. It is not an unnatural question to ask, in what way the *spermatozoids* can travel the intervening space? As in the case of the fern plants mentioned in Chapter II., the little bodies move along through the agency of water. By a beautiful arrangement, the flowers of the mosses do not come to maturity save in very moist weather, when the whole plant is covered with a film of water. Through this moisture the *spermatozoids* travel, aided in their movements by two long hairs which exhibit a considerable amount of activity. It is now generally believed that when they are ready for fertilisation the female cells give out into the surrounding moisture a certain element which attracts the male bodies to the source of the discharge.

We thus see why it is that the mosses are in a most energetic condition during the damper months of the year, for the scheme of reproduction cannot be carried through unless the plants themselves are covered with rain or dew drops.

There is much in this strange story which



THE SPORE CAPSULES OF THE HAIR MOSS

HOW THE HAIR MOSSES CLOSE THEIR LEAVES AS A PROTECTION AGAINST DRY WEATHER

is still shrouded in mystery, but it is more easy to appreciate the events which follow the blending of the sex elements. In the case of the Common Hair Moss it is a singular fact that, after the *spermatozoids* have left the male flowers, a fresh stem arises from the centre of the cup-like device, and in time this may quite likely produce a new inflorescence. With the "flower" containing the egg cell, however, it is not long before the production of the curious little capsules is started ; these are at first quite upright in their bearing, but will finally bend over in the manner indicated in the photograph. In the case of the Common Hair Moss the capsule is, during its early stages, enclosed in a hood ; but as the development goes forward this covering is shed, and discloses the square case with a little lid. Finally the lid falls off, or, for the purposes of examination, we may remove it, and it is possible to see that the capsule at its mouth is covered with a skin, save that all round the border there is a ring of tiny holes. In the different kinds of moss these openings in the capsule vary a great deal. Now our capsule is full of spores, tiny specks of life which are to be sent forth to the world

to establish a fresh moss plant, and we can easily see how well their dispersal is secured. On a breezy day in the early summer the cases will sway backwards and forwards in the wind ; meanwhile the spores escape, almost as light as the air itself, and floating away, may be carried to a great distance.

The most happy outcome of the journeyings of the spore is that it should finally come to a resting place in some damp, shady soil. The germination of the spore is followed by the production of a network of green threads known technically as a *protonema*, which lies along the moist surface of the ground. At certain points in the filaments there arise buds, very much after the same style as is to be seen in the case of strawberry runners. All these give rise to moss stems which develop on the familiar lines. By the dying away of the *protonema* these stems may become isolated, so that the members of a great colony of moss plants appear to be individuals, although as a matter of fact they may all owe their origin in the first place to the same mass of green threads. From the stems are developed certain fibres which chiefly serve the mechanical purpose of fixing

the moss plant in the soil. These must not be thought of as roots, for such underground organs are not found in the mosses. It is obvious that in the absence of true roots some special means of securing moisture are necessary ; the matter being of great interest is dealt with somewhat fully on a succeeding page.

In addition to the method of increase by spore production which has been outlined, some kinds of moss are able to reproduce their kind by the production of brood bodies, or *gemmæ*, as they are called. These represent little collections of advanced cells borne directly on the leaves of the mosses, yet capable of giving rise to new plants when they become separated from the parent. It should be noted in this connection that the brood bodies are produced without any sort of fertilisation. The most likely kind to meet with bearing brood bodies is the Four-tooth Moss (*Tetraphis pellucida*), which should be sought for on the lower parts of old trees or decaying portions of wood. Many of the showy green stems end in small cups, which contain brood bodies capable of giving rise to fresh plants when, after being detached, they settle down into moist places.

Like lichens, mosses are well able to hold their own in inconvenient situations. Within limits it seems almost impossible to kill certain kinds. The various species which make their homes upon rocks, walls, or roofs are subjected to a terrific ordeal of heat and dryness during the summer months; yet with the return of the wet weather they become delightfully green in a short while. In a general way one very important matter which helps the mosses to conserve their moisture is the habit of growing in colonies. A very slight knowledge of mosses will tell us that it is a common feature for these plants to grow crowded together, quite often—as is the case with the Common Hair Moss—forming large cushions. Apart from this, many species have special cells in their construction, expressly designed for the purpose of storing water. Everybody who has been in a fir or a beech wood has noticed the rounded cushions of the white-leaved Fork Moss. They are pleasant to feel, and it is a natural thing to pick them up. One of their most striking features is that they are quite moist on the under side, even though we may have had weeks of dry summer weather. By

PATCHES OF THE FORK MOSS (*LEUCOBRYUM*) IN A WOOD

pressing a mass of this moss in the hand it is even possible to squeeze out some drops of water, a wonderful thing, indeed, when we consider how dry everything is around us.

An examination under the microscope of the Fork Moss would show us that it has been provided with special cells, whose sole business it is to take in and to store water, whenever there should be moisture about. In the case of the Sphagnum Moss it is seen that the same kind of cells are present, although the fact that they are well charged with moisture does not impress us so much as did the condition of the Fork Moss, seeing that the former species always grows in places which are more or less damp.

Speaking in a general way, mosses, unlike the more familiar type of plants on this earth, depend for their supply of moisture on what they can absorb through their leaves. The fibres, which it has already been pointed out are not real roots, are not specially adapted for the absorption of moisture, although in some cases they may possibly help in this direction. In a general way, we must think of the moss plant as taking in moisture all over its foliage,

and this it is able to do from the air or from actual drops of rain or dew.

Some of the mosses, notably the species of *Polytrichum*, have special means of guarding against undue loss of moisture. The great cushions of *Polytrichum* will present a very different appearance during the dry weather which so often comes with March from that evinced during the time when there is plenty of moisture about. If we examine a single stem we shall find that instead of the leaves being spread out, they are drawn up closely to the stalk. In this way the exposed surface is very much reduced, and the rapid evaporation of moisture will be checked. These Hair Mosses are astonishingly sensitive to a dry air, as can be readily proved. If we take a bunch of the stalks home with us during moist weather and place this in an ordinary room, it will be found that quite soon the leaves close up, and so rapidly will this take place that it is often difficult to examine the plant indoors. In addition, a certain number of the Hair Mosses have filmy processes which cover the entire green part of the leaf.

Happily some of the most distinctive mosses

ONE OF THE BOG MOSSES (*Sphagnum*)

are either very common or, at any rate, are not difficult to discover, and it may be of interest to touch upon a few representative species. One might say that it would be very difficult to find a bog in which one or other of the Sphagnum Mosses could not be found. The most abundant of these is certainly the Blunt-leaved Bog Moss (*S. obtusifolium*). This species is a large moss with short clustering branches, and, like so many of these bog mosses, grows in great masses in damp situations. The individual stems are of a weakly habit, but they gain sufficient support by leaning against one another. It is only during its early days that the Bog Moss has any attaching fibres. The "flowers" are produced at the summit of the shoots, and the female processes give rise to small stalked spore cases. Another very common Bog Moss is the Slender Bog Moss (*S. acutifolium*), a tall kind which is often whitish in colour, and tinged with pink. It can be readily distinguished from the preceding species by its delicate habit of growth. The floating Bog Moss (*S. cuspidatum*) is of somewhat similar appearance, though when, as is often the case, it grows more or less submerged

in water it is of a most vivid green. In contrast to these tall-growing Bog Mosses, there are several kinds of dwarf habit. Most of these are to be found on moist heath, growing in compact masses. One of the striking species is the Red Dwarf Bog Moss (*S. rubellum*), which has short, closely matted stems of a reddish colour.

Another important group is that of the Thread Mosses (*Bryum*). One of the most abundant of these is the Silver Thread Moss (*B. argenteum*). This species is usually found upon walls and is very distinctive, owing to its pretty silver appearance. When the red spore cases are produced the whole plant is one of the most attractive of our small mosses. In somewhat similar situations is to be found the Hairy Thread Moss (*B. capillare*), a plant which grows densely matted together and has leaves which are tipped with bristles.

The Thyme Thread Mosses, which are typified by a very common species, *Mnium hornum*, as a rule favour somewhat damp situations. The kind which has been named often completely covers the ground of moist, shady woods with tufts which may be three inches high. The spore cases are oval in shape, and are

BRYUM ARGENTEUM (A wall moss)

BRYUM PALUSTRE

A moss to be looked for on upland pastures

borne in a drooping fashion. The leaves of this moss are decidedly large and are lance-shaped. Growing amongst rocks we shall find certain of the small Fringe Mosses (*Grimmia*). Some of these species grow in dense cushions, and one (*G. pulvinata*) is readily distinguished by the circumstance that when young the fruit stalks are arched in such a way that the spore cases touch the leaves. The Screw Mosses (*Tortula*) are also common on rocks and walls. One, the Wall Screw Moss (*T. muralis*), is almost certain to be found in such places, and its little cushions look quite downy by reason of the hairy points on the leaves. The spore cases are long and narrow and the curious teeth-like processes at the mouth of the case are spirally coiled. As the weather becomes quite dry, the teeth uncoil to an extent, and thus allow the spores to escape. The Apple Mosses (*Bartrammia*) grow upon dry banks, walls, or rocks. These are chiefly found in more or less mountainous districts, though some of the kinds have a wide distribution. The young spore cases are rounded, and, being a bright green colour in the spring, bear a resemblance to miniature apples.

The various kinds of Fork Moss have been grouped together into several genera. Mention has already been made of the White-leaved Fork Moss (*Leucobryum glaucum*), which is so common in dry woods. The Flat Fork Mosses may be distinguished from the fact that their leaves are placed alternately on either side of the stem, in such a way that they almost resemble minute ferns. The Common Flat Fork Moss (*Fissidens bryoides*) is abundant in moist woods and also on shady banks. In this instance the spore cases are produced at the end of the stem, but this is not the case with all the Flat Fork Mosses. A species called *F. adiantioides* produces its spore-bearing stalks about half-way down the stem. The Broom Fork Mosses are somewhat larger plants, some of the species being four or five inches in height. These mosses are grouped together under the name *Dicranum* and *Dicranella*. The Lily Fork Moss (*Dicranella heteromallum*) is common almost everywhere. It covers the earth with large patches of bright green, from which arise the brown spore cases. The stalk bearing the spore case is very much bent, and the case itself is furrowed.

THE COMMON CORD MOSS (*Funaria hygrometrica*)

THE NEAT FEATHER MOSS (*Hypnum purum*)

A very abundant species, which is familiar in appearance, if not by name, to almost everybody, is the Common Cord Moss (*Funaria hygrometrica*). This plant is of low growth, but as it is nearly always in fruit it is of distinctive appearance. It is to be found most frequently of all, perhaps, on tracts of moorland which have undergone the fire ordeal. The Cord Moss seems to be peculiarly happy wherever there is charcoal about, and sometimes the ground is quite golden with the clusters of little fruits on the burnt patches. A distinguishing feature of this moss is the behaviour of the stalks bearing the spore case. In dry weather the stem is coiled, but under the influence of moisture (which may be applied in any way) this stalk twists in a curious fashion, moving the capsule from side to side. The purpose of this movement does not seem to be very clear, for it only occurs when there is moisture about, and in such conditions a distribution of the spores would be almost impossible.

The Common Hair Moss already mentioned is, of course, only one out of a number of species, some of which are now

classed under the name *Catherina*. The Wavy Hair Moss (*C. undulata*) is very plentiful in moist woods, and may be quite readily distinguished when in fruit, as it usually is throughout the late autumn and winter, by the long curved spore cases. Each of these has a curious beak-like lid which is not infrequently as long as the case itself. The Bristle-leaved Hair Moss (*Polytrichum piliferum*) is common on heathy land, and is notable for the sharp, hair-like points at the ends of its leaves and its oblong spore cases. In this plant the male "flowers" are generally of a bright orange colour.

The majority of the mosses which have been described bear their spore cases at the ends of the shoots. There are a large number of species which are side-fruiting in habit.

In woods and on damp shady banks we shall almost certainly meet with the very beautiful Feather Mosses. One of the commonest and most attractive of these is the species which has been called *Hylocomium splendens*, and the distinguishing feature of this plant is the manner in which the foliage is produced, so that it appears to resemble the fronds of

A BEAUTIFUL FEATHER MOSS (*Hylocomium*)

miniature ferns. One species which has been called the Neat Feather Moss (*Hypnum purum*) is excessively common. It is rather a large kind, bearing erect stems which are simply branched, the rounded leaves giving to the plant quite a distinctive appearance. Another very abundant species is the Triangular Feather Moss (*H. triquetrum*), a species which is very often dried and dyed a hideous green. The plant grows to the height of five or six inches, and the leaflets are generally turned back, closely protecting the stem. The Striated Feather Moss (*H. striatum*) is another kind which is likely to be met with on tree stumps and growing amongst short grass. The moss often completely covers the object over which it is growing. The shoots are covered with delicate leaflets which are very decidedly striated. The spore cases in the Feather Mosses are borne on rather long stalks which are generally curved, and rise from the sides of the shoot. Some of the Feather Mosses are not very commonly found in fruit.

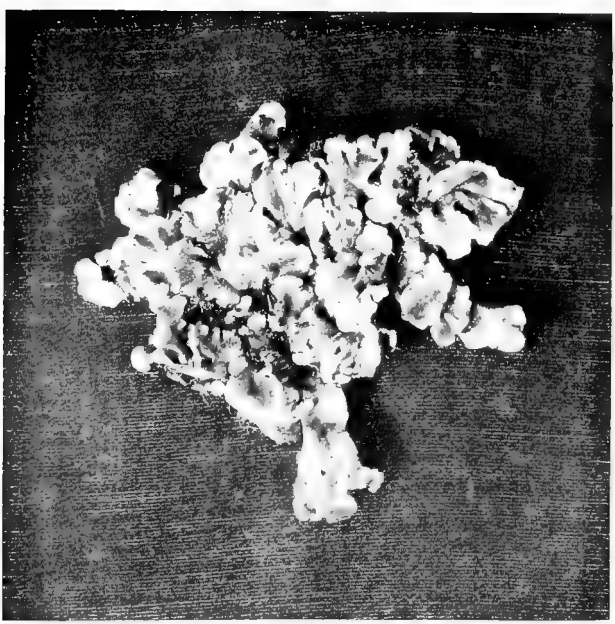
Certain species of moss grow to a large extent under water. The one with which we shall be most likely to meet is the Great Water Moss

(*Fontinalis antipyretica*). This plant is to be found in running streams all over the United Kingdom. It is a large species with long stems, which are usually attached to a stone and are borne forward on the rushing current. It is possible to draw huge masses of this moss from the water, and we may then find the developing capsules on the sides of the stems. The dispersal of the spores takes place when the stream is at its low summer level and the plant is partly above the water.

Nearly related to the mosses are the liverworts (*Hepaticæ*), plants which, as a rule, are only found in very moist situations. Years ago the liverworts were classed with the mosses, and many of the species are quite often placed with the latter plants by those who have not studied the differences. Some kinds of liverwort, such as *Tricholea tomentella,* which often forms dense tufts of pale green by the sides of streams, is singularly moss-like in appearance. The most important distinguishing feature between the two classes of plants is to be found in the spore cases. With the mosses the capsule hardly ever (with a very few exceptions) opens to allow the contents to escape ; as against this,

DICRANELLA HETEROMALLUM

A very common moss



A COMMON LIVERWORT (*Pellia epiphylla*)

the cases of the liverworts generally split into four valves when mature. In a general way, even these liverworts which resemble mosses are seen to have more delicate leaves than the latter plants, a distinction which is readily appreciated when the two examples are compared. Most of the liverworts prefer a damper situation than would be favoured by mosses, though it should be added that not a few kinds are commonly to be found growing amongst Sphagnum and other bog species.

The number of species of liverwort which have been identified in the United Kingdom is very considerable, and it may be most useful to indicate a few of the kinds which are most likely to be met with. Certainly one of the most abundant is the Leaf-like Liverwort (*Pellia epiphylla*). As a rule, this plant grows in large patches in shady, wet places, such as on the banks of streams, where its ribbon-like foliage, of a bright green, is sure to attract attention. On the underside of the plant are to be found a quantity of rooting hairs which fix the growth, or *thallus*, as it is called, to the soil. Almost any time in the spring we may discover the spore capsules on this plant; these have long,

slender stalks, and the actual cases are black. The spore case has arisen as the result of the blending of the sex elements which are present on the leafy growth of the liverwort, the actual process being somewhat similar to that which has been observed in the case of the mosses. Of course, the spores which are scattered with the ripening of the case give rise to the new plant through the agency of a very inconspicuous growth (*protonema*). In nearly all the liverworts it is found that mingled with the spores in the capsule are a number of spiral bodies which have been called *elaters*. It is probable that these bodies play some part in assisting in the escape of the spores from the capsule. A liverwort which is less abundant in a wild state, but is often found in greenhouses and on garden paths, is *Marchantia*. In this case the male and female organs are produced on little stalked devices which look like miniature umbrellas. The spore cases arise in groups on the underside of the female branch. Apart from this method of reproduction *Marchantia* bears on its *thallus* special brood bodies in cup-shaped vessels. These are capable of giving rise to fresh plants when

THE MARCHANTIA (LIVERWORT)

mature. The same kind of thing is to be noticed in the species known as *Lunularia vulgaris*.

The species of liverwort which have been noticed could never be mistaken for mosses, but such is not the case with the foliaceous kinds. The *Tricholea* has already been mentioned, but this plant is only one of a very large number which bear a leafy stem. In many of these liverworts the foliage is of a delicate nature, which rapidly shrivels when brought into a dry atmosphere. One very common species is *Radula complanata*. This plant has a small stem densely covered with leaves; it usually grows over tree trunks. In this case the leaves, if examined, will be seen to be divided into two lobes. The lower fold forms a small pocket in which water is usually to be found. The same kind of thing is to be observed still more clearly in a very common tree-trunk species (*Frullania dilatata*). Doubtless these little vessels assist the plant in dry weather, on account of the moisture which they contain. Strangely enough, it is often found that minute animals, such as the microscopic Rotifers, live in the pockets of the *Frullania*. There is no real evidence that the plant receives any bene-

fit from the presence of these tiny creatures, which seem quite happy in their little homes.

In the case of these moss-like liverworts the general process of reproduction is on somewhat similar lines to that described in the case of the *Pellia epiphylla*. A type of a very simple form of liverwort, aquatic in habit, is that known as *Riccia natans*. This little plant grows in damp places, but it quite often floats on the surface of water like the duckweed.

CHAPTER V

A WORLD IN THE WATER

CROWDED as is the earth with vegetation, we shall find an even more extensive collection of plants in the waters of the world. In the element which probably first sustained the beginnings of vital matter, there are still a myriad forms of plant life, ranging from the green slime, so often to be seen in stagnant pools, to the large branched marine weeds. Gathered together under the name algæ, there are a prodigious variety of plants, to supply a detailed description of which would be the labour of a lifetime. All these organisms are of comparatively simple structure, many of them consisting of but a single cell, whilst even the most elaborate are largely an aggregation of cellular tissue. Nearly all the forms are more or less aquatic in habit, although it must not be understood that they all exist in water. A large number of algæ are able to live upon the surface of rocks and trees in damp

weather, where they form a greenish stain. Individually, these plants are very minute, and when in a dry condition they frequently float about in the atmosphere, tiny specks of life waiting for an opportunity to start life afresh in some damp corner. Certain of these small algæ have entered into the strange alliance with the lichen-making fungus, a matter which is fully discussed in another chapter. The mysterious Nostoc, which often appears after rain on paths in gelatinous masses, is due to the formation of colonies of certain algæ, which, prior to the coming of the moisture, have been in a dry resting state. In this condition they are quite invisible, and the almost magical manner in which the Nostoc appears after rain was very mystifying to the early observers.

Many of the microscopic algæ to be found in water are exceedingly beautiful objects. The Desmids and Diatoms have for long been the admiration of those who have taken the pains to study them with the aid of a microscope. A few drops of pond water will often show a vast variety of forms, many of which are most pleasing in design. Not a few of these strange little plants are free swimming, and move about in the

water with the greatest ease. It is difficult, indeed, to think that they are plants at all, were it not that the colouring matter indicates the presence of the wonderful chlorophyll. Each of the tiny Diatoms is enclosed in a hard flinty shell, most exquisitely sculptured. These minute shells have played a big part in changing the level of the earth. In some parts of the world, notably in Virginia, deposits of Diatom shells have been found forty feet in depth. How many generations of these little plants must have contributed to this vast mass it is not easy to conceive.

Many kinds of tiny algæ hang together in threads; others may be attached to some water plant or have found a resting place on a rock. They evince an enormous variety of colour, ranging from the most vivid green to a dull brown. Yet in all it is possible to detect the presence of chlorophyll, and each atom is playing a part in the re-oxygenising of the water. As well it is quite certain that these plants use up a good deal of impure matter, so that many a stagnant pool is really more pure, so far as its water is concerned, than the running stream where the number of algæ is more

limited. Of course, where water is in swift motion the amount of vegetable life is always much less than is the case with lakes or slow-moving rivers.

In the case of a very large number of these minute algæ the process of reproduction is comparatively simple, in that it chiefly consists of a division of the cells. Increase by means of small bodies known as *zoospores* is very common in some orders. These are really tiny specks of protoplasm—the life basis—which are released from the cell of the plant and move about in the water by means of delicate cilia. After awhile they come to rest, and are finally invested with a cell wall, and in this way give rise to a new individual. In some cases it is to be observed that two masses of protoplasmic matter become joined together, and so give rise to a new individual. The large colony of cells which go to form the Volvox so familiar to microscopists evinces the union of sex elements. Within the hollow sphere (which is continually being propelled about through the agency of cilia which certain of the cells thrust out) there are formed egg cells which are fertilised by the very active male bodies, the

A FRESH-WATER TREE (*Zygnema*)
(Enlarged

ONE OF THE CHARAS (*Chara vulgaris*)

spermatozoids. With the maturing of these egg cells the colony breaks up.

The minuteness of many species of algæ inhabiting fresh water causes them to be difficult subjects for study. Most of the forms which present remarkable features can only be really appreciated when viewed under the microscope. A very good way of observing the general character of some of our fresh-water algæ is by floating them out in a dish of water, placing a sheet of white paper beneath them, and gradually draining the water away. Such kinds as *Batrachospermum* and *Lemanea* may be treated in this way. The former is rather unpleasantly slimy to the touch, but when floated out is seen to be composed of branches which are really very beautiful, in that they resemble a string of beads. The commonest kind is of a brownish colour, as a rule, though it varies in different localities. The *Lemaneas* are very abundant in streams with a rocky or stony bed, and these are worth floating out on paper, in order that their olive-coloured branches, sometimes a foot in length, may be examined. The *Zygnemas* are excessively common in ditches and ponds, where they resemble cloudy masses

pale green in colour. On being floated out it is noticeable that the plant is composed of an infinite number of green threads. The same thing is even more plainly to be seen in the case of *Spirogyra*, an algæ which always attracts attention on account of its vivid green colouring. This species is also very abundant in ditches.

A group of fresh-water weeds to which attention should be called are the stoneworts, or *Characeæ*. These plants are of a much more robust habit of growth than the algæ, which have been noticed, and in a superficial way bear a resemblance to the horsetails. The stoneworts are generally placed in close proximity to the green algæ, although their actual position in the scheme of things has not been very clearly established. One of the most abundant species is the Common Chara (*C. vulgaris*), a plant which is usually about ten inches in height and is of a delicate green colour. At the joints of the stem are arranged circles of leaf-like processes in a manner which is strangely suggestive of the Horsetail. If these "leaves" are examined it will be found that they, in turn, are producing small leaflets, and it is

these which are responsible for the reproductive organs. In the case of the plant under notice the female, or egg cells, are present in close proximity to the male processes. The latter are in the form of rounded bodies of a bright orange colour, sufficiently large to be plainly seen with the naked eye. At the time of maturity these globes open and allow the fertilising element, in the form of *spermatozoids*, each producing two long hairs, to escape, and these enter the egg cell and in this way complete the process. Soon after the egg cells become detached and, sinking to the muddy bottom, lie in a dormant condition for the winter. With the coming of the spring a tube is pushed out from the cell, and this ultimately bears the adult plant. A singular feature of some of the species of *Chara* is that the plants have the habit of incrusting their delicate stems with lime during the summer months. This gives a curiously brittle nature to the growth. In the autumn, when the plants decay, the accumulation of lime is, of course, left behind, and this deposit may gradually raise the level of the bottom of the pond. There are, perhaps, about half a dozen species of *Chara* in

this country, though some of the kinds tend to resemble each other very closely.

The other genus of stoneworts, which is known as *Nitella*, is remarkable for the fact that the stems are quite destitute of any hard rind, such as is to be observed in the case of the *Charas*. Typical of these plants is *Nitella translucens*, where the stem is smooth and transparent. The limy coating mentioned in connection with the *Charas* does not seem to be such a feature in the case of the *Nitellas*, though it does occur on occasion. Most of these plants have a decidedly unpleasant smell when they are removed from the water.

With many of the fresh-water algæ it may be that it is only after a close examination that we are able to appreciate their real beauty. It is quite certain that this cannot be said of the large number of seaweeds which attract the attention of the most indifferent by their distinctive appearance. A very large number of these plants are quite different from any of the fresh-water species, although here and there will be found examples which are closely allied to the kinds which abound in our brooks and ponds. Certain species of the red seaweeds, for

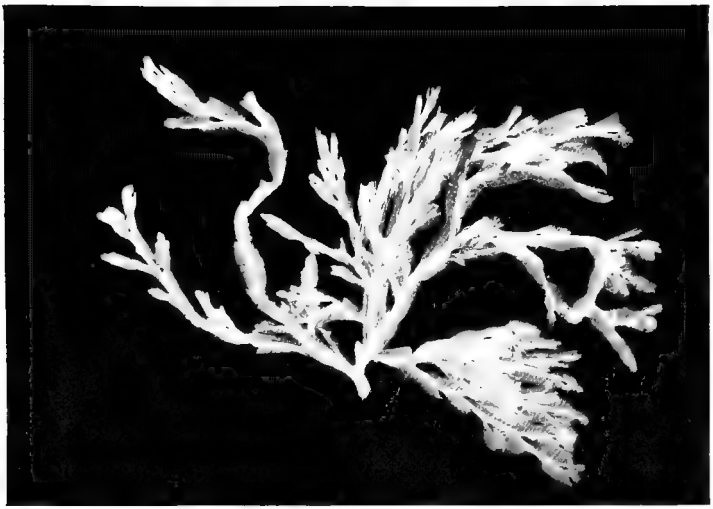
instance, are closely related to the brownish *Batrachospermum,* the slimy fresh-water weed which has been mentioned. On the other hand, amongst the great class of brown seaweeds we shall find any number of forms which are exclusively marine in habit, or can only support an existence where the water is brackish, as in the estuary of a river.

Although so varied in habit, the algæ of the sea fall roughly into three groups—the green, the brown, and the red. These terms must not be taken in an arbitrary sense, however, so far as the colour is concerned. Many of the red seaweeds may be of a purple or even a brown colour, whilst some of the green seaweeds (such as *Cladophora,* a bushy plant with rigid branches quite common in pools which have been left by the tide) vary in colour from brown to grey.

There has for some years been a great deal of discussion as to the significance which should be attached to the colouring of seaweeds. Even if we cannot draw very hard and fast lines from the actual tinting in all cases, the plants, in a general way, fall naturally into these groups. One theory on the subject is interesting, although it is not quite a complete

explanation. It is well known that, in its passage through water, the rays of sunlight undergo some modification: the red, yellow, and orange rays, which are so essential to the green plant, are absorbed, and it is chiefly the blue rays which are allowed to pass. Now, owing to the peculiar pigments to be found in the red seaweeds, the blue rays, of which there are an abundance, even in quite deep water, are changed in their character within the tissues of the plants. Actually they are to an extent altered into the red and orange rays, which aid the green plant in the manufacture of its chlorophyll.

To a modified degree the same process is to be observed in the case of the brown seaweeds, which live in more shallow water than the red seaweeds usually favour. Thus, although the red and brown seaweeds may be living under many feet of water, they are able to derive quite as much benefit from the light as if the rays did not have to pass through the watery screen at all. It is very natural to assume that the red seaweeds will always be found growing in very deep water, the brown seaweeds in moderate depths, and the green weeds only in the



THE WINGED DELESSERIA (*Delesseria alata*)

THE SEA LETTUCE *Ulva latissima*)

shallows. This is not by any means the case in all instances. The beginner in the study of seaweeds soon finds out that representatives of all the classes may be found growing near to the high tide mark. Some very bright green seaweeds (*Struvea*) have been found at a depth of more than a hundred feet, where, theoretically, the red and the orange rays must be almost entirely screened away. One must, therefore, be careful not to dogmatise on the question of the habits of the seaweeds. In a general way, however, we may say that in the deeper waters the red seaweeds will preponderate ; in moderate depths we shall find the brown seaweeds most in evidence ; whilst in the shallows the green varieties are most likely to be abundant.

Although in a rough way one may speak of the leaf, the stalk, and even the root of a seaweed, it should be remembered that these terms will have only a limited significance. Even in the most distinctive of the seashore species there is nothing to correspond with the parts of the higher land plants. The root-like processes, for instance, are largely a means of attachment to hold the plant in one posi-

tion. So far as the scheme of nutrition is concerned they are capable of nothing more than is accomplished by the leaf-like expansion. It is important to bear these points in mind when studying such plants as seaweeds, for the terms "leaf," "stem," and "root" are often useful for descriptive purposes, although they must not be taken in a strictly botanical sense.

There are not a large number of green seaweeds which attract a great deal of attention. The *Ulvas* (Sea Lettuces) have already been mentioned. Of this group there are two or three species which are commonly found. These are popularly known under the name of Laver, in company with some of the Red Seaweeds such as those in the genus *Porphyra*. The latter are generally spoken of as Purple Laver. Nearly all these plants are said to be good to eat, and indeed are largely consumed in some districts, though it must be admitted that the taste for the delicacy is an acquired one. The *Ulvas* are often a very attractive feature in the pools which the receding tide leaves behind. All the green Sea Lettuces seem to flourish exceedingly wherever the water is in an impure state owing to drainage

THE BLADDER WRACK (*Fucus vesiculosus*)

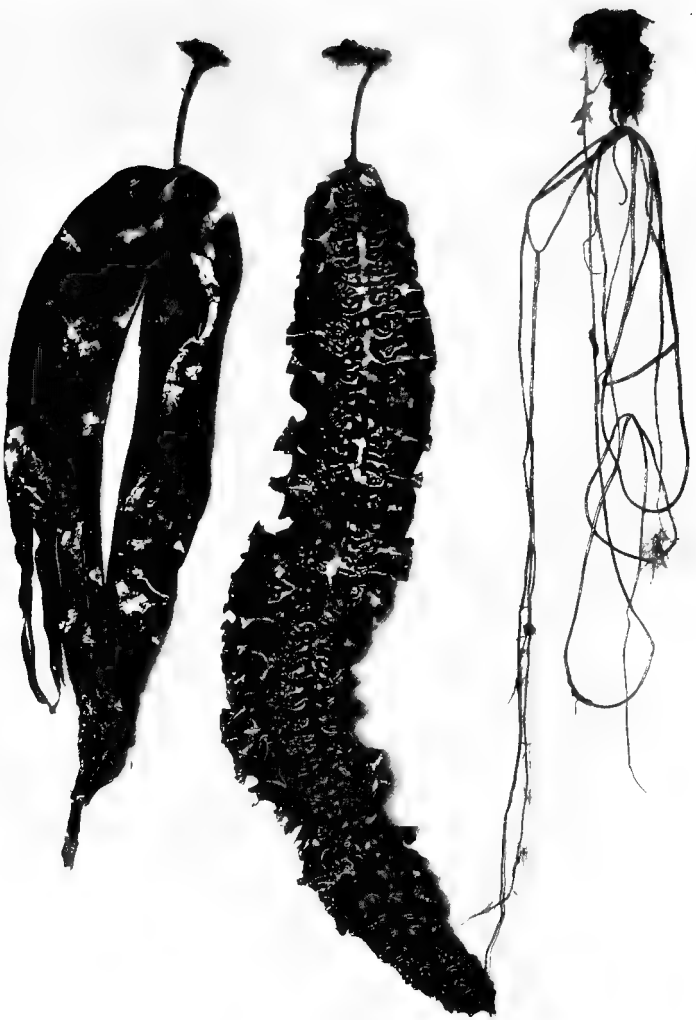
outfalls. Sometimes they grow so thickly as to threaten to block up channels where the waterway is narrow and shallow.

Some of the marine species of *Cladophora* are pretty little greenish brown plants which are often found in abundance in pools which have been left by the tide. These green seaweeds are usually very bushy in habit, and their charming manner of growth is plainly seen if they are floated out on to a piece of white paper. A single group of the green seaweed is that which is represented by the *Rivularia*, a plant which is often responsible for bringing about a terribly slippery condition of the rocks. If examined, it will be found that the growth of this species is usually in the form of small rounded masses.

In many of the green seaweeds the actual manner of reproduction is not very clearly known, but in the case of the Sea Lettuces (*Ulva*) a prominent method adopted seems to be on the following lines. When all circumstances are favourable for reproduction, a change takes place in the contents of the cells which go to the formation of the plant. These undergo certain alterations, and even-

tually escape into the water in the form of little bodies (zoospores) which, by means of certain long hairs, move about in the water with the greatest activity. These bodies, small as they are, vary considerably in size in some of the green seaweeds, and their real character is not in every case fully understood. It is generally believed that after a journey, which may carry them to a considerable distance, the zoospores in the case of the Sea Lettuces settle down upon the sea bottom and start the formation of new cell walls. The extension of cellular tissue then goes forward, with the result that at last a new plant is formed. There are indications of other reproductive schemes in the case of the *Ulvas*.

It would be difficult indeed to suggest any portion of our coastline on which some of the many species of *Fucus* could not be found. These plants may be taken as typical of the brown seaweeds, and, on account of the ease with which specimens can be secured, it may be well to deal with them in the first instance. Most of the *Fuci* are of a brown or a yellow brown colour, and in nearly all cases they display a well-defined shoot, often much branched.



THREE LARGE COMMON SEAWEEDS

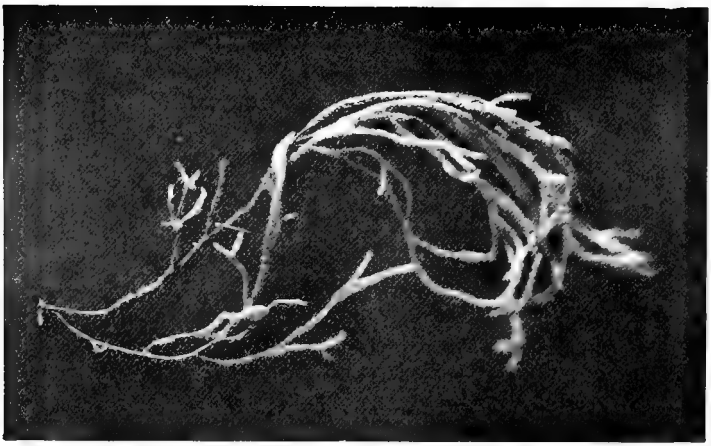
1. *Laminaria digitata* 2. *Laminaria saccharina* 3. *Chorda filum*

In a normal state they are attached to a rock, the sides of a quay, or they will frequently festoon the piles of a pier. One of the most abundant is known as the Bladder Wrack (*F. vesiculosus*), a plant which varies enormously, according to the condition under which it is growing, though its many-branched leaves are generally of an olive colour. This species, as indeed are many of the *Fuci*, is very accommodating, and seems to get on equally well in positions where the receding tide will leave it high and dry for some hours, or farther out from the shores where it is never entirely uncovered. Its foliage is maintained in a floating attitude in the water by means of air bladders, which all children—and many grown-up people too—love to "pop."

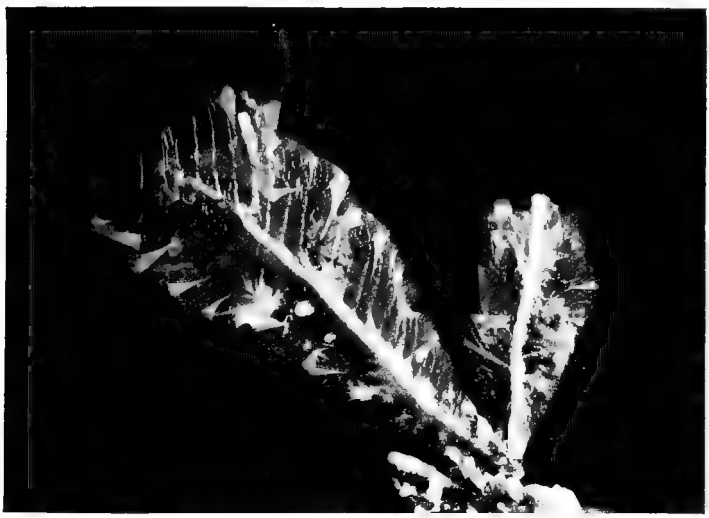
At almost any time during the summer and autumn it is possible to find the reproductive organs of the Bladder Wrack at the ends of certain branches of the leaves. To the naked eye the collections appear like so many nobs with somewhat roughened surfaces. The actual organs of reproduction arise in flask-shaped hollows in these parts. In certain of these cells the male bodies (*spermatozoids*) are pro-

duced, whilst in others are present the egg cells. In most cases the sexes are produced on different plants, though this is not invariably the case in all the species of *Fuci*. At a particular stage in the development of the male cells the *spermatozoids* escape, and at the same time the female elements (*oospheres*) are extruded from their hollow. The *spermatozoids* make their way to the *oospheres* and bring about fertilisation. Soon after the new plant is born. Like many other seaweeds, the Bladder Wrack is frequently increased by means of fragments which have become detached from the main plant. Many of the odd portions which strew the beach after rough weather will eventually become attached to some rock by a sucker-like disc.

The other prominent family of the brown seaweeds to which attention should be called is that which is typified by the genus *Laminaria*. One species is particularly common, and has been called *Laminaria digitata* from the fact that the great leaf is divided into segments like so many fingers. The plant has a very large stem, terminating at the bottom in a thick cluster of roots, which hold with the



ONE OF THE SMALLER BROWN SEAWEEDS (*Cladostephus verticillatus*)



A BEAUTIFUL RED SEAWEED (*Delesseria sanguinea*)

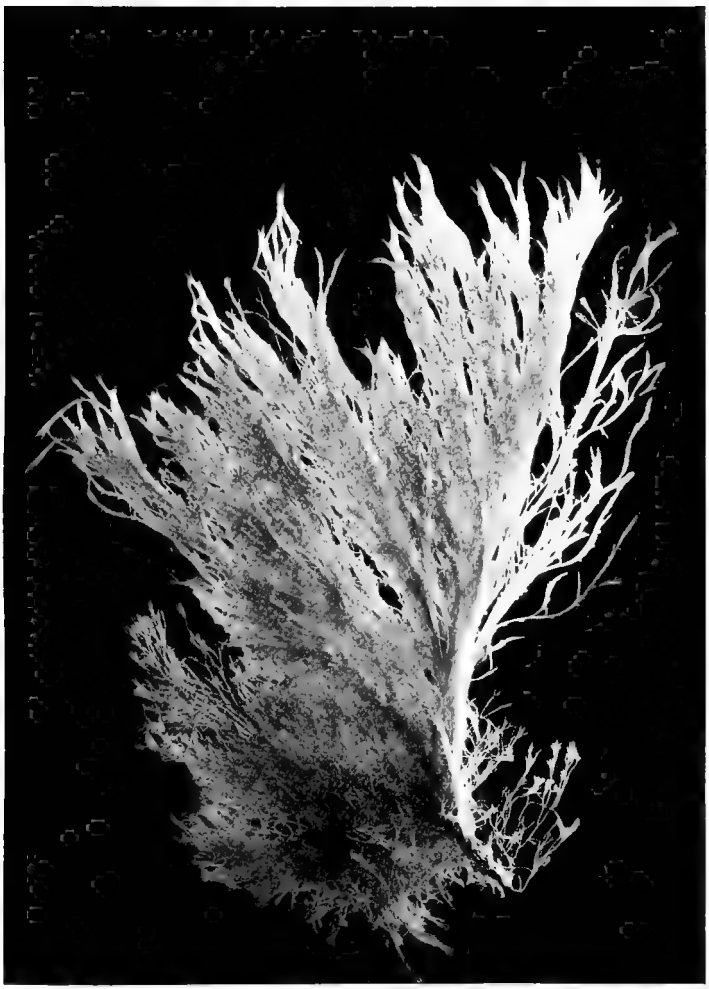
greatest tenacity to the rocks on which the weed grows. It is not unusual for this *Laminaria* to be four or five feet in length, and such examples may be seen growing in great abundance upon a rocky coast. Another *Laminaria* which is also very abundant is the so-called Sweet Tangles (*Laminaria saccharina*), a seaweed which has on occasion been eaten on account of its sweet taste. The general character of the plant is in the form of great tongues, which may be six feet in length ; these have curled edges, and the centre part is often very much puckered. The method of reproduction in the case of the *Laminarias* is in many cases imperfectly understood.

The Sea Whipcord (*Chorda filum*) is a weed which often grows to the length of twenty or thirty feet in rope-like fashion. At intervals the stem-like growth is hollow, and it is these air chambers which support the plant in the water. The organs of reproduction are collected in pear-shaped bodies, which often cover the surface of the long ropes.

Not all the brown seaweeds are coarse, large plants, the kind known as *Cladostephus* being quite small, with dark brown branches, which

are, however, very stiff. Nearly related are the species belonging to the genus *Ectocarpus*. These are frequently found growing on the larger seaweeds, and are usually of a delicate description, often looking like a filmy cloud of brown colour when in the water. The commonest kind is *Ectocarpus littoralis*, which is frequently found attached to some of the *Laminarias*.

Even the most attractive of the brown seaweeds is cast into the shade by the extreme beauty of the red forms. From childhood everyone has admired these, and delighted to float out the delicate branches on to sheets of paper. All the species of this group, apart from a few examples, are of a red or pink colour. Most of the red seaweeds grow attached to some object or other, whence they spread out their delicate branches into the water. One of the most beautiful forms is that which is represented by the *Delesserias*. One species which has been called the Crimson Seaweed (*D. sanguinea*) is a most charming plant with leaves of a fine rose colour, which are normally about six inches in length. Two other species, which are smaller and quite often may be found



A COMMON RED SEAWEED (*Polysiphonia elongata*)

growing on some of the large brown seaweeds, are *D. alata* and *D. sinuosa*. Closely allied to these plants are the *Nitophyllums*, although, as a rule, the species are larger than the average *Delesseria*. In some cases the leaves of the *Nitophyllums* are divided into lobes. One of the red seaweeds which is to be found chiefly on our northern shores is the *Odenthalia dentata*, a plant which is not altogether unlike the brown *Fucus*, except in so far as its colour is concerned.

Of the more delicate kinds of red seaweeds there are a large number, many of which are exceedingly common. In the very large genus of *Polysiphonia* the stems are often somewhat substantial; but the ramifications of the branches are frequently of a most delicate description. In the species known as *P. elongata* the stems are long and thick, but the growth divides itself into thread-like branches. Many of the smaller kinds grow on the larger seaweeds. Most beautiful of all the red seaweeds are the *Callithamniums*. These are of a bright pink colour, and the feathery branches are often almost transparent. The species known as *Callithamnium plumula* is a small

but very attractive example, with its branching stems, which at their tips resemble so many miniature ostrich feathers. Many of the *Callithamniums* grow on the larger kinds of brown seaweed, as well as on rocks and stones.

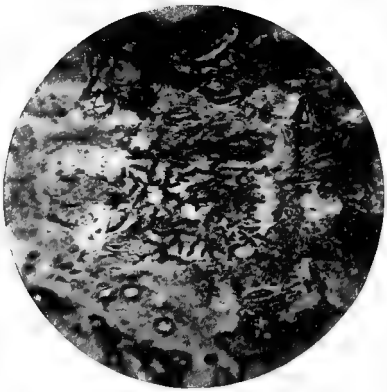
The manner of reproduction in the case of many species of red seaweeds is not fully understood. On some kinds spores are produced in little cases, and it is often possible to discover these on the leaves, notably in the case of *Delesseria*. These after floating about in the water for awhile come to rest at last and develop into the new plant. In other species, however, it has been demonstrated that sexual organs are borne on the leaves, and the blending of the elements will give rise to masses of spores which will ultimately develop into the mature plant.

CHAPTER VI

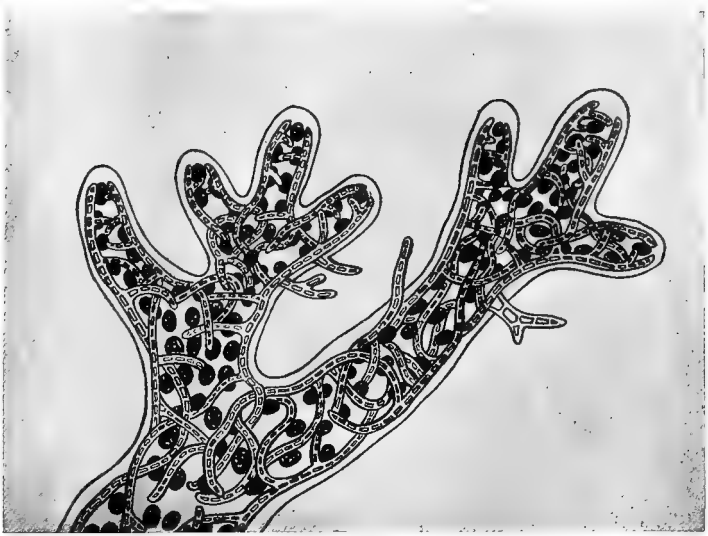
THE STRANGE STORY OF THE LICHENS

MANY people with a fair general knowledge of plant life discover fresh worlds to conquer in the study of the flowerless vegetation. What is this grey substance spreading over the bark of an old tree, very similar—yet not quite the same—to a growth which was noticed the other day on a wall? It is probable that most of us have a hazy idea that it is a lichen of some sort or another, yet it appears to be almost incredible that such a dead-looking object can really be a living and growing plant. It goes without saying that the life story of such singular organisms must be interesting, and, indeed, in many ways the tale of the lichens is one of the most romantic in the whole book of Nature. These singular grey growths, concerning which the botanist of two generations ago devised a special branch of botanical study, are not, as was then thought, individual plants at all. Although, for the sake of convenience,

we still speak of the lichens as species, they are only so in so far as they conform to a certain manner of growth which makes such an identification possible. Far from being one individual, every patch of lichen is composed of many thousands of entities, some of which could, and indeed often do, lead a separate existence. It is now some years since the idea of the dual composition of lichens was first of all mooted, when De Bary suggested that many of these plants bore striking resemblance to fungi on the one hand and algæ on the other. The idea was taken up by certain patient observers, who set themselves the task of finding out the truth of the matter. This work was carried out in the face of an enormous amount of opposition from those who had made lichens their special study. Finally, it was established beyond a shadow of a doubt that all these plants are not simple growths at all; rather are they to be regarded as colonies formed of thousands of individuals, with, however, one predominant partner. The principal in the alliance is a fungus which, as in a network, encloses large numbers of small green algæ. It is this dual arrangement which



A WRITING LICHEN (*Graphis*)



THE DUAL NATURE OF THE LICHENS

A combination of a fungus and a large number of algæ

makes it possible for lichens to support an existence in such inhospitable places. There is little doubt that these humble plants played a very big part in the early history of this earth, and we must regard them as one of the oldest forms of land vegetation.

Many people during the summer time have had an opportunity of exploring one of the thousands of rocky inlets around the coastline. The vast number of these are only just above high-water mark, and even the thrift and the coarse sea-grass have been unable to find a foothold. Yet the rocks are golden and green with lichens, able to support an existence, despite the fact that all the summer they are baked quite dry, whilst during the winter they are saturated with sea water. What other plants could possibly sustain life under such conditions? In these little rocks we have a very fair representation of the character of the earth in those far-away times when there was no covering of kindly soil to provide a rooting medium for plants.

In a broad way, we may say that the fungus element of the alliance in the case of the lichen is parasitic on the algæ; the fungus, in com-

mon with nearly all its tribe, is not able to live on inorganic material; it must have its food prepared for it by some green plant. Hence it has captured a whole host of algæ, mere specks of green life which are abundant everywhere. Encircling these tiny plants in its embrace, the fungus lives upon the food products which they are able to manufacture from the sun and air. We must not, however, waste any pity on the little captives, for in their enslaved condition it seems that they are quite happy. Indeed, they generally bestir themselves with greater activity than is the case when they lead an independent existence. As a matter of fact, the alliance is not entirely one-sided, for although the fungus may be described as a parasite, yet it gives a return for the favours which it exacts. The algæ, in common with all plants, require a certain amount of mineral matter, and it seems that the fungus element in the lichen has the power of breaking up the elements in the rock over which the plant may be spreading, and presenting these to the captives. As well there is no doubt that the chief partner of the alliance plays a big part in collecting and con-

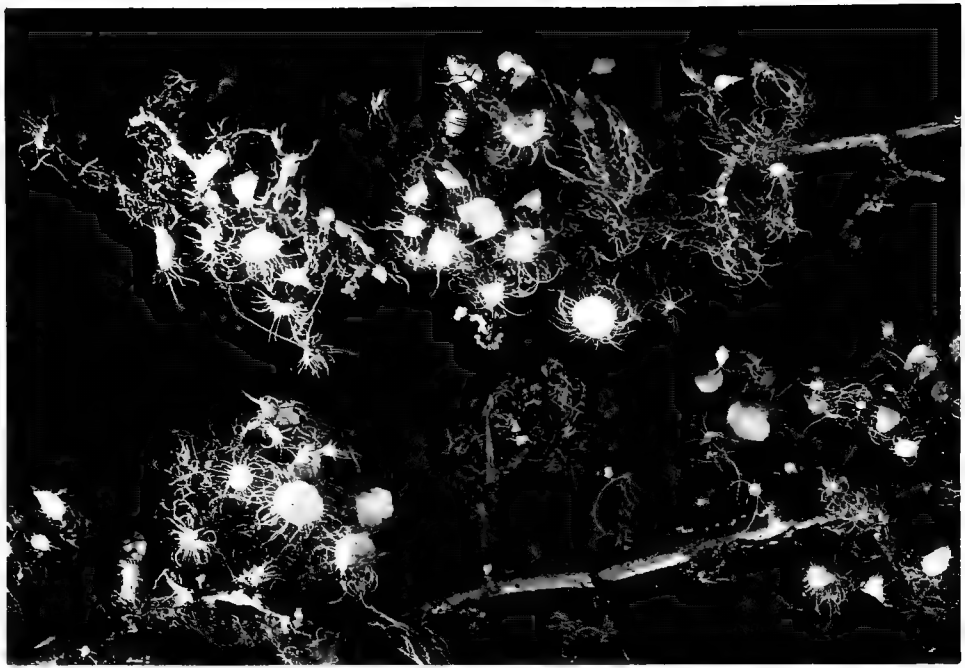
OLD MAN'S BEARD LICHEN (*Usnea barbata*)

serving moisture for the enslaved algæ. It has been intimated that many species of algæ which have been discovered in the lichen alliance may be found supporting a separate existence. Time and again the experimenter, in isolating the green cells from the lichens, has discovered that the little plants were identical with well-known algæ which had been named and known for many years.

Undoubtedly these algæ are the most omnipresent of all kinds of vegetation. The waters of the world are full of them, and the same may be said for the atmosphere and the earth. So small are they, however, that it is only when they occur in vast numbers, such as on the surface of rocks or barks of trees, that we are aware of their presence at all in the ordinary way. Then they appear as somewhat slimy coatings, more or less green in colour. In a dry state algæ float about in the air and do not seem to suffer in the very least from a prolonged period of inactivity. With the arrival of moist conditions the minute plants settle down and resume their normal method of growth. When the wonderful powers of adaptation in the algæ are considered, side

by side with the fact that they form the really essential element in the lichen alliance, it is easy to understand how it is that these plants can grow almost anywhere.

We have seen that the algæ which go to form a part of the lichen can, and do at times, support a separate existence, and it is not unnatural to inquire whether the fungus is able to do so. In the majority of cases the answer to this question is No. In recent years certain instances have come to light in which the fungus element of a lichen alliance has been found living apart from its helpmates, relying for its sustenance upon some organic material, of course, after the manner of its kind. Generally speaking, however, if the fungus portion of a lichen is separated from the algæ it soon languishes and dies, no matter how carefully it may be tended. This experiment has been actually carried out, and, more wonderful still, the constituents of a lichen have been artificially blended. The spores produced by the fungus element of a lichen have been scattered on algæ, and the result has been the development of a well-known species of lichen. This is an absolutely conclusive proof of the dual



OLD MAN'S BEARD LICHEN (*Usnea barbata*), showing the disc-like fructifications

character of lichens which could not but satisfy even the most sceptical. In the course of the investigation it was still further demonstrated that not infrequently more than one kind of algæ might be embraced by the lichen, each one being an easily recognised species.

We have seen that in the lichen alliance it is the algæ which carry on the business of supplying the growth with nutriment ; but the fungus looks after the not less important matter of attending to the scheme of reproduction. This is brought about in two ways, the first of which consists in the mere production of spores on a part of the fungus. These tiny bodies are produced in fructifications which often form rather an attractive feature in a species of lichen. The common Old Man's Beard Lichen (*Usnea*) bears disc-like processes wherein are produced spores or, as it sometimes happens, bundles of spores. Like the spores of independent fungi, these are very light, and float away on the breezes. Such a large number are sent out that it is almost certain that some of them will be thrown into contact with algæ, which we have seen are almost everywhere. Under suitable conditions of moisture the union

will take place, the hyphæ, as the vegetative part of the fungus is called, spreading out like a network and enclosing the algæ, which are henceforth destined to live in captivity.

A very large number of lichens commonly adopt an even more effectual way of reproducing their kind. A very slight acquaintance with the appearance of these plants is sufficient to show how often the grey green growth is covered with a curious meal-like deposit. The rough appearance which this gives to the plant is very plainly to be seen in the case of the so-called Cup Moss (*Cladonia*), which, we must admit, is rather unhappily named, seeing that it is not a moss at all. Now, this coating of dust really represents the second method of propagation at the disposal of the lichens. It is seen under the microscope to be built up of green cells either singly or in groups, enclosed in minute portions of hyphal threads. In plain language, they are just a few algæ wrapped round with a strand or so of the fungal element, giving all that is necessary for the establishment of a fresh lichen. Their manner of dispersal is quite simple, seeing that when in a dry state they are light and easily detached

CUP MOSS (*Cladonia pyxidata*)
A very common lichen

from the parent by the wind, and are in this way carried to new situations where, given the right conditions, they will develop on the lines of the plant in which they originated.

It has been said that the algæ enclosed within the embrace of the fungus, as evinced in the lichen, do not suffer from their imprisonment at all, but even seem to benefit by their captivity. We may push this point still further, and say that in their new conditions they are able to live in situations which would otherwise be impossible for them. To come back to our rocky islet, it is very doubtful whether these algæ would be able to settle and grow for many years on a surface which is, first of all, deluged with salt spray, then baked by the summer sun ; under the protection of the fungus this is rendered quite a simple matter. Moreover, the part which the fungus element plays in supplying the algæ with water and mineral matter already mentioned, is a real service. We must always remember that the inorganic material is probably of no direct use to the fungus, and it is simply transmitted to the algæ for treatment.

Certainly one of the most interesting fea-

tures in connection with the lichen alliance is its bearing upon the whole question of parasitism. The subject is a vast one, which can only be touched upon very briefly. There is a good deal of reason for believing that in many instances the outcome of parasitism is a much more satisfactory state of affairs. In extreme cases the parasite forces its attention upon its host to such an extent that, more often than not, the object of attack is killed altogether. In the case of the lichen alliance the fungus is a parasite, but, far from killing its hosts, it makes life easier for them. It is surely the better plan to keep on good terms with hosts who are serving you well, and so continue to receive favours, than to plunder to such an extent that you rob them of even life itself. Instances of this symbiosis, as it is called (literally, a living together), are nowadays continually being brought to light, and the reader is referred to the chapter on Fungi in the present volume for another very remarkable case.

Of all plants, lichens are perhaps the most dependent upon atmospheric moisture, so that the business of securing a sufficiency to keep the little colony in an active state is not a

light matter. Of course, there is no doubt that those kinds of lichens which spread over the surface of the ground, or grow over tree trunks, will be able to absorb a good deal of water directly, but even in such situations they must rely to a considerable extent upon the moisture which they can draw from the atmosphere. In the case of those lichens, such as the Old Man's Beard, which hang down from the branches of trees and are only attached in one place, the difficulty of securing a sufficiency of water is even more perplexing. By their very formation lichens are well adapted for absorbing watery vapour from the air. During the summer, when they are dry, lichens suspended in a moist atmosphere, such as is induced by the steam issuing from a kettle, will quickly become damp and flabby—a marked contrast to the crisp and brittle condition in which they were a few moments previously. It goes without saying that plants which take up moisture so readily from the air will no less quickly lose it by evaporation when the atmosphere is warm and dry. It has been seen, however, that lichens seem to be best able to withstand extremes of heat, cold, and drought.

One point in connection with the growth of lichens which is often noticed is the extreme aversion of these plants to towns. Hardy and accommodating though they may be, pure air, free from any taint of smoke, seems to be essential to their welfare. This is rather singular when it is remembered how well many of our familiar plants have been able to adapt themselves to town life. It is possible that in some way the air, laden with all kinds of impurities, prevents the little algæ from carrying out their work, and thus the plants are unable to flourish. Whatever is the reason, it is necessary if we want lichens to leave the streets and houses far behind us, and we shall find that the farther we go the more interesting are the forms which we shall discover.

One advantage which is attached to the study of lichens is that the matter can be admirably taken up in the winter. Then, when so much of the vegetation is resting, the lichens are at their very best, thriving on the abundance of moisture which is present during the dull months of the year. Considering there are nearly two thousand well-established forms in Great Britain, it is clear that any descrip-

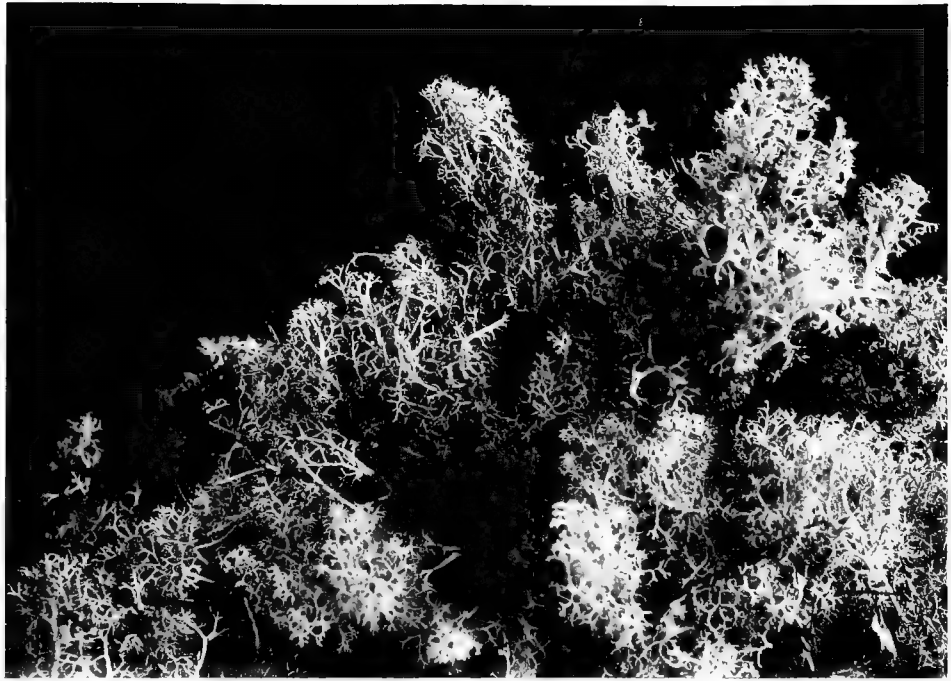
CLADONIA GRACILIS. **A pretty and very common lichen**

tion must be limited to some of the most striking kinds. In a general way the lichens may be roughly classed into three groups, according to their habits of growth. In the first place there are those which are of a shrubby habit and grow with distinct upright or drooping branches. The most numerous of these are to be found in the genus *Cladonia;* many of these are familiar to most people on account of their pretty cup-like fructifications. One of the most beautiful is quite common in moorland districts, and has been called *Cladonia cornucopioides*, and is always recognisable from the bright red tubercles which grow from the upper portion of the stem. These look very much like spots of red sealing-wax, and, on examination, are shown to be the parts of the fungus element in the lichen in which the spores are produced. The common Cup Moss (*Cladonia pyxidata*) is a charming species with fructifications fashioned on the lines of dainty cups. A species of *Cladonia*, without definite cups, which will almost certainly be found, is *C. gracilis*. Very frequently the little stalks in this species end in a point, when they are not adorned with the small brownish fruit bodies.

In their manner of growth many of the shrubby lichens bear a strong resemblance to the leaf-like kinds which will be mentioned later, the chief distinguishing point being that the fructifications are borne upon stalks.

Some of the shrubby lichens are very much branched, and of these the most interesting is the Reindeer Moss (*Cladonia rangiferina*), a kind which in one or other of its many forms is abundant on heaths and commons. As a rule, the plant seems to be most at home amongst heather, where it grows to a height of as much as six inches, forming a very attractive object with its grey-green branches. Like the grasses the Reindeer Moss loves to grow in communities, and in certain parts of northern Europe, notably in Lapland, enormous areas of country are covered with the plant, which there grows to the height of ten or twelve inches. During the winter it is almost the only food available for the reindeer, and these creatures are said to clear away the snow to get at the lichen. As well the plant forms quite a valuable food crop for cattle in some of the more inhospitable regions.

Other forms of shrubby lichen are to be



REINDEER MOSS (*Cladonia rangiferina*)

seen in the familiar *Usnea*, of drooping habit, to which reference has already been made. In its young days the *Usnea* usually displays a fairly upright manner of growth, with stiff, grey tufts. Another lichen which will be found on tree trunks very frequently in company with the *Usnea* is that known as *Evernia prunastri*. This lichen generally grows in a pendulous manner, and is whitish on the under side of its branches. On the upper surface the colouring is of a grey green. The general growth is very irregular, and the plant as a whole presents a wrinkled appearance. The *Evernia* is not very commonly found in fruit, and it is one of those lichens which rely to a large extent upon the brood bodies which have already been mentioned.

The second group into which the lichens may be divided are those which are generally spoken of as "leaf-like." These creep along the surface of the ground amongst the grass, or spread over the trunks of trees. In their general habit of growth some of these lichens are not unlike that of the flat-growing liverworts, although the bright greenness is lacking. The most striking of these is certainly

the *Peltigera canina*, a very handsome species which is abundant in many country districts upon mossy banks, or in moist places upon moors. When dry, the plant is rather an unattractive grey colour ; but in the moist autumn weather it assumes a rich green tint. The under side of the growth is of a shining white, and from this spring a number of "roots," by means of which an attachment is secured. The fructifications consist of bright brown lobes which arise from the border of the growth. The specific name of the plant is due to the fact that it was at one time considered to be a remedy for hydrophobia. In the case of many of the leafy lichens the manner of growth is in the form of a rosette. Many kinds belonging to the genus *Parmelia* may be found in the greatest abundance upon tree-trunks and rocks. One of the commonest is *P. physodes*, which forms large rounded patches which may be as much as a foot across. It is of a grey-green colour above, and is brown on the under side. Another species, *P. pulverulenta*, is also very common on trees. In a moist state it is of a deep green colour, although it assumes a paler hue when the growth is dry. This lichen

LEAF-LIKE AND SHRUBBY LICHENS ON A TREE TRUNK

may sometimes be found with fructifications, although it is very often covered with the tiny brood bodies, which appear like so much grey powder on the growth.

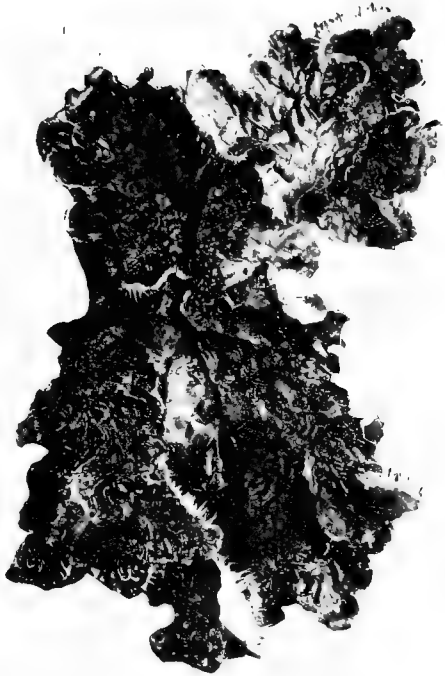
One of the most handsome of the leaf-like lichens is *Physcia parietina*. This occurs very extensively on the roofs of houses, walls, rocks, and even on old hawthorn bushes. On flat surfaces it grows in a more or less circular patch, and its bright yellow colouring makes the plant a very distinctive feature. Years ago, and quite likely in some parts of the world at the present time, this lichen was largely used for the dyeing of cloth. It seems that the drier the situation the more brilliant is the tinting, for examples found in damp and shady spots are frequently of a less striking colour, and on occasion are quite green. The plant is often covered with spore-bearing cups which, on account of their orange colouring, add very much to the appearance of the growth.

The third group into which the lichens may be divided are those which form crusts on objects in such a way that they cannot well be removed without injury to the plant. The most abundant forms of these lichens are the

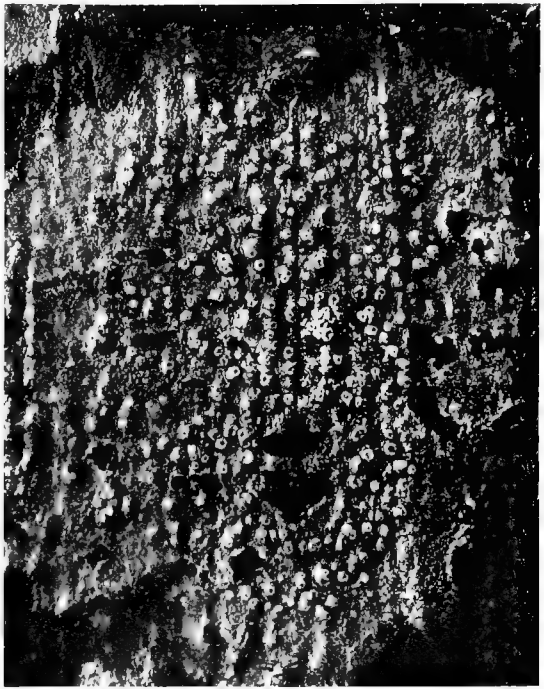
Lecanoras and the *Lecideas*. *Lecanora tartarea* is a plant forming greyish crusts on rocks, which at certain seasons of the year are studded with brown fruiting bodies. In *L. subfusca* we have a crust lichen which is very common on smooth-barked trees. The crust is usually of a greenish grey colour and the spore-bearing bodies are brown. Another frequent crust lichen is *Lecidea contigua*, a whitish growth, much cracked and frequently sprinkled with black fructifications. The *Urceolarias*, sometimes common on smooth-barked trees, bear their spores in singular little urn-shaped processes.

Reference should be made to the so-called "writing lichens," which in their manner of growth bear a singular resemblance to hieroglyphics. The species have been well named *Graphis*. The plants form a grey film on the barks of trees which are not rough, and the fruit-bearing processes spread hither and thither in the form of dark lines. These are sometimes straight, but on other occasions may be curved; the general effect is that of a weird kind of writing.

It is quite easy in the case of many of these crust-like lichens to verify the truth of the



PELTIGERA CANINA
A typical leaf-like lichen



ONE OF THE CRUST LICHENS (*Urceolaria*)

statement that lichens are able to dissolve the mineral elements from the rocks on which they grow. Many of the crust lichens, for instance, may frequently be found actually sunk into the substance of the rock on which they are growing. In the course of untold ages one can understand what a big part these humble plants must have played in preparing the surface of the earth for the more highly specialised vegetation.

In the foregoing descriptions of the various kinds of lichens an endeavour has been made to use only the simplest words and phrases. This has been done in order to give more graphic word pictures of the kinds described. It should be clearly understood, however, that such terms as stalk, leaf, root, etc., can only be used in connection with lichens in a very general sense. Properly speaking, the spread-out portion of the lichen should be spoken of as a *thallus*, whilst the stalk or branch has not the distinctive character which these parts have in an ordinary plant. The little root-like processes on the under side of the leafy lichens (*Peltigera*, for instance) are more for the purpose of securing an attach-

ment than anything else ; certainly they may absorb water, but it is doubtful whether they do this to a greater extent than any other part of the plant. It is clearly important to bear these facts in mind when considering all the interesting points which arise in connection with the study of the lichens.

THE MARVELLOUS GILLS OF THE TOADSTOOL

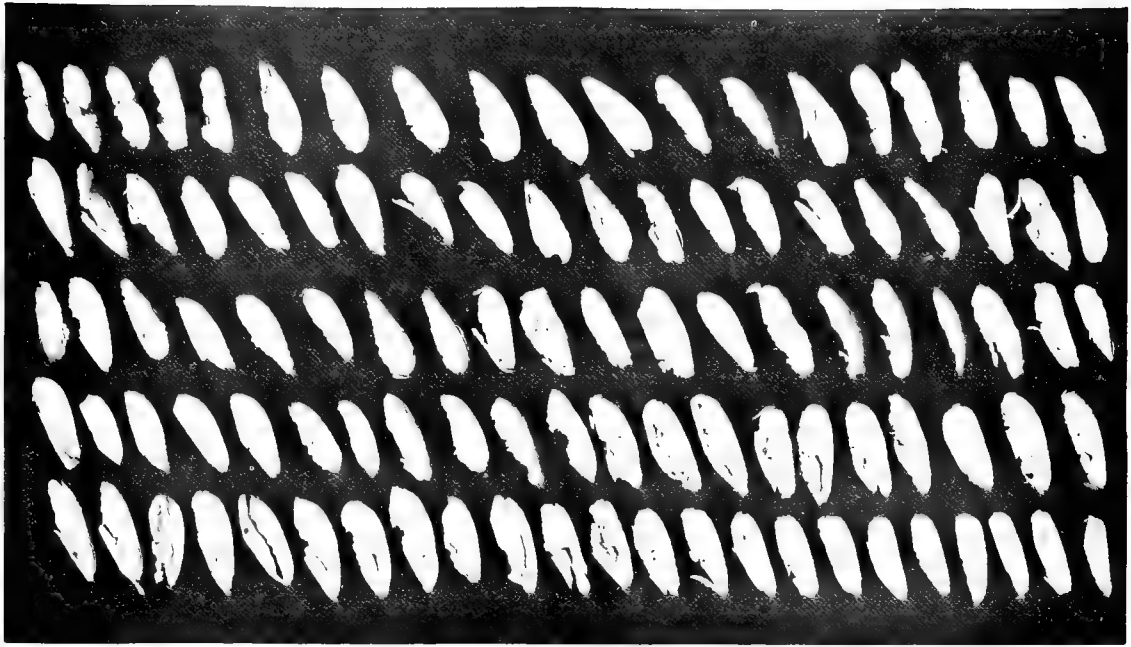
CHAPTER VII

THE STORY OF THE FUNGI

To the nature student each season brings its special interest. Even the autumn, which is traditionally a time of death and decay, signalises the beginning of great activity on the part of an important group of plants. In all kinds of places during these damp days, but particularly in the neighbourhood of trees, there are springing up large numbers of mushrooms and toadstools, many of which are exceedingly beautiful in appearance. So suddenly do these growths come on the scene that it is easy to understand the idea of the early naturalist that vegetation of this kind arose spontaneously. In those times, of course, nothing was known of that great underground system of which the toadstools and mushrooms are simply the reproductive processes. Before dwelling on the life story of the fungus it is useful to consider the real place of these plants as compared with other kinds of vegetation.

It is very plain at the outset that there is no green colouring matter in the tissue of fungi; thus they are unable to make use of inorganic matter in the soil and air. This statement must not be taken as absolutely final, however, for recent investigations have shown that some species of fungus can absorb mineral salts. Generally speaking, however, we must regard the fungi as needing the same prepared food as animals; so that, although they are plants, they cannot live independently, having none of those wonderful chlorophyll factories which are present in the forms of green vegetation. Hence we shall always find fungi living on something. Many species, as will be explained, are positively parasitic upon living plants; others thrive upon dead wood or rotting leaves, whilst again there are kinds which find a home upon all sorts of decaying matter. With so large a group of plants it will only be possible to indicate the leading characteristics, and there is much in this fascinating tale which will remain untold.

It will be of interest briefly to outline the manner in which the fungus originates. This, of course, varies a good deal in the different

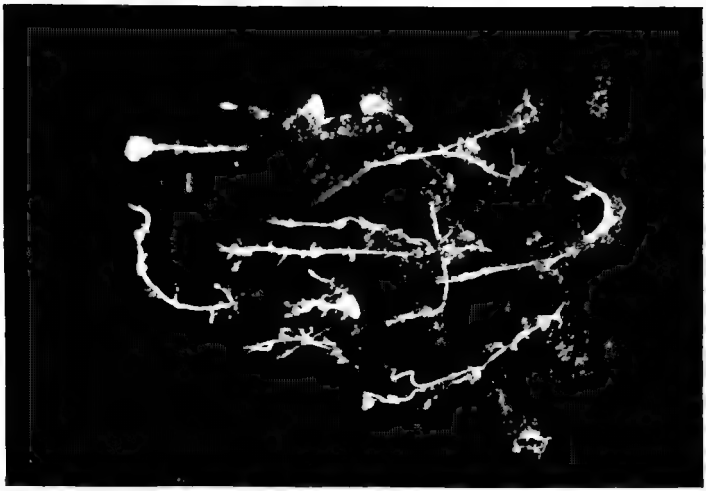


THE GILLS OF A MUSHROOM

These, 103 in number, were all removed from a small mushroom barely two inches in diameter

species, and the description can only be applied in a general way. If an example of the common mushroom be gathered and, after the removal of the stem, is placed gills downwards on a piece of white paper, a very curious happening is to be observed a few hours later. It will be found that the paper is thickly covered with fine brown dust, beautifully arranged in radiating lines. This has fallen from the sides of the gills (where it has been produced) and under a magnifying glass it is resolved into atoms which have been called spores. The very lightness of these ensures for them a wide dispersal, seeing that they will float away on the most gentle of breezes. Sooner or later the spore will find a settlement, and the first stage in germination consists in the sending out of an infinitely small tube. This is at first extremely simple, but with age it becomes increasingly complicated, branching out in all directions. The branches are spoken of as *hyphæ*, and the whole mass forms the *mycelium*, or spawn, of the particular kind of fungus. In appearance this *mycelium* is generally white, as we can see in a mushroom bed where the spawn has started to "run," as the gardener

says. Here and there cases are to be found in which the *mycelium* is coloured brown or red. Sometimes the *mycelium* on the fungus is composed of only a few threads, whilst on other occasions it may be in the nature of a great mass. In certain species there is a tendency to form a hard, thick body, which is called a *rhizomorph.* One of the best known examples is to be found in the case of the Honey Agaric (*Armillaria mellea*), an exceedingly common pale brown species which is found in clusters at the base of tree-trunks. The *rhizomorphs* of this fungus are frequently to be found between the bark and the wood of trees which are more or less in a state of decay. A somewhat similar form of *mycelium* is that which is in the form of a rounded nodule, technically a *sclerotium.* These are very largely to be seen in the case of many parasitic fungi, and their production arises quite frequently when the host plant is dying. It is likely that the *sclerotium* conserves the energy of the *mycelium* in some way, that before it perishes altogether the production of a fruiting process is possible. Quite often *rhizomorphs* are phosphorescent. With those who live in woodland districts it



THE *MYCELIUM* OF THE COMMON MUSHROOM

PEZIZA VESICULOSA

One of the few large and fairly common ascomycetous fungi

THE EDIBLE MUSHROOM (*Agaricus campestris*)
Readily recognised by its pink gills when young

is a common experience to find pieces of decaying branches which give out a greenish light quite bright at times. This state of affairs will only continue so long as the wood is damp, for it is only when the conditions are moist enough for their growth that the *hyphæ* are luminous.

Any classification of fungi by the mere appearance of the *mycelium* would be almost impossible, for in hundreds of instances it is of similar appearance. In a general way, then, identification is only possible by noticing the difference in the spore-producing process.

It has been found practicable to divide all the fungi with which the ordinary person is likely to become acquainted into two orders. These have been called the *Basidiomycetes* and the *Ascomycetes*. In the first instance it is noted that the spores are borne on the end of club-shaped bodies, whilst in the latter case they are produced in a cell. Of course, it is only possible to observe such matters as these with the aid of considerable magnification. In order to classify the fungi more completely, the *Basidiomycetes* have been subdivided into two groups, which have been called *Gasteromycetes*

and *Hymenomycetes*. In the former the spores are developed within the plant and only exposed when mature. A typical instance is seen in the case of the Puff Ball. In the latter case the spores, almost from the beginning, are fully exposed. An example of this manner of bearing is to be seen in the case of the Common Mushroom, where the little stalks bearing the spores are present on the gills. The *Ascomycetes* are also divided into sub-orders—*Pyrenomycetes* and *Discomycetes*. In the first instance the spore-bearing surface is enclosed in a bottle-shaped body, whilst in the latter case the position of the spore-producing cells is much more exposed. It may be said that, apart from a few common examples which are almost certain to be met with, a huge number of the *Ascomycetes* are very small, and could only be studied satisfactorily with the aid of a microscope.

Under the sub-order *Hymenomycetes* are included some of the most interesting of families. Most familiar of all are the Agarics, two familiar types of which are the Succulent Mushroom (*Agaricus campestris*) and the highly poisonous, though most attractive, Fly Agaric

THE BAY BROWN BOLETUS (*Boletus badius*)
A common fungus in fir woods

(*Amanita muscaria*). The abundant Chantarelle (*Cantharellus cibarius*) is a representative of another type of the Agarics. Half a dozen sub-families have been formed, and the different members are largely determined by the colour of their spores.

Additional families of the *Hymenomycetes*, in which the representatives are of very distinctive appearance, may be briefly summarised. In the case of the *Polyporaceæ* a very marked feature is that the spore-bearing surface appears to have been covered with pin-pricks. A typical species with which almost everybody is familiar is the Bay Brown Boletus (*Boletus badius*), which is very common, especially in fir woods. A normal form is bright brown in colour on the top, and yellow on the spore-bearing surface. Another branch of the family is that which includes the woody bracket-like fungi. These grow on many kinds of trees, both living and dead, and in the case of the former are calculated to do a good deal of harm. A typical species is the Soft Tinder Fungus (*Fomes fomentarius*), which is of a brown colour with a white spore-bearing surface.

A very common fungus, *Hydnum repandum*,

is typical of the family to which it belongs, the *Hydnaceæ*. Here the distinguishing feature is that on the under side of the cap where the spores are produced there are quantities of sharp spines. In the *Thelephoraceæ* the spore-bearing surface is absolutely smooth. In hazel copses the "Horn of Plenty" (*Craterellus cornucopioides*) is often found, and this is a good example of the family.

Another family which can hardly fail to attract special attention is the *Clavariaceæ*. Here the spore production is on very similar lines to that which is noticeable in the *Thelephoraceæ;* but the general character of the fungi is very different. As a rule, the plants are club-shaped, and often are much branched. Some of the species belonging to the genus *Clavaria* are most singular in appearance, and somewhat resemble besom brooms. A very common kind belonging to this family is the white-tipped "Fairy Club," *Clavaria luteoalba*. This is in the form of a small yellow club tipped with white, and is abundant amongst grass. Another species which is not uncommon in certain districts is the Besom Fungus (*Clavaria stricta*).

SOFT TINDER FUNGUS (*Fomes fomentarius*)

A common fungus on forest trees; a most dangerous parasite

The "cauliflower" fungi are perhaps the most singular of all, the kind most likely to be met with in the south of England being *Sparassis crispa*. The plant is usually found at the foot of fir trees, and resembles the white part of a cauliflower in its general appearance.

In the remaining family of the sub-order *Hymenomycetes*, which has been called *Tremellaceæ*, the fungi are very distinctive, owing to their gelatinous nature. These plants are common upon rotten wood, and several of the species are almost certain to be met with even during a short ramble. A very abundant form is that known as *Tremella mesenterica*. This is of a bright orange colour, and is to be found growing on certain trees and shrubs, such as oak, and particularly gorse. Indeed, it would be difficult to find a piece of common land with furze where this fungus is not present during the winter, at any rate.

In the sub-order *Gasteromycetes* are included all the many kinds of Puff Balls. Here, although the spores are borne on stalks, they are produced within the fungus, and are not exposed until quite mature and ready for dispersal. This is

well seen in the case of the Common Puff Ball (*Lycoperdon gemmatum*), where, at first, the enclosing skin of the fungus is completely unbroken. When the spores are mature, a definite opening occurs at the top of the Puff Ball, and allows the tiny specks to escape in a cloud. Now and again we may have the good fortune to come across specimens of the Giant Puff Ball (*Calvatia gigantea*). This fungus is sometimes as much as a foot in diameter, and when in a mature state releases a huge number of spores. Another remarkable species belonging to the sub-order is the Stinkhorn (*Ithyphallus impudicus*). This singular fungus arises from an egg-like process, and when mature presents a most remarkable appearance. The question of spore dispersal in the case of the Stinkhorn is touched upon on a later page. Included amongst the *Gasteromycetes* are the rare and beautiful Earth Stars, as well as the strange underground fungi which are gathered together under the term of "False Truffles."

It has already been mentioned that a large number of the species of fungus belonging to the order *Ascomycetes* are very small, and only a limited number are likely to come under the

THE CHANTARELLE (*Cantharellus cibarius*)

This fungus is common in beech woods in late summer. The whole plant is coloured like the yolk of an egg

notice of the ordinary observer. Of these some of the members of the sub-order *Discomycetes* are perhaps the most striking. The different species of Elf Cup (*Peziza*) are almost certain to be met with in one form or another. A familiar species is the Bladder Elf Cup (*P. vesiculosa*), which in the summer and autumn is often found on rotting leaves. The colour of this fungus is usually of a pale brown, whilst in shape it resembles a little bowl. A very charming Elf Cup is *Peziza coccinea*, which is of a lovely carmine colour. This is not uncommon in country districts in the spring, and is perhaps most frequent in the west of England. Many people have come across the edible Morels. *Morchella esculenta* is the common form, and this is very distinctive on account of the many-sided pits with which the plant is covered. Included in the sub-order under consideration is the singular Caterpillar Fungus (*Cordyceps militaris*). This is in the form of a club-shaped process, red in colour and about an inch in height. If the soil is disturbed it will always be found in association with a caterpillar or a pupæ, on which it is, of course, parasitic. The most distinctive

of the fungi belonging to the sub-order *Pyrenomycetes* are the truffles. Many species of these strange underground plants are very rare, and those which might be called common are not to be found save in limestone districts.

In a broad way it is possible to divide all classes of fungi into two sections: those which live on organic matter that is dead, such as rotten leaves and wood or decaying animal matter, and those which are actual parasites on living plants or animals. The former class of fungi do no harm, and may even do a certain amount of good in aiding the processes of decomposition. It is an altogether different matter when we come to the parasitic fungi, many of which do more harm than any other pests that it would be possible to name. Of the larger kinds of harmful fungi, those which are parasitic on forest trees are the most conspicuous. In this country, where forestry is a sadly neglected industry, people scarcely realise with what the woodmen in some parts of the world have to contend. A fungus which is very common in many parts of Europe, including the British Islands, is a most destructive parasite. The plant is known as *Fomes annosus*,

A COMMON FAIRY CLUB (*Clavaria incarnata*)

and may be frequently seen in the form of brackets jutting out from the trunk of the trees. The particular habit of the *mycelium* of this fungus is to creep into the tissue of the tree, destroying everything which it touches. Often the white felt-like *mycelium* starts round the roots of the victim, and thence spreads upwards throughout the whole of the trunk. The tree, of course, speedily becomes sickly in appearance, and finally dies altogether. When it is cut down it may well be that it is a mere shell, practically all the woody centre of the trunk having been destroyed.

The Honey Agaric is also an excessively harmful pest, attacking, as it does, almost every kind of tree. It may often start at the roots of its victim, but once having secured a hold, the *rhizomorphs* into which the *mycelium* is formed spread upwards into the newly formed wood, drawing away the vital matter which the unfortunate tree has really elaborated for its own use. In all these cases it is well to remember that the actual fungus, as it appears to the observer, represents only a fraction of the system of the parasite, it being simply that part which is concerned with the production of spores.

There are very large numbers of small fungi, amongst which can be numbered some very destructive pests. Everybody has noticed the black patches on the leaves of the sycamore, which often bring about an early falling of the foliage. These are due to an *Ascomycete*, *Rhytisma acerinum*. Many of these minute fungi, about which the ordinary person scarcely thinks, cause a huge amount of trouble to the gardener and the farmer. The mildews which hamper the grower of roses, the smuts and rusts which wreck a crop of wheat, are all most obnoxious fungus pests which the world could very well do without. Unfortunately, many of these small parasitic fungi possess most efficient means of increase. During the summer time ordinary spores are produced, and these are ready for immediate germination. Thus if they do not get into a suitable position almost at once they will very speedily perish. But in view of the winter special resting spores are developed; these will not germinate until after a considerable interval. The real purpose of these winter spores is to tide the fungus over the time when the host plants have no foliage or, if they are annuals, are not in existence at all.

A COMMON PUFF-BALL (*Lycoperdon gemmatum*)

THE BESOM FUNGUS (*Clavaria stricta*)

Even though they may not be produced in large numbers, these resting spores are quite sufficient to infect the victims with the coming of the warm weather. When the fungus is mature there is a rapid and abundant production of the ordinary summer spores, and these will, of course, spread the pest in all directions. Just occasionally the parasitic fungus does not seem to do a great deal of harm to its host. The outgrowths sometimes to be seen in birches, alders, and conifers, commonly known as "witches' brooms," are the outcome of the attacks of a small fungus known as *Exoascus turgidus*. It should perhaps be pointed out that a very similar result is sometimes traceable to the energies of certain mites, extremely small creatures related to the spiders.

Modern research has clearly demonstrated that the outcome of parasitism is not uncommonly a mutually helpful compact. This symbiosis, already instanced in the lichens, is further illustrated by the strange alliance between many fungi and trees. It was at one time thought that the reason for the abundance of fungi in woods was to be found in the fact that so many of these plants thrive on rotting

leaves and wood. But this is only half the story. It has been proved that a very large number of species of fungi—how many it is difficult to say—are actually in the closest association with the roots of trees. The *mycelium* is not only entangled with the fibres, but it often closely embraces, and even on occasions penetrates, the young roots. There is little doubt that these fungi are helping themselves to the organic material which the tree has been able to elaborate with its green leaves in the sun and air above. So far there may not seem to be anything very astonishing, but there is a most singular side to the question. Far from any harm arising to the trees, there seems to be good proof that the presence of the fungus on its roots is beneficial, and in some cases essential, for the welfare of the host. Although we must be careful not to dogmatise, it really seems as if certain trees would not grow at all unless the fungus guest was present. For example, seedlings of beech and fir will not succeed in the chemical solutions which suit other plants so well. Further, it is a common experience for gardeners to find great difficulty in establishing these trees, in common with rho-

GIANT PUFF-BALLS

dodendrons and azaleas, unless they take care to put in some of the soil from the woods, which, of course, is extremely likely to contain some of the fungus *mycelium*.

It has not been positively decided what part the fungus plays in helping the roots, but it seems that it probably renders aid in the absorption of moisture and possibly mineral salts. Most of the trees and shrubs which have entered into this alliance are able to support an existence in dry places ; this points to the fact that they may be receiving special aid in the matter of moisture supply.

One should not jump to the conclusion that all fungi in woods are living in this manner. Undoubtedly many kinds flourish on the dead organic matter, whilst it is quite likely that a number divide their attentions impartially between the tree roots and the rotting leaves. It is significant, however, that certain species of fungus are almost always found in association with definite trees. As an instance, which anyone might observe, may be mentioned the Fly Agaric, which always grows at the foot of either fir or birch. This relationship between trees and fungi is one which it is necessary to

dwell upon with a good deal of reserve, seeing that there are a great many points which are not as yet completely understood.

The general question of the production and distribution of spores is one which the student may find of interest after he has become familiar with some of the leading types of fungi. Most of the species produce their spores in the greatest abundance. In some groups, notably amongst the Agarics and the Puff-Balls, the amount of the fertile dust is simply prodigious. Owing to the special arrangement of the gills in an ordinary mushroom, the spore-producing surface is very great. Here we have a hundred or more thin plates, grouped together under a protecting cap, each one of which bears spores on both sides. An enormous surface capable of spore production is thus provided. A very large number of fungi, probably the great majority, must rely upon the wind for the dispersal of their spores. Large quantities will fall into unsuitable places, but the number produced is so vast that a sufficiency of the tiny atoms will make a successful start. In some cases it is known that animals play a useful part in the distribution of fungus spores.

THE FLY AGARIC

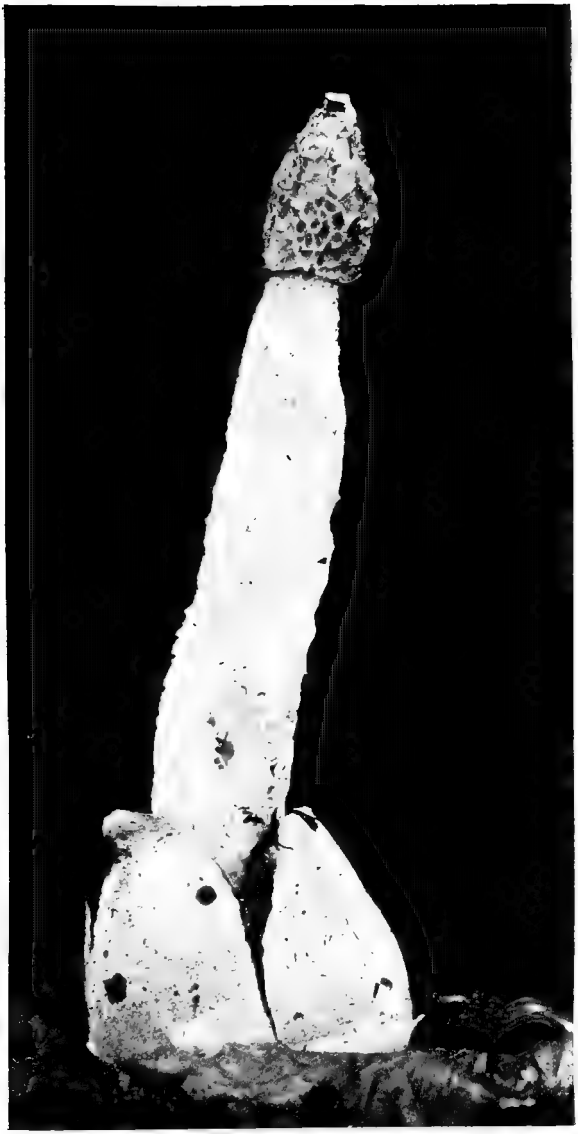
STAGES IN THE GROWTH OF THE FLY AGARIC

The strange Stinkhorn associates its minute spores with a strong-smelling secretion which seems to be very attractive to flies. In devouring the slime the insects swallow the spores as well, and these are finally distributed over a wide area. It is also known that slugs play a part in dispersing the spores, seeing that these creatures show a strong liking for certain fungi, notably some kinds of Agaric. The spores seem to be well able to withstand the digestive juices, and are ready for germination when they have passed through the body of the slug. Squirrels, rabbits, and other small animals are known to carry about the spores of certain fungi in their fur, and in this way act as useful agents.

Several points in the growth of fungi seem to call for special comment. One of the things which the casual observer is bound to notice is the rapidity with which certain species grow. It is not an uncommon experience to find that large and well-developed fungi have grown up in a single night where previously there was no sign of them. The Stinkhorn fungi, which start life (so far as the reproductive process is concerned) in a curious egg-like receptacle,

are noteworthy for the rapidity of their growth. In some tropical species it has been observed that these fungi will grow at the rate of two or three inches in an hour.

In connection with the growth of fungi the habit of many kinds of spreading out in a circular fashion and forming the well-known "fairy rings" calls for comment. This is peculiarly noticeable in the case of many Agarics, but the phenomenon is by no means confined to these fungi. The happening is really due to the way in which the *mycelium* of the fungi spreads out more or less evenly on all sides from its original starting point. In some the manner of growth may be in the form of a very complete circle, whilst again it may be only a section of the arc. It is generally to be observed that the grass and herbage inside and parallel to the fungus ring is often of a very bright green colour and of great luxuriance. In some cases this is undoubtedly due to the nutriment provided by the decay of the last line of fungi. In many of the Agarics this does not apply, however, seeing that these fungi are positively harmful to and will even kill grass, on the roots of which they are para-



THE STINKHORN FUNGUS (*Ithyphallus impudicus*)

sitic. Here it is usual to find an almost bare strip next to the fungus line, in which the plants are dead and brown. Beyond this to the centre of the ring the herbage is of a very bright green. The explanation of this lies in the fact that the original meadow grasses have been killed by the fungi, and in their dying the ground has been well manured. Other plants have arisen and prospered upon the ground, which is really fallow in nature. These newcomers are often quite distinct types from those usually associated with meadow land.

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