THE OUTDOOR BOTANIST

A SIMPLE MANUAL FOR THE STUDY OF BRITISH PLANTS IN THE FIELD

BY

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"PLANT-LIFE IN THE BRITISH ISLES," "PRACTICAL FIELD BOTANY,"
"BRITISH WILD FLOWERS IN THEIR NATURAL HAUNTS," ETC.

ILLUSTRATED WITH TWENTY PLATES, TWO MAPS, AND FOUR FIGURES IN THE TEXT

T. FISHER UNWIN LTD
LONDON: ADELPHI TERRACE

G. B. Dixon.

A DERBYSHIRE DALE, WITH STUNTED HAWTHORNS AND LIMESTONE PASTURE.

Frontispiece.

TO

GEORGE CLARIDGE DRUCE

HON. M.A. (OXON.), LL.D. (ST. ANDREWS), F.L.S.

THE FOREMOST FIELD BOTANIST

IN GRATITUDE FOR HIS EXAMPLE, STIMULUS

AND HELP

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PREFACE

In a practical age, especially where science or technology is concerned, practical work is of especial value. Botany is no exception to the rule. A knowledge of plants *in the field* is essential to a proper understanding of their characteristics, their behaviour, apart from their actual growth and development. It is out of doors, or in the field, indeed, that a practical knowledge of plants is best gained.

Plants are not, as some would seem to treat them, dead organisms. They are beings with likes and dislikes, as ourselves, living an active existence, though their means of expression differ so greatly.

The plant world is full of wonders to the enquiring spirit. These wonders are spread out around us—in the field, the wood, on the marsh, along the shore.

To succeed in understanding them, to achieve a knowledge of the living plant, let the botanist therefore *take the field*—in a word, let him or her be an *outdoor botanist.*

We forget that the very beauty of scenery, which appeals to the soul of every man and every woman, is based very largely upon plant life—*e.g.*, woodland scenery on the trees, and so on. We recognize the seasons, too, by the flowers in bloom.

This work, then, is intended to be a guide, if brief and simple, to living plants, which the beginner may study most surely and most healthfully out of doors. The terms of study are easy, the criteria of success are simple and pleasant. But let the reader judge for himself. The practical field botanist, to whom I appeal, will perceive that my data have been gained in the field. Thither would I lead others, deeming the field the courtyard or royal road to success in this arena.

As the study of plants in their habitats, or the study of the associations of plants and their relation to the habitat or surroundings, requires a term which can be used to avoid prolixity, it has been named *ecology* (Greek *οἶκος*, home; *λόγος*, study), and that word is used in the chapter dealing with plant associations (Chapter II.).

Similarly, the seasonal changes in vegetation, or the different periods when seeds germinate, leaves unfold, flowers bloom, fruits ripen, or leaves fall, etc., the times of which vary in accordance with temperature and other changes, are called *phenology* (Greek *φαινῶ*, appear; *λόγος*, study), and in the chapter dealing with the seasonal changes (Chapter V.) that word is used for short. Some words of this kind are unavoidable, and with this remark I must bid readers to be patient if they seem at first unfamiliar, and use the glossary which explains their meaning. As the words "photograph," "camera" are commonplaces to-day, so later will any terms used here be household words as fruit is borne of efforts to popularize the study.

For the loan of several blocks (Figs. 19, 20, 27, 30, and 32) I have to thank the Council of the Leicester Literary and Philosophical Society; and also Messrs. Flatters and Garnett for illustrations in Chapter I. (Figs. 1, 2, 3, 4, 5, 6, and 9). I am indebted also to Miss Isabella M. Charters for some drawings, and to Messrs. A. Newton, L. R. J. Horn, G. B. Dixon, and C. A. Allen, for photographs.

A. R. HORWOOD.

CITY OF LEICESTER MUSEUM
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THE OUTDOOR BOTANIST

CHAPTER I

SOME METHODS OF COLLECTING, PRESERVING, AND DRYING PLANTS

In order to obtain some knowledge of plants, if only to know how to identify them, it is at the outset necessary to make collections. These may or not be preserved. If they are, they serve for future reference, and for winter study in particular. Collecting, of course, is part of field botany, and must be undertaken whether the work is part of a systematic scheme, an effort alone to identify species, or part of an ecological, or other, scheme.

There are all sorts of ways of collecting. The best way is to know beforehand what the precise object is; then, whatever that be, having made plans accordingly, it is well to aim always at collecting a complete specimen. If, as usually done by the amateur, a mere scrap is deemed sufficient, the knowledge of plants gained will be equally scrappy. It is really necessary to see that the plant has all its organs represented, even where a plant is not rare, including the root, or underground organ. Obviously, this applies to plants of a size convenient for preservation. It cannot apply to shrubs and trees, a small portion of which, with flowers, fruit, and leaves, alone can be collected. The reason for collecting roots may be exemplified by some of the Grasses, for allied species vary in this character.

Not only should the specimen collected be complete, but it should also show all the proper characters of the plant; it should be collected at the right season. A specimen without flowers alone is not much use. Where the fruit is essential to identify the plant, the specimen should then be in fruit when it is collected. One object of obtaining a complete specimen of moderate-sized herbaceous plants is to obtain an idea of the habit of the plant, so far as dried specimens are capable of exhibiting this feature. An illustration will suffice. A rosette plant, such as the Dandelion, unless it is complete does not show this characteristic growth-form. Plants whose aerial flowering stems are scapes must always be collected as complete as possible; also, the radical leaves often differ from the stem leaves, and therefore one should collect the whole plant in order to have both. Some aquatic plants have submerged as well as floating leaves, and here again one requires both. Speaking of radical leaves, these often disappear at an early stage, therefore one requires more than one specimen to illustrate the plant completely.

Moreover, some plants flower before the leaves, such as many trees. Here one has again to collect at two different periods. The catkins of Willows are collected in spring, the leaves in summer or autumn. The Meadow Saffron develops its leaves and flowers at different seasons, and so do some of the Crocuses.

Brambles require special treatment. They ought not to be collected till August, and one needs a good panicle, with leaves, and also a piece of the barren stem with a typical leaf, making sure that the two are part of the same plant, for Brambles grow often intermixed. Roses should be collected in flower and in fruit if possible, and a piece of barren stem is also needed.

Plants that especially require collecting in fruit are

Water Buttercups, Crucifers, Starworts, many Umbelliferæ, Bedstraws, Composites, Docks, Sedges. It is well, however, not to collect some groups of plants in a too advanced state, such as Crucifers, Willow Herbs, Thistles, Grasses, as the fruits open and the seeds fall. The same applies to Goosefoots and Oraches.

A very important point is to ensure that the plant is typical and normal. Late in the year such plants as Brambles become far from typical, and every plant may, under abnormal conditions, assume a too luxuriant, starved, or otherwise unnatural condition. On the other hand, it is advisable to keep a critical eye open for any variations, and to collect all varieties and forms, if possible attempting to ascertain their permanence or otherwise.

When sufficient progress has been made, and all the common plants are known, the search for varieties and forms, and the study of the more critical plants, such as Brambles, Roses, Hawkweeds, etc., will become perhaps the chief object. Then, also, it will be desirable to make a study of possible hybrids, and to ascertain, if feasible, the parents of each.

There are some two thousand native British plants which can be identified by using any good flora with the help of a key. There are besides some thousand odd alien or casual plants, not usually described in such works. No doubt every collector will come across these, and they may in time be mastered, the identification being entrusted to such national institutions as the British Museum or Kew, if foreign floras are not available.

Having briefly outlined the main features of how to collect, which can be supplemented by personal experience and practice, it is necessary to add a few suggestions as to when to collect.

In a country where the four seasons vary considerably, such as the British Isles, it is obvious that one must choose the right season for collecting, since if it slips by one has to wait till another year before the chance occurs again. There are some flowers, such as the Winter Aconite and Snowdrop, etc., that bloom in January or February, whilst the season generally opens in March; but by the end of April the early spring flowers are over, and by May the flower world has begun to assume a different aspect. One does not look for Dog Roses in May as a rule, but in June, and though May is the month of "May" in poetry, often it does not flower till June.

The early flowering trees, especially some Willows, must be sought for in March and April. In August the Brambles and Hawkweeds are the chief feature. Grass of Parnassus rarely blooms till September, like the Meadow Saffron, and the Ivy is scarcely in flower till November.

Therefore it is necessary to consult a good flora in order to know when to search for a flower in bloom, preferably a local flora; for though general floras give seasons, often this extends over three months for the British Isles, for flowers in the south bloom earlier than those in Scotland, and there are local variations for every district. The seasons also vary from year to year. Taking a general flora as a basis, it is a useful plan to compile a list of the flowers of each month (see also Chapter V.).

If one is working in a particular district, the flora of which is known, the flowers of that district can be marked on the list for each month, and, given the localities for each in the local flora, one can then, more or less readily, find each one as it appears in flower. For each area the mean flowering season may be ascertained by several seasons' work, and such knowledge at first hand becomes especially valuable from the local standpoint.

Given the method of collecting and when to set out for each flower it is desired to find, there still remains the question of the habitat, presuming a locality is known. Here, again, good general floras cite the general habitat of wild plants. This, however, often varies in different parts of the country, and a plant may grow in a variety of habitats, or at least in more than one. Woodland plants are generally fairly constant in their habitat, but some species vary considerably. Much will depend on the plan of field work to be adopted. It may be possible to select a series of habitats of a general nature, such as moor, heath, marsh, etc. One may either visit these and explore them thoroughly, thus finding all the species each affords, or one may make an itinerary walk—go to definite spots for the species known to grow there; or a third method is to go out and to find anything that turns up. The first plan is perhaps the best. The last depends on good luck, which the amateur is always thought to possess above the veteran. Perhaps the latter is less contented than the former with his results, and searches less diligently, being possibly also somewhat more *blasé* than the former.

Really only practice and experience will teach one what sort of habitat to examine in order to find a particular plant. Regular systematic surveys, regardless of search for particular species, are of more real value than the latter. If a knowledge of soils and geological formations can be gained it will help much in the study of habitats. By degrees the appearance of a piece of ground will suggest at once, to one with some experience, what to expect to find there before actually examining the ground; but, like everything else, collecting has its surprises, and herein lies the charm of botanizing in an unknown, or even a known, district.

It should be pointed out, by the way, that plants do not always flower in successive years. This applies, for instance, to the Pasque Flower and many Orchids. A period of rest may be demanded, or browsing cattle may in some cases furnish the real explanation of this somewhat puzzling feature of plant life, when a species would seem to have disappeared.

As to where to collect, the question resolves itself into where to look on lines that will ensure better chance of success than if search is made in a haphazard manner, as is so frequently the case with the beginner.

A study of the habitats of plants shows that there is a great variety of these. The main types of habitat may be summed up in the popular terms for the physiognomy of vegetation, the units of which are meadow or pasture, wood, heath or common, moor, swamp, fen, bog, marsh. Besides these, speaking generally, there are all the physiographical divisions which make up aquatic vegetation—the former applying to land plants—such as lake, river, pond, pool, stream, ditch, etc. Each of these has a special flora of its own according to the rate of flow and character of the water (and see Chapter II.).

Maritime plants may be searched for under the general habitats of the saltmarsh, sandy shore or dune, the shingle bank. There are also estuaries and mud flats that have their special flora.

Thus each of these divisions may be said to have a different flora, and one can recognize such divisions by the plants that grow there. There are, of course, many other types of habitat in addition to the above, and, ecologically speaking, one may define between fifty and one hundred types of associations, included in sixteen main groups or formations, corresponding partly in a general manner with the above divisions.

Variation in some habitats may be sought in the difference in the amount of water in the soil, in the case of land plants. Thus a wet meadow differs from a dry pasture or meadow, a wet wood from a dry one, a wet heath from a dry one. One may merge into the other, but the extremes furnish different floras.

Altitude affects the distribution of plants, and the flora of lowlands differs from that of hills or mountains, to use a general term. Cultivation is unprofitable above 1,000 feet, and crops therefore will not grow above this line, so that plants of the cornfield (this is another habitat, like waste places, turnip fields, ballast heaps, etc.) should be sought in lowland areas. Waste ground plants especially are to be found where man's activities are in evidence, and this supplies us with a great number of different habitats around towns and cities, villages, farmyards, railways, docks mills, reservoirs, sewage farms, etc.

Rocks, again, are special habitats, and so are walls roofs, stone bridges, etc., which provide similar conditions. According to soil, moreover, we may look for arenophilous plants on sand, pelophilous plants on clay, calciphilous plants on limestone, chalk, or marl turfophilous plants on humus or peat, etc.

Climatological effects cause us to look for boreal or northern plants in the north, austral or southern plants in the south, and other plants in the west or east.

The point is that in collecting it is wise to study these habitats, and to collect by habitat. This enables one to study the kind of plant that forms each habitat, the growth-form. It is also a more certain method of obtaining good results, and should therefore be recommended.

There is some general apparatus that may be suggested for the use of the botanist for collecting and allied operations for those who wish to form herbaria, which may be outlined at this stage.

Those appliances that are required for drying, mounting, etc., will be mentioned as the descriptions of the methods adopted in each case are dealt with

Such general apparatus includes the impedimenta needed for collecting.

A botanist's outfit need not be large. It is not within the scope of this chapter to outline any but the requirements of the field botanist, and, except generally speaking, the apparatus for ecological work is not included. Some suggestions on this head are made in another chapter (on Ecology).

Initially one needs some receptacle in which to place the plants when collected. The best thing is a vasculum (Fig. 1), which is usually made of tin, japanned over, furnished with belted straps to sling it over the shoulder. The size may be large or small according to requirements. If one is a cryptogamist, a small tin may be carried for lichens, mosses, etc. This may be an empty two-pound tobacco tin or similar box. It will also serve for small flowering plants.

For carrying water plants it is recommended that some waterproof paper (bags if desired) be put in the vasculum before starting out, and used as occasion arises. An ordinary confectioner's paper bag is a rough-and-ready substitute, or a sponge bag.

There are many botanists who prefer to put their plants directly they are gathered into a portable press (Fig. 9), which may be made of stiff boards with drying-paper between, and straps for carrying and pressing the plants together. There is no doubt that this plan has its advantages, for the plant is fresh and un-

FIG. I.—VASCULUM, WITH STRAP FOR SHOULDERS.

FIG. 2.—TROWEL FOR DIGGING UP PLANT BY ROOTS.

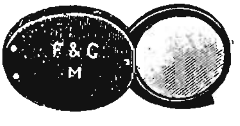

FIG. 3.—LENS FOR EXAMINING SPECIMENS.

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withered when put in the press, and it can be arranged just as required in the field. On the other hand, this takes up valuable time in the field, and for some this may be a disadvantage.

A trowel (Fig. 2) may be used, where the whole plant is collected, especially when there are tubers, etc., deeply seated in the soil. But I would discourage the use of this implement save in the case of common plants. For on no account has a botanist any right to endanger the existence of a plant. Such behaviour savours of selfishness and vandalism, and has been far too prevalent, as reports in my possession prove.

An indispensable adjunct to field work is a lens (Fig. 3), for examining small organs, glands, hairs, stamens, and the flower and fruit. A broad watch-maker's lens with a shallow mount, and protective case working on a pivot, is a simple, useful, and effective lens for the field. Better ones should be left at home, for personal losses cause one to reflect upon the folly of arming oneself in the field with expensive apparatus, easily mislaid.

No one should be without a knife. Parts of trees should be cut with this, and not torn away, causing disfigurement and possible damage to the tree, if a young one. Scissors serve better for cutting brambles (barren stems) and herbaceous plants generally; and for dissecting purposes fine-pointed ones are handy.

As already emphasized, a notebook and pencil cannot be dispensed with. A field notebook should not be elaborate, nor large. Field notes can be copied fair into a larger one at home, and amplified if need be.

In every case some form of notebook is required, for no memory, however good, is perfect, and notes made on the spot are worth ten times more than notes made from memory at home, perhaps after a long lapse of time since the observation was made.

It is also very necessary to carry maps. A general small-scale topographical or orographical map, or both, is valuable. The ordnance map gives one a chance of locating one's observations by reference to any tract upon it by number, thus making them at once much more valuable and accurate than otherwise—*i.e.*, if made without such location. A geological map enables one to determine relatively the type of soil. Another valuable adjunct is a pocket botanical handbook, which enables one to identify a plant in the field. I know of no better manual of this kind than Druce's edition of "Hayward's Botanist's Pocket Book," in which the characters are so concise that identification is readily made.

A useful method of obtaining plants out of reach is by aid of a gripper or stick fitted with a spring clip with which catkins, twigs, etc., of shrubs or trees out of reach may be secured. It answers well, also, for obtaining water plants. Duckweed and small plants may be collected with a pond-net fitted with a long rod, or some special pond-collecting outfit may be used (Figs. 4 to 6).

Often it is necessary to tie together separate parts of the same plant, such as catkins and leaves, or panicle and barren stem, in order that they may not get mixed in the vasculum. This may be done by tying them together with string, which may be carried for this and many other purposes. Labels may also be found useful for writing down particulars, attached to the string used for tying up such loose parts.

When the plants have been brought home they must be dried and pressed, if intended for the herbarium. For this purpose a few accessories are necessary. There is, first of all, drying-paper (Fig. 7). This is

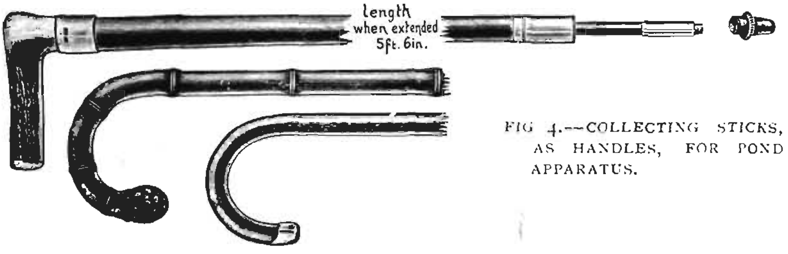

FIG. 4.—COLLECTING STICKS, AS HANDLES, FOR POND APPARATUS.

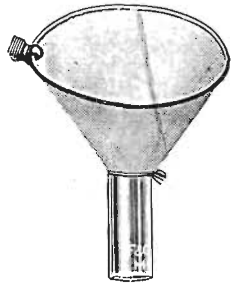

FIG. 5.—ROUND NET FRAME FOR POND APPARATUS.

FIG. 6.—STRAINER FOR FITTING TO POND APPARATUS.

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sold by various firms who supply botanical outfits,* and is of large and small size, and different textures. A medium size is best, and a texture neither too porous, as in coarse paper, nor too close, as in fine-grained paper, resembling blotting-paper. As a substitute old newspapers may be used. Once folded they are of the right size, and a sixteen-page paper supplies the necessary thickness of paper between consecutive layers of specimens. In addition to drying-paper weights are required to give the pressure required. They may be books, bricks, or similar weights. Some botanists prefer iron weights used with scales. Instead of drying-paper and weights, a drying-press (Fig. 9, *post*) may be used fitted with boards, paper, and straps, as suggested for field work.

Before the specimens are put into press a certain amount of treatment is necessary. The roots and rootlets need cleaning by washing or brushing. All foreign objects should be removed from leaves or other parts, as spiders that weave their webs under Bramble leaves, or caterpillars, mud, etc. Dead leaves should be cut off and the plant, if too large, should be trimmed to the size required, without rendering it incomplete if possible.

Very succulent plants, such as some Crucifers—*e.g.*, Brassicas—Stonecrops, Heaths, Thistles, and many maritime species should be immersed for a moment or so in nearly boiling water to kill them, as otherwise they will continue to grow in the press. Thick stems, large flowers, or fruits should be sectioned so that pressure may not be unequal and shrivelling may not result therefrom. Scissors and a sharp knife are needed for trimming and sectioning. For arrange-

* Messrs. Flatters and Garnett, Oxford Road, Manchester, supply all forms of botanical requisites.

ment of parts on the drying-sheet small plate-glass slips may be used, which act as weights, as the specimen is gradually covered by an upper layer of drying-paper. Thick flower-heads, such as those of many Composites and Thistles, need a layer of wool for embedding so that there may be equal pressure and no shrivelling. Delicate flowers may be cut off and dried separately in tissue-paper, thus preserving better their colours, and the flowers can be later attached again to the plant for mounting.

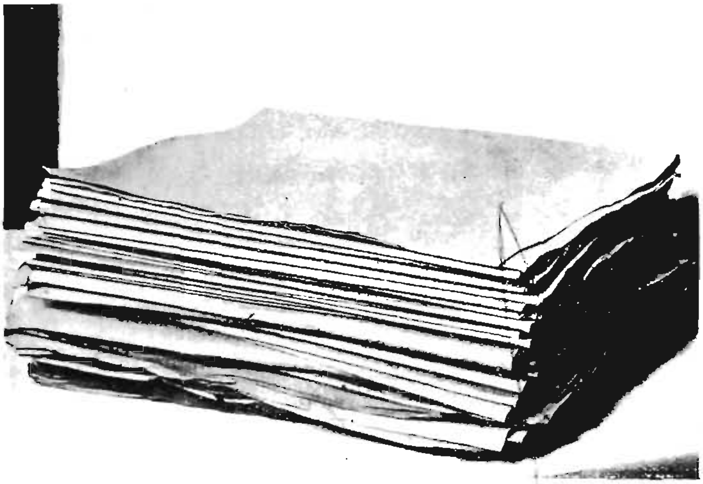
Water plants that are limp when taken out of the water should be floated out in a basin, and thin paper (cap paper) placed below them so that they may be dried in an extended, natural manner, by drawing them out of the water gradually on the cap paper. In this way they do not collapse, but lie as if in the water. A piece of cap paper may be laid on their upper side, and thus enclosed they may be dried between ordinary drying-paper. Water Buttercups, Stoneworts, Starworts, etc., require this treatment.

In making up a pile of plants for drying, care must be taken that too many layers do not lie above each other without an interval of ventilators for the escape of water vapour. Ventilators may be made of narrow slats of wood made into small racks, placed cross-wise, or they may be made of wires. A good supply should be at hand.

A final word should be said as to labelling. As each layer of plants is arranged on a drying-sheet a label with particulars of date, locality, etc., or a reference to field notes, and, if desired, to the date when first put into press, should be placed with each.

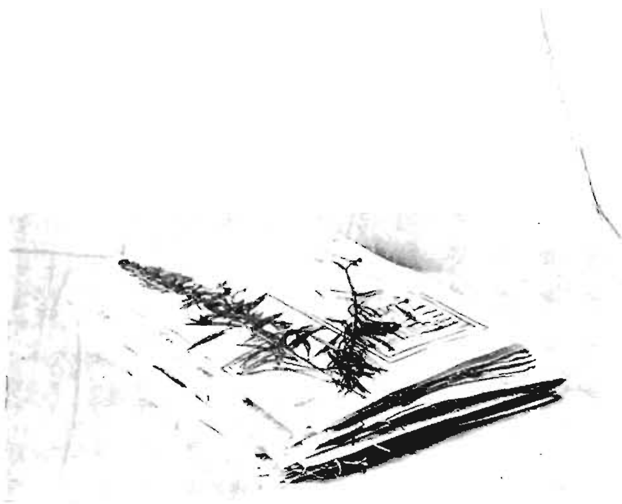
The operation of drying takes from a few days to a week.

The essential point is to change often and quickly. The first interval may be twelve hours or twenty-four



A. Newton.

FIG. 7.—DRYING PAPERS FOR PLANTS IN THE PRESS.



A. Newton.

FIG. 8.—STACK OF PLANTS AFTER DRYING, STORED AND LABELLED.

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hours, and go on till a third or fourth change with longer intervals. It is fatal to success to leave too long in damp papers as the moisture is reabsorbed after extraction, and this causes discoloration. The true colours of the green parts and the flower are only preserved, where this is possible, by changing the papers as often and as soon as possible, so that directly the moisture is extracted and resides in the drying-papers these are removed and do not become mouldy. The drying-papers can be dried in an oven, on a rack over a range, or in the sun. In changing limp, flaccid plants open out the wet paper, lay over the plants one side of the dry sheet, turn the two upside down, then remove carefully the other wet side, and turn back the second dry sheet (if the papers are folded). If the drying-sheets are single just invert the dry and wet, and peel the specimen carefully off on to the dry sheet below, and cover with fresh dry sheets.

After all the specimens are dry take dry store sheets, newspapers, etc., and lay the fully dried specimens on them with their labels, and put aside till they are ready to be mounted (Fig. 8).

As a preliminary to mounting it is almost essential to poison the specimen to prevent mite or moth. If the specimen is to be pasted down to the mount entirely the poison can be put in the adhesive material. If the specimen is to be mounted with slips (adhesive music paper) only, then some loose moth preventant should be used, as camphor, naphthalene (loose or in the Mikado pad form).

It seems to us that the second method is better, because if mite or moth do effect ravages it is less easy to deal with them when the specimen is fastened down entirely to the sheet. And a second reason against adopting this method is that as the specimen gets drier and drier with age bending of the sheet in handling may cause the specimen to crack. A third objection lies in the impossibility of remounting. A fourth objection, unless two separate specimens are mounted, showing both sides, is that only one side can be examined and the underneath side is invisible. True, if desired, parts, such as a loose flower, leaf, or other essential organ, can be placed in an envelope and fastened down to the sheet so that both sides can be examined.

Some plants are more liable to attack from insects than others. Such groups as the Buttercup group (on the flower-stalk of Buttercups many eggs are laid), Crucifers, Pink or Stitchwort group, Brambles and Roses (here also eggs of moths or butterflies are often laid), some of the Hemlock group, the Dandelion group especially, Borage group, Deadnettle group, Spurge group, most trees, and many Orchids are especially vulnerable. It must be remembered that plants afford food to insects. Their eggs are laid upon them. They mature in the press and herbarium, grubs develop, eat through stems into which they may burrow, and play havoc with the leaves and flowers. A few poisonous plants are immune, and those with leaves beset with stiff bristles, or too thick for attack, as in some trees—*e.g.*, Holly.

In order to prevent a herbarium from being utterly ruined by insect ravages—as may happen if proper initial precautions have not been taken—it is wise to go through the collection periodically to see if any evidence exists as to their presence. If taken in time this may end in the extermination of the pests, but repeated vigilance is necessary, as fresh plants are inserted from time to time.

Another foe is damp. Dried plants readily absorb moisture if kept in a damp place, so that it is advisable to store them where there is no risk of mould or

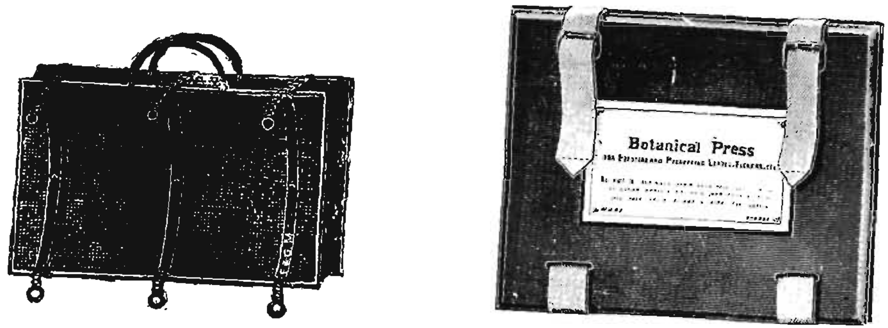

FIG. 9.—BOTANICAL PRESS FOR DRYING INDOORS OR IN THE FIELD.

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mildew. This can be removed by spirits of wine if it is ever discovered, unless the whole tissue of a leaf, for instance, is damaged, when it should be removed entirely to prevent it from spreading, and to remove the disfigurement caused thereby.

When one has reached the stage of mounting the plants collected and dried, usually left till the winter months when collecting is impossible or limited in scope, one has to make certain decisions as to the aims and objects in making the collection and the extent of one's ambition—largely a matter, as regards accessories, of the pocket. However the plants are to be mounted (and stored) some few materials, etc., for preparation are needed. As noted there are two media for fixing the specimen down to the sheet, by adhesive gum or strips. The former may be made by dissolving gum arabic and gum tragacanth, equal parts in water, and a small proportion of corrosive sublimate for poisoning. The bottle should be labelled POISONOUS. If this is used take the specimen, lay it on a sheet of newspaper with the side downwards that is to be shown on the mount. Then with a wide-tipped, fairly soft brush dipped in the solution paste all over the specimen, and, having laid the specimen on a clean newspaper as before, take the mount and lay it over the specimen so that the latter comes just where required. Carefully press the mount down upon the specimen with a duster. Take up newspaper and mount, invert, and peel off the former. Then place the mount with its label between drying-sheets and leave under pressure for a day or two.

It is then ready for fixing down further by aid of adhesive strips and for labelling. Adhesive strips for this purpose, or when used alone (without gumming down), are best made of transparent music binding paper sold in reels and cut up into strips of the desired length 1 to 2 inches long by $\frac{1}{8}$ to $\frac{1}{4}$ inch wide. They should be placed, especially when used alone, at those points that appear to need fastening down most, at the extremities and sides of the specimen. Usually four to six strips will suffice, but some specimens will require more and larger or longer ones. To cut up the strips some fine-pointed scissors are needed, and these serve also to do any necessary final trimming off. For keeping a specimen in position whilst strips are being affixed a few small lead weights laid down upon the more elastic parts of the specimen may be used with advantage.

An important point is the labelling. As to position, the best place is the bottom right-hand corner. The form and size of the label will vary with personal inclination. It is a good plan to have labels uniformly 4 by 3 inches. The extent of the information given is important. Generally one needs the Latin name, the authority, the habitat (wood, etc.), locality, county, the date of collection, and the collector's name. Other useful information may be the soil, altitude, number of vice-county, reference to notebook or published report, and the number in a list—*e.g.*, "London Catalogue," List of Seed Plants, Druce's List. The merits of these are discussed below. If the specimens are numbered in a reference list, the reference number should be given.

If only one small specimen is available this should be placed in the top left-hand corner to allow of further specimens being added. If a single sheet does not suffice for the complete specimen, and more than one sheet is used in the case of a large specimen, the separate sheets should be kept together and bear a cross-reference to each other by, *e.g.*, letters of the alphabet each having also a label, as above.

The size of the sheet used is optional, but it is desirable that it be uniform throughout, as large as store cupboards will allow. Quarto size, so largely used by beginners, is too small. Only scraps of large plants can be mounted on this size. A usual size is 16 by 10 inches or 17 by 11 inches, allowing sheets to be stored in partitions 18 by 12 inches. The quality and texture of the paper is important. Limp cheap paper is not recommended. The best type is cartridge paper of a uniform tint. As the tint varies from time to time as supplied by different firms, or from the same mill when purchased in small quantities at intervals, it is a good plan to obtain a good stock in advance—say, 2,000 sheets, costing, say, £4.

Usually plants are mounted on a single sheet; but some botanists have mounted plants on a double sheet, the second lying above the specimen and serving as a protection to it.

Emphasis should be laid upon the importance of mounting one species only upon a sheet, so that a series of sheets may be arranged on the card system, each sheet being independent of the rest.

This allows for the arrangement of the sheets in systematic order, or by locality, or in any other desired manner—that is, unless they are mounted in a portfolio (Fig. 10), inserted on guards for the purpose in their systematic order.

When the plants have been mounted, unless they are permanently set aside on store papers and are not intended for mounting, it is necessary to consider carefully how they are to be stored. As this, when it involves the making or obtaining of a cabinet, is an expensive matter, it is well to give the matter close attention. Perhaps the best method is to select some form of cabinet best suited to one's needs and means. The material and details are a matter of choice. Good oak or mahogany are durable woods giving a good finish. But an important point is the fitting of the cabinet or cupboard with its shelves, for plants must not be piled in big bundles on top of each other; and the best plan is to have two or more rows of main horizontal divisions and a central vertical partition. As to whether the minor divisions are vertical, two to each vertical partition, giving three divisions between on each side, and two horizontal, giving three horizontal divisions each side, or eighteen divisions of 4 inches in width, or whether these divisions are all horizontal on each side of the central partition, and 4 inches deep—this, again, is a matter of choice.

If the plants are arranged vertically, the sheets should be, if not arranged in covers (see *post*), placed with the left side of the sheet innermost, so that they can be readily referred to, and any particular sheet quickly found. If they are arranged horizontally, they will lie as when placed before one on the table. In either case, if covers are not used—or if, as a matter of fact, they are—the wooden divisions below may bear a label with the name of the genus of plants in the partition immediately above, or, if more than one is represented, the first and last, with the number the first and last species respectively bear in the plant list followed, or only the numbers may be given. The cabinet should be quite dustproof, the doors fitting into a rabbet with a pad of chamois leather, and should be fitted with bolts and a lock.

Supposing it is preferred to have the plants arranged in portfolio fashion bound up like the leaves of a book (Fig. 10) in a volume, it is necessary to take two precautions if this method of storage is to be convenient and effective at the same time. First, the number of plants in each volume should be decided upon beforehand, and a linen guard should be provided for each.

A. Newton.

FIG. 10.—METHOD OF BINDING UP PLANTS IN VOLUMES (LEICESTER MUSEUM).

As a species is mounted it is pasted upon its proper guard, numbered in pencil with the number in the plant list, room being also allowed for varieties, etc. Extra guards for new species can always be inserted, and allowance should be made for such possibilities in apportioning the number to be included in each volume. Secondly, the book (as it really is) should be provided with a case into which it can be inserted, leaving the back exposed. This should be lettered with the orders, genera, first and last specific numbers in the plant list above. Such a precaution makes the book, by means of the case, dustproof. Naphthalene pads or camphor pads should also be used in each partition in the cabinet to make them mothproof.

Another method is to have the plants loose in their covers, and to use a double portfolio. The inner is limp, and tied in front with tapes to act as a handle. This is inserted in, and easily drawn out from, a stouter case with a deep shoulder, upon which a deep back fits. This enables one to keep the plants in loose form in a strong case, the contents of which can be changed as the collection grows, or rearranged as plant lists vary, and allows of insertions. The back is lettered as in the last case. When the limp inner case is drawn out of the outer case and the tapes untied, it is easy to take out a cover with the included species without risk of crushing the sheets, as the limp sides easily give.

Other methods include the placing of so many plants, say a genus, in a portfolio with overlapping flaps, something like a music portfolio, which is tied round with tapes to secure the flaps acting as dustproof covers.

It is important to remember that scraps of plants pasted or fastened in a scrapbook, several on a page, however pretty they may look when well dried, are perfectly useless, and this amateur method should be discouraged. The author has examined many of these collections, to find usually no information is given with each plant, that they are generally arranged promiscuously, pasted or fastened in as they are collected, and frequently the specimens are quite indeterminable owing to their scrappy nature. When names are attempted they are frequently wrong, or merely English names such as Dog Rose for a plant which belongs to a genus with thirty or forty species, and so on; but it is to be admitted that very often such misplaced enthusiasm leads to a better method later on, and such collections may sometimes contain a very rare plant.

Whatever arrangement is adopted in the herbarium, it is usual to collect the species together under each genus. Each genus has a cover of durable, fairly thick brown paper slightly larger than the mounts, so that the former may cover the latter when there is a large number of species. It may happen that more than one cover may be needed, as in the genera *Rubus*, *Rosa*, *Hieracium*, *Potamogeton*, *Carex*, etc. On the bottom left-hand corner of the cover should be given the name of the genus and its number in the series, with the first and last specific numbers. This position is important in the case of plants arranged vertically. When the plants lie horizontally the label and number should, of course, be at the bottom. In the former case it may be as conveniently at the top, especially in the bottom row.

The genera may, when not too large, be placed again in a family or ordinal cover. The genera *Clematis*, *Anemone*, *Adonis*, *Thalictrum*, *Ranunculus*, etc., thus may be placed in a cover labelled Ranunculaceæ.

The cabinets may not include all the plants, and, if so, the outside of the doors may bear a card giving the contents of each so far as the orders go with the first and last specific numbers.

As to the order to be followed, this is, again, to some extent, a matter of choice; but really the fact is that each of the three lists already cited has its special value, and such comparison as is made does not refer to their intrinsic value, but to their suitability for particular purposes. Each differs from the other, and so no real comparison is possible. Moreover, as to the actual nomenclature employed, this is not a work in which it is necessary to go into the pros and cons of any one list in this respect. The lists being primarily useful as a convenient reference list, and for numbering specimens, it is not expedient for the layman to weigh the matter of the superiority, or priority, to use the special term, of one name over another

The "London Catalogue of British Plants," tenth edition, 1908, gives about 2,000 species, including many colonists, casuals, and aliens, that have been found in a wild or semi-wild state in the British Isles. Having attained a tenth edition it is obvious that it is in wider use than the other lists which are younger. We may recommend it here. It is unfortunate that each list contains a different number of species, for this means that the species bear different numbers in each list, and this is awkward.

Mr. Druce's list of British plants includes over 3,000 species, many more aliens, in fact all that have ever been noticed, many being well-known garden plants that have escaped the confines of the garden, and have taken root on other ground. It is a very comprehensive list, and all the plants, whatever their status, that grow in wild habitats, in the plantation, or on rubbish heaps, are included in the list, so that it is very convenient for this purpose, being the only list that shows the position of other plants amongst the generally accepted British plants.*

The list of British seed plants does not include all the British species as understood, and so is incomplete; but this list is useful, as it gives many synonyms.

In the field it is necessary to attempt to identify the species seen if possible, to avoid useless accumulation of duplicates, and to ensure that similar species are discriminated and that those that have not been collected are not overlooked. Some species exhibit a homœomorphic resemblance, and therefore care must be taken to avoid confounding those that are alike or failure in distinguishing similar plants.

Therefore one must be prepared to identify at sight. This habit is only acquired after long experience, and the recognition of plants by certain field characters.

These may not be the specific characters, but certain features that assign a plant at a glance, even from a distance—*e.g.*, the habit of a tree, drooping in the case of the Wych Elm—to a certain species. There is as yet no published work that gives such field characteristics, therefore the details have to be learnt by each botanist for himself by constant acquaintance with plants in the open. Be it remembered, however, that this method applies only to the better-known plants, which cannot admit of mistake. The so-called critical species must be gathered and examined in the hand with the lens, and by aid of a key referred to their species.

But the beginner has to take his time over the identification of even a few common species at first, save the few generally known types, although even

* Mr. Druce is preparing a guide to the alien flora which, as the only British work of the kind, and coming from his pen, will be invaluable for identifying alien species.

these as an exercise in using a key might be treated as unknown, and identified by actual characters, instead of by the general form, habit, or whatever else appeals to the mind.

Some general suggestions on this head may therefore be offered. The British Flora, apart from aliens of rare or recent occurrence, consists of 2,000 species. These are distributed throughout 500 odd genera and some 90 orders. In any classification the first thing to do is to familiarize oneself with the main divisions and the meaning of them. This is best done by attempting to refer a few plants to the main groups.

Flowering plants are Phanerogams, and the possession of a definite flower is the main basis of this grouping to distinguish them from Cryptogams. So a Sunflower is easily distinguished from a Moss. Again, Phanerogams are divided into Gymnosperms, with the ovules or seeds naked, as in the Pine; Angiosperms, with the ovules enclosed in an ovary —*i.e.*, the seed being surrounded by a fruit wall; or several seeds (fertilized ovules) may be enclosed in a fruit—*e.g.*, Poppy. There are other correlated differences. Angiosperms, again, include two classes, Dicotyledons and Monocotyledons. In the former there are two cotyledons, the leaves are generally net-veined, the flowers have five or four or two parts, the wood exhibits bundles in regular rings, as in an Oak. The Monocotyledons have a single cotyledon (usually), parallel-veined leaves, flowers in three or six parts, wood in scattered bundles, as in the Narcissus.

Each of these groups is divided again. The Dicotyledons are divided into Thalamiforæ, Calycifloræ, Corollifloræ, Incompletæ. A Buttercup illustrates the first, a Rose the second, a Harebell the third, and a Dock the fourth. Monocotyledons are similarly divided into several main groups.

Each of the main sub-classes includes a number of orders or families (90 *circa*). Before much progress is made in identifying the species the characters of the orders should be learnt. It is well to choose a few common ones, such as the Buttercup group, Charlock group, Campion group, Violet group, Geranium group, Vetch group, Rose group, Dandelion group, Harebell group, Convolvulus group, Deadnettle group, Oak group, Orchid group, Cuckoo-pint group, Duckweed group, etc.

The main characters of these should be learnt from the book. Some of the types included in it that are well known should be collected, their descriptions framed, and the reason for their inclusion in a particular order well mastered. With the confidence thus gained, learn the characters of the main genera in each order, collect again some known species of the common genera, describe them, and note the reason for the inclusion of several species in a genus.

By this time some skill will be acquired in the appreciation of differences, great or small, in the reference of a known type to its genus or order. Then the reverse process of collecting an unknown plant, and working out its order first and then its genus by the ordinal and generic keys in such floras as Hooker's "Student's Flora," or Bentham and Hooker's "Handbook of the British Flora," may be attempted.

When the order and genus have been determined, then the species remains to be ascertained. This is effected in the same way by means of the analytical key.

It should be emphasized that success is only to be obtained by collecting material in the best condition. The plant should be fresh, complete, typical, and, above all, mature. A good plan is to make a dissection. This applies to the flower, and the number of the parts, their form, arrangement, etc., should be carefully noted. The dissection may be temporary. If desired the parts of the plant may be arranged on a sheet, pasted down, and kept as a permanent dissection, with a diagram of the flower, and its floral formula (see any textbook). In addition, it is a good habit to write out a description of the plant, following the order of development (see also any good textbook).*

It is a fatal mistake—though this is made by many beginners—to rely upon the use of pictures of flowers to try and identify specimens thereby. It may be an easy road to success, or means to an end, but it is not a sure one. If the key method is tedious it is more scientific. The illustrations serve to illustrate the plant, its habit, and to explain the meaning of the characters. They may be used, *with the key*, as an assistance, but should be considered subsidiary to the former.

In addition to the two books already mentioned there are some others that are of first importance. No better manual for the pocket can be recommended than Druce's edition (15th) of Hayward's "Botanist's Pocketbook" (Bell and Sons, 4s. 6d.).

A very good flora which may be used when fair progress has been made is Babington's "Manual of British Botany," ninth edition. This gives a number of the critical species not mentioned in either Hooker's or Bentham and Hooker's works. Druce's book is even more up to date, and as a brief summary more handy, though (intentionally so) less ample in information as to locality, full characters, etc.

* *E.g.*, an elementary work, such as Evans's "Botany for Beginners" (Macmillan).

Babington's and Druce's works give details of the many sub-species, varieties, and forms that are known. It is advisable to leave these until a good knowledge of species has been acquired.

Obviously, the acquirement of a knowledge of the whole British Flora is a long business. Many species are extremely rare, known to occur only in one place. The distinctions between very closely allied species of such genera as *Rubus*, *Hieracium*, etc., are very difficult to appreciate until the plants are seen in the field.

Hardly any British botanist—save, I believe, Mr. Druce—can say that he or she has seen every British plant. Moreover, continental travel is almost essential to the proper understanding of our British species, and the limits of variation of our own and foreign types.

There are some accessory aids to the study of botany in the field (of which we wish mainly to treat) that may appeal individually, and are calculated, as accessory aids, to help the beginner.

A great deal of useful information is to be obtained from photographs of wild plants, either singly in the habitat, or taken indoors, or when associated with others, and showing both the habit and habitat or type of association.

Even a photograph of a large area with but little detail, giving a picture of moorland, will impress upon the mind the type of vegetation of any selected area and the sort of habitat any particular species requires. The taking of the photograph demands skill again (for methods see any good work, and Bedford's "Floral Photography").

It may even be recommended, as has been done in the case of birds and their nests, that the photograph take the place of the specimen, which is left to grow, after it has been studied in the field.

Drawing flowers of plants, or their parts helps greatly to emphasize their characteristic form, colour, structure, and those who are skilled in this art may find that profit is linked with pleasure in the following up of this practice. Certainly there is much satisfaction, if not knowledge, to be gained from a set of drawings from nature, with surroundings if desired, of British plants. But the scarcity of works with such figures seems to show that few avail themselves of this method of studying flowers.

What has just been remarked applies with greater emphasis to the painting of flowers or plants. Not a single British work at present contains really good, and at the same time beautiful, paintings of British plants. Partial studies of the British Flora there are in fair number, but the entire flora yet remains to be illustrated on these lines. It is a desideratum, and here lies an open field for the aspirant to general fame, and better, the general gratitude of British botanists.

Note-making, again, has its profitable side, since field notes upon British plants can with little difficulty afford original information, so little has this method found favour in the past, or so seldom have the results of pursuing it found expression in British botanical works. But neither a hobby nor a serious study is commenced on mercenary lines, and note-making is important, from the beginner's point of view, in order to accumulate facts of interest and value for personal use and enlightenment. A diary is in itself of value, even if it does not contain the results of continuous systematic study. The habit of note-making is valuable. It emphasizes observations made, and trains in the art of recording what is seen. Aside from the diary entry extended notes may be made of special features or a series of observations upon the same plant. (See Chapter V.)

Nowadays there are a large number of museums that exhibit the wild flowers of the neighbourhood in vases, properly named and labelled, usually in systematic order. A visit to one of these by a beginner should be most helpful at an early stage in the work. The study of a few score plants in fresh condition already named, with the aid of a handbook, may act as a great stimulant, and constant visits to such a table will soon help to familiarize the student with the common plants of the district. Thus encouraged, progress with the thornier subjects will not be so long delayed.

In museums also there are usually dried specimens of British plants. These are useful for reference, and can generally be seen on application. In such a collection (Fig. 10) one will usually find any plants that one has not yet come across in one's travels, and this, when studied with the handbook, will help one to know what to expect when later one does discover it.

When one is collecting it is well to know exactly what purpose the collection is to serve, and what it shall comprise. There are various forms of collections, as many as the divisions into which botany can be divided; and each of these will be different in character. For systematic purposes good complete specimens of all the species one can find are required. For ecological purposes all the species of each formation are needed, and they are best kept separate, and not arranged systematically.

Physiological collections will comprise material collected to show the meaning of the functions of organs, and, therefore, they will be arranged under organs or the factors that determine their form or structure.

Similarly, morphological collections (Fig. 10) will comprise series of forms of different organs, types of leaves, flowers, etc.

For general biological purposes one may collect especially climbing plants, insectivorous plants, parasites, epiphytes, and the plants that exhibit special forms of pollination or dispersal may be separately arranged. These are only a few of the many types of collections that are worth forming. So far only, as a whole, systematic collections have been made. There is an open field for the collection of plants on any of the other lines suggested, and many more that could be mentioned did space permit.

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CHAPTER II

THE ECOLOGY OF PLANTS, OR THE STUDY OF PLANTS IN THEIR HABITAT, AND THE REASONS FOR, AND MEANING OF, THEIR DIVERSITY

So far we have considered plants as individuals, the species being the unit, without considering especially the *habitat* of the plant, the manner in which it grows in the field, or its associates, or the reasons for such differences.

It is necessary at this stage to deal with what is known as the ecology of plants—that is to say, to study the *homes of plants*, their mode of occurrence in the field, and the factors of the *environment*.

In discussing briefly the subject-matter of physiology, however, it has been seen that a plant is made up of a number of organs, and each of these organs demands certain factors, which are of a climatic or physical or chemical nature. These factors are provided by the atmosphere, the earth, or water. The plant, in order to fulfil its proper functions, must be in a state of equilibrium with its environment. The requirements of each organ, or the plant as a whole, must be found in the environment. Obviously, as any ordinary experience tells us, the environment is not everywhere uniform. If it were, the forms and habits of plants would exhibit a close similarity, especially in their adaptations to external conditions, in each of the orders that have primarily arisen as a result of organic evolution.

But we know that the external conditions in all climates and countries vary considerably, hence, as the nature of the habitat affects plant distribution, so in any country diversity of plant life will be found. It is, in fact, *difference* of habitat, and the conditions making up the habitat, that cause the variety of plants in such a habitat as a meadow, a wood, a pond, a marsh, etc. Each plant in the course of ages has thus found in a particular type of habitat exactly those conditions that best suit it, and it will be found only in that habitat or a very similar one. Since the habitat varies locally from altitude, aspect, soil, water capacity, etc., many different plants grow in apparently the same type of habitat. The influence of one plant upon another—*e.g.*, of trees upon the plants that grow below them—has also a great effect; hence the *relationship of one plant to another* is equally as important a factor of the environment as the climatic and physical factors. If a species, again, finds its exact requirements in one habitat, and other plants do not, it may become the sole possessor of the habitat—*e.g.*, Ling or Heath—or this possession of the soil may be disputed by several plants, as where Whortleberry and Ling grow together, mainly to the exclusion of other plants. These plants form an *association* (used in a general sense), and such a mode of occurrence is a good illustration of the subject-matter of ecology. It empirically illustrates the bearing of plant life upon its habitat, their close connection.

The variable types of habitat of which the vegetation is made up give us the variable arrangements of plants over all the earth. These variations may be caused by major factors, such as climate, when the study becomes one of plant geography, as whole regions are concerned—*e.g.*, the tropics and its peculiar floras. In any one floral region ecology further helps us to analyze the facts of plant geography on a more detailed basis. Plants that live together under similar conditions form an association, whilst other plants requiring different conditions do not grow there, but form other associations under different conditions. But all the plants that demand certain conditions will not be found to grow in the same type of habitat, as conditions of distribution are often a bar to the occurrence of certain species beyond a certain range. The same type of habitat, however, will yield different members of the association in a different area. And since the same species must, owing to the struggle for existence, oust individuals in order to survive, the association of different species is likely to be more general as a rule, since the different individuals will not exert so strong a pressure upon each other as the individuals of the same species. There will be a better adjustment where the flora is diverse than where it is, as in the case of a heath, uniform.

Not only is the vegetation adapted to its environment, but it is also influenced by the environment, and in adaptation to the external conditions lies the cause for the modifications of the plant that are obviously due to habitat. Thus, meadow plants differ from woodland plants, because all or some of the factors of each are different.

Ecological botany is a section of geographical botany or plant geography, and, as opposed to floristic plant geography, dealing with the flora of an area, ecology deals with the character of the *vegetation as a whole*, and discusses the causes of the distribution and factors of the environment of each of the different units that make up the vegetation. Each one has a definite physiognomy, and it is the variation in physiognomy of a landscape that gives it its characteristic scenery. Such units may consist of wood, meadow, lake, etc., and each of these can be studied from a more special point of view. Each of these gives one a concept of an association of different plants (in a wood, trees, scrub, ground-plants, etc.) which is always associated in the mind in thinking of such a type of habitat, and of the plant association or community which is to be found there. As will be seen, these are general terms, and require strictly to be better defined from a scientific standpoint. Thus there are many types of wood—*e.g.*, Beech, Ash, Oak, etc. The division of areas into such groupings is a division of the vegetation, but a plant association consists of an assemblage of plants characteristic of a particular habitat, and this is the (or an) object for study in the case of ecology. We may properly call this "ecological plant geography." It deals not only with the plant community, but also with the relation of the plants that make it up to the habitat.

Warming says of ecology: "It teaches us how plants or plant-communities adjust their forms and modes of behaviour to actually operating factors, such as the amounts of available water, heat, light, nutriment, and so forth."

"A casual glance shows that species by no means dispose their individuals uniformly over the whole area in which they occur, but group them into communities of very varied physiognomy."

Ecology sets out (1) "To find out which species are commonly associated together upon similar habitats (stations). This easy task merely involves the determination or description of a series of facts. (2) To sketch the physiognomy of the vegetation and the landscape. This is not a difficult operation. (3) To answer the questions—Why each species has its own special habit and habitat? Why the species congregate to form definite communities? Why these have a definite physiognomy? This is a far more difficult matter, and leads us to—(4) To investigate the problems concerning the economy of plants, the demands that they make on their environment, and the means that they employ to utilize the surrounding conditions and to adapt their external and internal structure and general form for that purpose. We thus come to the consideration of the growth-forms of plants."

The growth-forms of a plant community are usually very varied. But some species group themselves into communities with the same combination of growth-forms and the same facies—*e.g.*, a meadow with Grasses. In other cases, where plants do not make the same demands on the habitat, there is an interdependence of one species on another—*e.g.*, Hazel and the parasitic Bird's-Nest Orchid.

Owing to the various factors that influence the life of the plant it is possible to distinguish grades of response to any particular one. If we take water as a variable factor, it may be seen that there are four ecological groups that may be distinguished according to the relative amount of water in the habitat:

(1) Hydrophytes, growing in water, or under very wet conditions, water plants.

(2) Hygrophiles, that demand moist conditions, but do not actually grow in water, marsh plants.

(3) Xerophytes, which live under dry conditions, dry soil or dry atmosphere, heath plants, desert plants, etc.

(4) Mesophytes, plants requiring a medium supply of moisture, meadow and woodland plants.

Water plants are adapted to life in water. The aquatic flowering plants were originally land plants which, having been worsted in the ordinary competition between their congeners on land, have retreated to the water, where competition is less severe. There is always a gravitation between the one and the other type of habitat.

Water plants must have an abundant supply of water. They live in it. Some 30 per cent. of monocotyledonous flowering plants are aquatic, and there are many species which are distributed all over the world. Water plants have to get their light from the water (when submerged), their air, and their food. Though conditions are more uniform, aquatic plants suffer from a low temperature, and do not flower early in the year, but later.

In order to fit themselves for their life in the water, aquatic plants exhibit various adaptations. In the first place, the roots may be entirely wanting or much reduced, and the root serves mainly as a means of anchorage. The walls of the epidermis are thin, for there is no need for them to be thick, and the plant absorbs at all parts, hence it is really an advantage for the epidermis to be thin. It follows from this—viz., since absorption takes place at all points—that there is no need for special tissue for conveying water, and wood is not developed as in a land plant. Similarly there is no need for supporting tissue, since the water supports the plant, and woody tissue is not needed. A further peculiarity of aquatic plants is the large air-spaces they possess. This is to enable the plant to receive oxygen, and to keep the plant buoyant. The leaves of submerged types are finely divided, so that air and light, and so food, may be more readily accessible. Floating-leaf types have dimorphic foliage, the submerged leaves being finely divided, the floating leaves broader.

There are several types of association amongst aquatic plants. There is a plankton of free-swimming microscopic Algæ and other cryptogams, which is to be found in lakes and the sea. In stagnant or slow-flowing waters there are some free-swimming flowering plants, such as Duckweeds. Floating-leaf types live partly on the surface of the water, and are exposed to light, so that compared with submerged types, which are shade plants, they may be called sun plants.

Many types of aquatics are not free-swimming but are rooted in the mud and develop submerged leaves or floating leaves, or they may have both types.

Amongst these are some attached to rocks, such as Marine Algæ—*e.g.*, Laminaria and Sea Wrack. The phanerogam Grass Wrack is rooted in mud. These plants have sucker-like, root-like structures for attachment. The Freshwater Algæ and Mosses are more frequent in swift-flowing streams.

The Marine Algæ are of variable colour, which is an adaptation to surroundings varying with the depth, the red forms lying at greater depths.

Amongst the aquatic plants that grow in loose soil are all types of plants, such as Pondweeds, and these are generally of social habit.

The floating leaves are broad, the submerged leaves have ribbon-growth to adapt them to the current. Of submerged types the main are the dissected type, as in the Water Buttercups; the ribbon type, as in some Pondweeds, the awl-like type, as in other Pondweeds, in Pillwort, Lakeweed, etc. The latter may often, when the water is low, form large meadows with stems of aerial type. Amongst floating-leaf plants the leaves may be rounded as in Frogbit, long and ribbon-like as in some Manna Grasses. Many aquatics have dimorphic or trimorphic foliage, as in Arrowhead, the leaves being ribbon-like, then ovate, then arrow-shaped.

In addition to the submerged-leaf and floating-leaf types of aquatics there is a third or littoral type, where the plants live in water below, but above are aerial, and in this respect combine the characters of aquatic and land plants. In this way the normal aquatic plants have adaptations below the water-level to water, and above they have the characters of aerial plants. Such plants are collectively termed swamp plants. Certain types are specially adapted for aeration by the development of knee-roots, as in the Swamp Cypresses.

In many cases the swamp plants help to bridge over the area between land and water, the boundary between which is always in dispute. Aquatic vegetation may, by their agency or allied causes, become dry land, and *vice versa*. The plants at the margin that are half aerial are best adapted to a transitional state, or are adapted to either condition. They have long rhizomes, and are tufted. They play the same part along the margin of aquatic vegetation that sand binders do along the coast.

Thus, along the margin of all types of aquatic vegetation, there is usually a third type, the reed-swamp, consisting of Reeds, Flags, Sedges, etc. They grow in fairly deep water. But the social habit of these plants causes them to lead a nomadic existence. For the current brings down flood refuse, detritus, etc. This gets caught in the reed swamps, and gradually they silt up, and land is gained. In order to persist the reed-swamp must push out into deeper water. In this manner gradually a piece of aquatic vegetation may become dry land, or first a swamp, with plants only rooted in water, and partly aerial, and finally dry land, or a moist, damp meadow. This last condition becomes suited to mesophytes, as the former, swamp vegetation, may be suited to hygrophiles. Finally, if drained, the soil, which is peaty, may become dry humus, and give the conditions for xerophytes.

In the reed-swamp there is often, relative to the light, a zonal arrangement of plants—the tallest plants on the side farthest from the light, and gradually graded, with the opposite sequence on each bank if the river be oriented north and south.

In habit the reed-swamp types are tall and erect, with the grass habit and terminal inflorescence. The stems are slender and the leaves are ribbon-like, erect, sometimes, as in the Iris, equitant.

Swamps are intermediate between the reed-swamps and meadow and pasture, etc.; they are marshes or fen. There is abundant water, which may or may not reach the surface. The peat formed is black, and the water is alkaline, not acid in reaction. The soil is rich in nitrates, whereas in acid peat, as on moors or heaths, these are wanting, or unavailable to the plant. The plants have a luxuriant growth like shade plants in many cases; others have the habit of plants of the reed-swamp which invade the habitat. Many Sedges and tufted Grasses grow below the swamp plants.

Woodland forms in such habitats, and consists largely of Willows, Alder, etc.

Some hydrophytes are adapted to xerophytic conditions, not because there is a lack of water, but because the water is not available. The water is too highly charged with mineral salts, and in this condition water cannot be absorbed, and osmosis is retarded. The plant is adapted accordingly to dry conditions, so that transpiration may not exceed absorption.

There are associations of freshwater type formed by peat moors or sphagnum moors, which are dominated by the growth of sphagnum or bog Mosses. These Mosses die away below and continue growing till a great thickness of peat, of a brown colour, with evident remains of plants, is formed, of an acid character.

In Ireland these bogs are often moving, and burst or quake. The peat is used as fuel, and dug to a depth of 30 feet or more. Water lies at or near the surface, and the conditions are moist.

The vegetation differs from that of a marsh, where there is black amorphous peat. Sedges and Grasses grow here, and Cotton Grass, also Orchids. Heath plants are typical. Sundew and Butterwort grow here, and are adapted to obtain their nitrogen by aid of their carnivorous habit, as it is not obtained from the soil or soil water in sufficient quantity. The water is at a low temperature, and this, in addition to the acid nature, brings about physiological drought, and evokes the calling forth of xerophytic adaptations, the heath type of leaf, hairy or waxy covering, dwarf or stunted habit, infolded leaf margin, etc. The water is poor in the nutrient substances that contribute to form proteids, but instead contain much humous acid. This helps to retain the peat in its organic form.

The type of woodland developed on peat moors is coniferous—*e.g.*, the Pines, and in some areas the Larch, Juniper, Cypress, Birch. Remains of these are found in peat at great depths.

In maritime associations the mangrove-swamp is a littoral type of vegetation in tropical regions. The Mangrove forms thickets along the coast. The roots are prop-roots adapted to growth in water. Like the reed-swamp, such vegetation tends to conserve the margin or to add to the land area.

Another type of maritime aquatic vegetation is the salt-marsh. Here the water is too rich in mineral salts of the sodium chloride type, and consequently, though the conditions are moist, the plants can absorb with difficulty, and such plants are adapted to physiological drought, with hairy, fleshy leaves and stems, waxy surfaces, reduced foliage, a stunted habit, etc. Many have the grass or heath habit. Some have spines, as Saltwort, which are adaptations to resist drought.

All but the true Hydrophytes above may be regarded as Hygrophiles, or moisture-loving plants, in some respects by requiring a moist atmosphere, such as ferns; but they lose their organs in winter, and in this way are adapted to drought in summer, and in winter are in a resting state. In winter the temperature is low, and there is a likelihood of physiological drought; hence some plants, such as marsh plants, are adapted to resist this condition in winter, and are called Tropophytes—*e.g.*, the Toad Rush, an annual. Thus the xerophytic characters of the marsh plants are adapted to winter cold rather than summer drought. If evergreen, the character of the summer is most useful in winter.

Xerophytes are plants adapted to dry conditions, not necessarily dry soil. There is physical drought and physiological drought. Physical drought may be irregular, or periodical, or continual—in the last case, as in deserts.

Where drought is prevalent the need for water results in reduced absorption and increased transpiration, or this would be the case if the plant had not developed adaptations to avoid this result. The adaptations are, of course, to prevent excessive transpiration, and are characterized by fleshy leaves, reduced surface, linear foliage, stunted habit, hairy or waxy surface, etc., whereby the stomata are protected, or their opening and closing regulated.

Some plants, such as the Rose of Jericho, are able to live in a dried-up state until, being revived again by periodical rain, they can develop their normal functions. In the meantime they appear as if dead, and are shrivelled and dry. The "wind-witches" are blown along on the desert surface until they reach a rainy area or a moist spot, when they revive again, and for the time being develop their normal activity, being, in the meantime, like the African mud-fish, in a resting stage or æstivating condition.

In some cases the whole surface of the plant is reduced, and, until the drought is over, only part of the plant is functional. Annuals die down, and only the seed, which is protected against winter drought (cold), remains to carry on the life of the plant.

Many bulbous plants also die down to the underground parts, and in the same way are adapted to drought after their spring activities, storing up reserves in the tubers, bulbs, etc. These are called Geophytes, as the Snowdrop.

Cold and drought are similar in effect, and deciduous plants, by losing their leaves in winter, are xerophytic. They may also be classed as Tropophytes. Evergreens have the xerophytic habit developed in summer, and use it in winter when cold has to be resisted. Evergreens—*e.g.*, Conifers—generally have a reduced leaf surface, so that transpiration may not be excessive.

If drought is temporary plants may adapt themselves accordingly by an improvised means of resisting it. Thus plants generally reduce the area exposed by rolling up their leaves, or turning the margins under to protect the stomata and check too rapid transpiration. Similar effects may be seen in windy periods, the drying effect of prolonged gales having the same result as that of heat.

Leaves are normally fixed in position and at right angles to the source of light, but in some cases these positions may be changed and, as in Grasses, adapted to drought; the leaves may become vertical under drought. *Compass plants can change the position of* their leaves, and the sleep movements of plants may be employed to resist drought or cold. Exposure to intense light means loss of water. Leaves are also reduced in surface area in order to resist the effects of drought, and may be linear, or needle-like, grass-like, heath-like, as in Heaths, with inrolled margins. Cactus plants have reduced their leaf surface to zero, and the stems carry on the function of leaves. In another way leaves are modified to resist drought by developing a hairy surface, which screens the leaves from the sun. The hairs reflect light and the leaf is shaded.

In general habit also the Xerophyte is stunted. Many plants are trailing or creeping, thus exposing only one surface to the light, as Cranberry. Plants that form cushions or rosettes, as Saxifrages, are usually xerophytic, the overlapping leaves being protected by each successive whorl.

A very marked adaptation to dry conditions is the possession of spines or thorns by such plants. The Furze is a common example. Desert plants, such as the Cacti, have them well developed. Some plants develop thorns and spines also for protective purposes, as the Holly.

The epidermis of Xerophytes, as might be expected, is protected by a thick cuticle. In aquatics we have the opposite extreme, where it is very thin. The bark of trees is a waterproof covering to protect them from drought. The palisade tissue, in which water and chloroplasts are found, is thick. They are long and narrow; hence less area is exposed to intense light. The chloroplasts may alter their position in relation to the light, and protect themselves thereby. Xerophytes also possess water reservoirs, or tissue of colourless cells. The leaves are often fleshy, thick, and succulent, as in Stonecrops, Samphire, etc. Cactus stems are very succulent, and in dry regions the stem is globular, and thus serves as a regular reservoir. The difficulty of killing succulent plants shows how successfully they have solved the problem of maintaining an adequate water-supply under dry conditions

There are xerophytic water plants, as there are xerophytic land plants, for the plants in the reed-swamp have their aerial parts much exposed.

Of the xerophytic associations there are many types. A few may be mentioned. Plants that grow in shallow soil or on rocks are Xerophytes. Plants growing in crevices, as many Saxifrages, Cotyledon, etc., are Xerophytes. They have the rosette or cushion habit to adapt themselves thereto.

Plants that grow on sandy soils are also usually Xerophytes. Heaths are commonly developed on sandy soils, and maritime associations are usually developed on them. A strand association, whether on the coast or on a dry lake margin where the soil is sandy, is xerophytic.

Beaches are generally characterized by a scanty flora, and the plants are rosette plants, or trailers, or erect, shrubby, spinous. When large-leaved they are glaucous or coated with a layer of wax or hairs. Many are tufted types.

Dunes are desert associations, and the vegetation is sparse and peculiar. Here spinous types such as Saltwort occur, and fleshy types as the Seaside Bindweed. In mobile dunes the vegetation is made up of sand-binding Grasses such as Lyme Grass, or shrubs such as Creeping Willow, or Seablite, which help to stabilize the dune and to accelerate the formation of fixed dunes, where the vegetation, though more permanent and varied, is equally xerophytic. This in turn gives rise to the sandy vegetation of littoral meadows, which may alternate with salt-marshes on lower ground.

Heaths on sandy soil have a typical vegetation of Heath or Whortleberry, which are dominant, and of a few other sporadic species, where the Heaths are discontinuous, all xerophytic in habit. Mosses and lichens develop where the Heaths leave off. Heaths develop on lowlands, and also on moors, where the peat is dry and drained at higher elevations. Successive zones of heath plants are regulated by altitude, and Bracken usually grows up to 1,000 feet, and is succeeded by Heaths, Heather, Whortleberry, with Birches up to 2,000 feet.

Some parts of the world are characterized by their extensive uniform flatness. In such areas, called plains, the atmosphere is dry, owing to the absence of hills or mountains where water vapour is condensed and rain falls. Instead, little rain is formed, and, though the plain is not necessarily a desert, the conditions are similar, and the plants are largely adapted to dry conditions. Much of this type of country is heathland, or steppe, or dry pasture. Winds contribute to the dryness of the soil. Grasses and scrub are characteristic growth forms. In the shade of the bush grow plants more adapted to woodland conditions. In dry regions in warm latitudes the Cactus is frequent. There is drought in summer, and the winters are cold, so that the vegetation is inactive during these periods. Active growth is most marked in the early part of the year, when the heat is less strong. On such plains there are few or no barriers to dispersal, and amongst the curious modes that are characteristic of dry plains are the Tumbleweeds, which are loosely rooted, and when in seed the whole plant is blown long distances and so widely dispersed. Some of the driest plains in the subtropical and tropical belts are true deserts, and here the Cactus vegetation is especially characteristic, with typical xerophytic adaptations.

Other plants are Yuccas and Agaves, with a tuft of long, lance-shaped leaves and thick, well-protected stems. The spines upon these desert plants and the sword-like foliage render them immune from browsing of animals. Owing to the lack of other vegetation this mode of protection is especially important to the plant.

In deserts in Asia and Africa large areas are devoid of vegetation, and it is mainly in the regions of wadis or oases where a spring of water occurs that plants, such as various Palms, are able to exist. Elsewhere few plants save the "wind-witches" can grow at all. As in other dry plain-like areas, grass and bush types are also represented, but less extensively.

In such regions, where heat is extreme, and moisture deficient in quantity, trees do not develop to form woods or forests. It is in the jungle areas alone that such luxuriant vegetation occurs, and they are not xerophytic associations. In place of forests, scrub or thickets occur, and are often dominated by Leguminosæ, such as Mimosa or Acacia. These have special sensitive adaptations, and are often supplied with an armature of thorns. Such thickets or bush may be almost impenetrable.

In less dry regions (atmospherically), where, however, the soil is rocky or dry, there are areas dominated by forests of Conifers, frequently at some altitude. The trees are adapted to dry conditions, having needle-like leaves and a peculiar habit. The Pines, Spruces, various Firs, Larches, are typical components of this type of vegetation. The shade beneath such trees, largely evergreen, or semi-deciduous, is intense, and few or no plants grow below the tree zone. Some forests consist of one tree type, others are mixed Conifers, or include Conifers and other tree types. There is a supplementary association of various shrubs, such as the Juniper, and of undershrubs, such as Heaths, Whortleberry, etc.

In other regions forests may be made up of deciduous trees, such as the Oak, Eucalyptus, Oleander, etc. In such cases the leaves are broader, but there are adaptations to dry conditions in other ways. In some areas the trees are leafless, as in the case of the Casuarina forests of the East. The tree-like types in Giant Cactus forests are also leafless.

Where there are steppes with fresh water, but much alkaline salt in the soil, as in North America in the Bad Lands, the plant has also to adopt xerophytic characters. In these regions fleshy plants, such as Samphires, are abundant. The ground is waste land, and not exactly desert.

Deserts of a salt or alkaline nature have a soil saturated with alkalies and a poor water-supply, hence the vegetation, as in the Dead Sea area, is xerophytic.

On some parts of the Alps, where snow does not lie, the extreme cold and dry conditions produce a vegetation of a distinctly xerophytic type.

In those regions of the earth where the climate is temperate there is a more or less uniform degree of humidity, and, where the soil contains a fair amount of humus, suited to the growth of Mesophytes. These require an intermediate amount of moisture. There is never, as a rule, too much rain, nor too little, in regions suited to this type of vegetation, which in temperate countries forms the major part of the vegetation. The plant type is characterized by broad leaves, and the foliage is far from uniform, being variously adapted to light conditions and to various functions, such as water-carriage, etc. The vegetation, besides being varied, is more or less luxuriant. The conditions suited to Mesophytes are met by the demands of agriculture, for where land is dry it is often irrigated, and where it is wet it is drained, so that arable land may be regarded as suitable to it as the natural regions where it is untouched or less directly affected by cultivation or other artificial causes.

Taking the open associations, not dominated by trees, large areas are characterized by plants having the grass habit, and by other herbaceous types that are Photophiles, or averse to shade.

In high altitudes, meadows on alpine heights, and in the arctic regions, exhibit a sort of mat vegetation, where the low-growing herbaceous plants form cushions, rosettes, or carpets. In such regions the growing season is short, and the vegetation is exposed to cold. So that the plants are best adapted to growing in this mat-like form, growing rapidly, and adapting themselves to cold. In early spring this vegetation is of a fresh green colour, as in alpine meadows. Growth is rapid. The plants are creeping or have underground rhizomes, and are renascent herbs. They form dense carpets, cushion-like, soft, made up of perennial, largely geophilous types whose underground parts are protected from frost, etc. The rosette habit prevents loss of heat by radiation, which at high altitudes is rapid. The colours of the flowers, which are large, are brilliant, and grasses predominate in moister habitats. The adaptation to alpine conditions of plants that grow normally at lower altitudes has long been recognized.

Meadows generally, natural meadows, contain a large number of different species whose occurrence depends on the edaphic factors or the soil. They are dominated by Grasses, but a large proportion of other plants is to be found. Such meadows are derived from woodlands, and are often to be found along the valleys formed by streams and rivers. Large areas of meadows exist in some parts of the world, as in the prairie regions in North America, where the plants exhibit some xerophytic characters, but where the moisture conditions are rather those of Mesophytes. The prevailing dry winds prevent a development of forest. Some part of the prairie vegetation owes its origin to the type of the soil, and is then successional to swamps; in other cases the prairies are due to the type of climate.

Pastures, compared with meadows, which are more lowland generally, are not so moist. In certain senses the pasture may include the areas termed meadows which are artificial, and mown periodically by man. In this country it is usual to distinguish meadow and pasture as in the one case a field laid to grass, in the other as given over to grazing. But there are natural pastures as well as artificial ones. As a rule, the difference in humidity may distinguish the two. Pastures are based on drier conditions, being often hilly, and formed on shelving ground. The dominant vegetation here again is Grasses. In addition, there are some other herbaceous types, which may be natural or introduced. In general the meadow may be distinguished by the greater prevalence of other herbaceous types, the pasture by its Grasses, A mown pasture also differs from one that is grazed.

Much mesophytic vegetation is of the woodland type, which precedes the meadow or pasture in origin. The thickets of the temperate regions that are suited to Mesophytes are less frequent and not so dense as thickets of Xerophytes. At high altitudes the willows form such thickets. In lowland areas the thickets are made up of various tree types, depending on the soil.

Oak Hazel Woods are common, with a scrub of Hazel and other shrubs.

A characteristic of temperate regions is the development of deciduous forests. The necessity of shedding leaves in winter is due to the cold winter, and a climatic adaptation, the plants being Tropophytes. This is in strong contrast to coniferous types, where the leaf surface is reduced, and though they retain their leaves in winter they do not perform so much work as the deciduous types whose leaves are large, but lost in winter. An absciss layer forms, and the petiole is separated from the leaf base, the joint being protected against cold by the layer formed between. The nutrient material in the leaf is drawn into the stem before the leaf falls, and so there is no loss. The withdrawal of this matter is an explanation of the coloration of leaves in autumn. The yellow tints show the chlorophyll is decomposed, the red colour indicates the presence of anthocyan, by which light rays are converted into heat.

Deciduous trees also protect themselves by the development of scales for the buds. The older parts of the plant are protected by cork.

In each wood is also a shrub layer, and below these the ground flora with Grasses and herbaceous plants, and below Mosses, etc.

Many plants in woods are geophilous, or bulbous, etc., and develop and flower early, so that they have all the necessary conditions of light, warmth, etc., to aid them. When leaves are on the trees light is shut out or diminished, and plant life would then be almost debarred. The leaves may develop before or after the flowers.

Woodlands consist of a single type of tree, as the Oak, or of several, and the wood may be mixed. Woods of upland type have fewer herbaceous plants in the ground flora than lowland forests, where the vegetation may be most varied, and the number of species numerous. In a Beechwood the shade is so great that few shrubs or herbaceous plants will develop.

In the tropics vegetation is rapid in growth. It consists of evergreens or of deciduous trees. In the former case the conditions are moister; in the latter a dry period, or monsoon, intervenes.

The evergreen forests are most luxuriant and occur in the path of the trade winds, laden with moisture, and, where the heat is extreme, promoting quick growth, and the soil is rich. Many plants develop drip-tips owing to the excessive moisture. Tree Ferns, Palms, Bamboos, etc., are typical tree types. There is no leaf-fall, so food is always being manufactured; there is no spring and no autumn, so that summer fulness is the feature. In such conditions the forests form a true jungle, quite impenetrable. Trees grow in tiers, with shrubs below, then Herbs and Mosses. Many plants are climbers, and Epiphytes are frequent, as well as Saprophytes.

The trees grow so densely that the trunks are straight, and foliage terminal and tufted as a rule. Many trees have to develop props or buttresses to support their tall trunks. The leaves are adapted to throw off excessive moisture, and are glossy, hairy, etc.

Deciduous forests are like the last, with climbers or Lianes and Epiphytes, but the trees are like other deciduous types.

Other general ecological groups that have been distinguished are based on the same relation of the plant to water-content of the soil, or the soil characters.

Helophytes are those plants that grow in marshes, and have been described already as part of the Hydrophyte group.

Where the soil is dry from physiological causes, the coldness of the soil, or the saturation of the soil, or water with mineral salts in too great abundance, it has the same effect as physical drought. Plants growing on cold soil are classed as Psychrophytes, and include alpine and arctic plants. These, like the next, have xerophytic adaptations.

Those that grow in soil of sour or acid nature are called Oxylophytes, and include bog plants and moorland types.

When the soil is saline the plants are Halophytes, and occur along the coast or in inland salt regions. These are Xerophytes.

The soil may again be physically dry, and where it is thin or rocky the plants are Lithophytes, a large number being Cryptogams. Many are crevice plants. Where the soil is sand or gravel, many of the plants are dune associations, forming heath, bush, or forest, or grass fields, and are collectively termed Psammophytes.

On waste land in various parts of the world the soil is dry, and a barren type of meadow or grassland occurs. The plants are termed Chersophytes. These again are Xerophytes.

When the climate is dry, as in deserts and steppes, and the vegetation scanty and peculiar, the plants are known as Eremophytes. Savannahs, llanos, patanas, and other types of formation developed on dry soil, in dry climates in tropical and subtropical regions, have a vegetation consisting of plants known as Psilophytes.

Under similar conditions bush and bush-forest in subtropical regions with a winter rainy season, and with summer drought, develop, and the vegetation is of the sclerophyllous type. The plants are dwarfed and are Xerophytes.

When the soil is physically or physiologically dry, and the climate is dry and overrules the soil characters, forests may be developed which are entirely coniferous.

These divisions are based upon the character of the soil, or water-content, or climate. In distinguishing the different communities of plants in any particular region other factors have to be taken into account, and these broad divisions must be divided, certain types predominating in one region, and associated with a definite flora of companion types. These ecological formations are described later. Where the soil remains the same the conditions may vary considerably, so that several formations may occur in close proximity. Some are derived from the others and have gone through definite changes owing to the altered conditions of light, moisture, etc. It is such formations that are dealt with in ecological botany as a basis of description.

Some general factors that regulate the distribution of plants may now be briefly considered. They are climate, altitude, general conditions of plant growth considered on a less comprehensive basis.

In considering the habitat or environment of a plant as a whole there are two main sets of factors. Those that are termed climatic are temperature, rainfall, light.

The characters that have to do with the soil are the edaphic characters. The physical and chemical character of the soil has to be taken into account, and also the nature of the water in the case of aquatic plants. Over and above these factors are others, such as the effect of other plants, animals, and the effect of cultivation, drainage, etc.

As regards climate the temperature has a great effect on vegetation, as seen if one compares the vegetation of the different zones of temperature—arctic, temperate, tropical. This is due to the fact that heat is mainly derived from the sun (the earth's surface is becoming gradually cooler in itself, the earth being a cooling mass), and as the relative position of the earth to the sun is different, so less heat is received, owing to obliquity, at the poles than at the equator—giving us the above zones. Again, in each area the amount of annual heat varies, hence the vegetation differs, as each plant requires a certain amount to develop. The yearly motion of the earth gives us the seasons, and the position of a place on the earth influences the character of the seasons there, just as the daily motion of the earth affects the length of daylight or night, which again affects temperature. At the tropics there is no variation, and only a wet and a dry season, but this difference has the same effect as a cold season, cold and drought reducing absorption, and so growth. Elsewhere, owing to short days and little sun, the season of winter gives a resting-period for plants, and adaptations to meet this.

The different zones of temperature, according to latitude, are similar to the difference in temperature if one ascends a mountain in tropical regions, between the base and the summit. As one ascends temperature falls, so that alpine types may occur in the tropics.

Another factor of climate is rainfall or humidity. Moist regions are not generally so cold as dry regions under the same latitude. Water retains heat, and its temperature is uniform, so that where there are large areas of water the climate is generally equable, save where the temperature is low, and ice forms. But snow, in the same way as water, retains heat.

Just as plants need heat, so they require water, and the climate of a country is influenced by the rainfall.

The rainfall of an area is determined largely by temperature. In tropical regions a much greater rainfall is needed than in a colder region. Rainfall must be uniform, or periods of drought affect vegetation, so that the number of days on which rain falls is important, as is also the period of rainfall, for if in winter it is useless. The amount of rainfall also depends upon the proximity of the sea. Countries on the coast have a more uniform and greater rainfall than inland regions, for the winds bearing rain across the ocean when they reach land tend to precipitate it, and the rainfall diminishes as the interior of continents is reached, unless other factors tend to produce it. The west coast of the British Isles is more humid than the east. But where there are mountains, the moisture in the atmosphere is liable to be precipitated, as the summits of hills are cooler, and the water vapour condenses. Hilly regions have a high rainfall, as in the Lake District and in Scotland generally. The west side is wetter than the east in regions where the prevailing winds are south-west. If hills form plateaux the summits are dry, the moisture being precipitated before it reaches the summit. The direction of the winds has an effect on climate, as noted. In the British Isles, south-west winds or west winds are moisture-laden, north and east winds are dry.

The influence of ocean currents has an effect on rainfall. On the west of the British Isles the Gulf Stream has the effect of causing the western portion of the country to be much more humid, milder, and more equable.

Clouds and fog affect climate by obscuring the sun. So does smoke, and in the north of England the great smoke cloud is very deleterious to vegetation, reducing sunlight.

Rainfall is greatly affected by the extent of forest land. Forests attract and retain moisture, and, if cut down, the rainfall is reduced and the climate becomes much drier, though there is a tendency to under-estimate this effect.

The character of the soil affects the climate in a manner. Dry soils do not retain moisture, but accumulate rain and surface-water at great depths. Clayey areas retain moisture, return it to the atmosphere, and it is returned again as rain. The retention of water in the soil in itself is a great factor in plant life.

In their effect, temperature and humidity are wide-reaching. Regions characterized by the same mean temperature extend over wide areas, whilst the rainfall of a region, as a rule, unless the physical features are very diversified, is more or less uniform.

Climate, however, varies, even in so small an area as the British Isles, to some extent independently of latitude, and the contour of the surface causes us to have in lowland areas wet conditions, and at higher elevations (save where rainfall is heavy) dry conditions. Owing to the temperate character of the climate, this country falls within the zone of deciduous forest. This is made up of woodland which is a physiognomic type of vegetation—*i.e.*, a broad landscape division—but owing to conditions of altitude the Oak flourishes below the Pine and Birch, and in wet areas the woodland (Alder Willow) differs from that on dry soils—*e.g.*, dry Oakwoods. The amount of rainfall determines the extent of woodland very largely, and this again affects rainfall. If the soil is cold, in place of Birch, moorland and bogs with peat and Heaths, and Cotton Grasses, take its place. So water and temperature are very important factors, and in this way climate affects vegetation on a small scale.

Even then in the British Isles climate varies, and we have warmer conditions in the south than in the north. Thus there is a southern or austral type, containing Lusitanian elements, and a northern or Boreal, and arctic alpine vegetation in the north and in the region of the more mountainous areas—Scotland, north and west of England, and Wales. We do not find the arctic or alpine types far south of Liverpool, or to the east. In part the southern plants owe their occurrence, as is thought, to either survival from preglacial times or accidental distribution. It is at any rate significant that they occur in South or South-West England, and South-West and South-East Ireland, in the most southerly areas. There is little real difference in the climate of West and East England except that the west is more humid and equable, the east dry. The western types or Atlantic types differ from the eastern or Germanic types. This may be due also to migration or accidental dispersal. In East Anglia remains of a steppe flora, surviving from late glacial times, occur. Probably the essential differences in the flora of these regions is rather due to soils than to climate, though all the factors determine the distribution of plants rather than any one particular factor. So that the flora of the low-lying areas is fairly uniform, and the most marked difference is due to the increase in altitude, which is seen again largely in the retreat of northern types to hilly regions, on the return of warmer conditions after the Ice Age, a secular force rather than a climatic one.

For the British Isles were at no distant date part of the Continent, and have become separated only since preglacial or midglacial times. Most of the British plants are to be found on the Continent, except some few endemic species. There are a few types in South and South-East England of Icenian type, others in South-West England and Ireland of Iberian or Lusitanian type. In Ireland and the Hebrides a few American types occur. The arctic alpine types have been mentioned. For the rest the flora is similar to that of Central Europe.

Such variety as is to be found in the plant-communities is based upon variation in the surface features and in the soil. The older rocks occur on the west and in Scotland. Their distribution coincides with areas of greatest rainfall. The rest of England is lowland and the rocks are more modern, softer, more resistant, giving rise to extensive clay areas.

As has already been said, altitude is an important factor in the distribution of plants. As one ascends temperature decreases. As noted, the older, harder rocks, which have been least denuded, occur on the west in England, in Wales, and in Scotland. Here the altitude is not generally less than 1,000 to 2,000 feet, and rises to just under 4,500 feet at Ben Nevis, with Ben Macdhui, 4,296 feet, in Wales, Snowdon 3,560 feet, and Scaw Fell 3,210 feet, in the Lake District. In Central England the altitude is rarely over 500 feet, there being only a few isolated hills above this and up to 1,500 feet. Altitudes of 2,500 feet or more are mainly confined to Scotland.

In the Pennines a few heights are as much as 2,000 feet, and similar altitudes are reached on Dartmoor.

In Ireland there is a central plain also, nowhere exceeding 500 feet, and the highest altitude is Macgillicuddy's Reeks, 3,714 feet, in South-West Ireland, whilst other hills occur in the north, south, and west.

Rainfall and altitude go together. The areas of greatest rainfall are in areas where the oldest rocks crop out, with lofty hills, as in Scotland, the Lake

District, etc. At Ben Nevis the rainfall is 151 inches per annum, and Scaithwaite in Cumberland has 171 inches, the central plain having the least, or about 25 inches. Between 40 and 60 inches is the average for the high ground in Scotland, Wales, North of England, and some parts of West Ireland, whilst 60 to 80 inches is the normal amount in South-West Ireland, West Scotland, parts of Wales, and North England. The lowest rainfall is at Spurn Head, 19·1 inches.

Related to altitude or the proximity of hills is the prevalence of cloud or mist. These occur where rainfall is heavy, and thus are most general in the above areas of high rainfall. The amount of sunshine, or hours per annum, is greatly reduced by cloud or mist. The British Isles generally has less sunshine than Central Europe.

In general the climate is insular, but is rather oceanic than continental, being influenced, so far as temperature goes, by the Gulf Stream and south-west winds. For this reason places in Cornwall and Kerry are as warm in winter as parts of France, the Riviera, etc.

In the British Isles the effect of the soil upon plant distribution is greater than that of the other factors. The soil is derived from the subsoil, which is in turn derived from the rock below. Some sandy soils have little or no subsoil, and the soil itself is mainly disintegrated sandstone. But where there is some humus, the soil then differs from the subsoil. Soils may be superficial and barely more than an inch or so in thickness, but in other cases they are thick, and may be a foot or more in depth. The origin of the soil in this connection has an effect upon its character, thickness, etc.

There are a large number of different rock formations in this country, a larger number proportional to its size than in any other country.

Irrespective of smaller divisions there are about forty or fifty geological formations, but the soils can be grouped together under half a dozen types. Generally the older, or Palæozoic, rocks, occupy the northern and western areas. They have been much disturbed. To the east of these mainly lie the newer Secondary rocks, and the Tertiary and recent formations, which are softer and less resistant.

There is a main ridge of rocks, the Pennine chain, which is made up of Carboniferous rocks, in the north of England. To the west of it come the older rocks of the Lake District, chiefly Ordovician. In Wales, the rocks along the coast are Cambrian and Ordovician, Carboniferous rocks forming the southern area, and the eastern area is made up of Devonian and Carboniferous rocks.

Some other old rocks form hills away from this main area, as the Wrekin, Stiper Stones, Malvern, Mendip Hills, Charnwood Forest, etc. In the Cambrian, Silurian, and Devonian rocks, besides slates, grits, shales, there are beds of limestone. Other limestone beds occur in the Permian. The main limestone mass is formed by the Carboniferous limestone. This forms a high ridge running north and south more or less, and with it are associated shales, grits, and sandstones of the Millstone Grit and Coal-measures which come above it. The former has an Ashwood type of woodland and limestone pasture, with a low scrub in places.

The sandstones and grit are siliceous, and have a different type of woodland, sessile Oakwood, and siliceous grassland, with Pteris and coarse Grasses. Where peat forms, Whortleberry moors, or Calluna, or Cotton Grass, with Sphagnum, cover wide areas.

Of later Secondary rocks the lowest member of the Trias consists of pebble beds and sands, occupying mainly the central portion of England, and some parts of Devon, and northward coming out on the Durham coast. The woodland is Oak and Birch, and the rest of the vegetation is of the heath type. The Keuper series is sandy below, and sandy Oakwoods occur here, and grass heath. The marls are not everywhere marly, but may be sandy. The woodland is Ash, Oak, or damp Oakwoods, with pasture and meadow.

East of the Trias comes the Lias which is made of limestone, marls, clays, shales (Lower Lias), at the top being more sandy, with beds of sandstone. The lower part of the Middle Lias is loamy or sandy, or shaly. The Middle Lias marlstone, like the Lower Lias extending from Yorkshire to Dorset, consists of sandstone beds, with limestone bands, and some marly beds. The Upper Lias consists of blue clays, shales, with limestone bands. On much of the Lias an Oakwood prevails, and Ashwoods on the limestone areas.

A somewhat broader area of outcrop is formed by the Oolites. These are predominant in the South-West Midlands and East Midlands. They are more calcareous in the south, and more estuarine and sandy northwards. On the limestone areas the wood is Beech or Ash wood, with calcareous pasture. On more sandy beds, Ash, Oak, or Oakwoods with heaths occur. Some of the Oolite series form blue clays, and much of this land is arable or pasture. The Oolites form a marked escarpment from north-east to south-west, running out to the South Coast from the Bristol area in a south-east direction. The Wealden beds are clayey and damp Oakwood develops on them. The Hastings beds are sandy or clayey with Oak and

Birch. On the Tunbridge beds, which are clayey, damp Oakwood occurs.

Above the Oolites come the Cretaceous rocks, of a chalky character as a whole. At the base is the Lower Greensand, which is of a sandstone nature, followed by the Gault, which is clayey and supports damp Oakwood. The chalk is predominant in parts of the south and east of England, with a clay with flints above, which may be loamy, clayey, or sandy, and gives rise to Oakwoods. The bare chalk is covered with Beechwood on the slopes, and chalk scrub and pasture, everywhere a very distinct flora. On some parts of the chalk in the south-west, Ashwoods occur.

The chalk ranges into Yorkshire, and covers large areas of Lincoln and East Anglia, and is found in isolated patches in Ireland, near Belfast.

The Tertiary beds contain at the base the London clay, with sands and clays, in the London area. The Oligocene beds are partly clayey or loamy, with limestone beds. Pliocene beds consist of sand and gravel and clay.

Above these come glacial beds, of boulder clay and sands and gravels, spread over a great part of the country north of the Thames Valley. Some of the beds are non-calcareous, derived mainly from Palæozoic rocks, with included boulders. A large area is covered by the chalky boulder clay, a part of which is sand and gravel (mainly ferruginous). The character of the boulder clay in any area varies much. There are local sandy deposits with the clay above and below it. A deposit in South-West England appears also to be glacial.

The woodland is Ash Oakwood. It is probable that the capping of clay with flint overlying the chalk may be of this age. On it is developed heathland in East Anglia, as in Norfolk.

In the beds of the valleys is a sort of drift which is locally widespread, a sort of brick-earth. As the rivers have cut their beds, they have deposited river gravels at successive levels, and these beds are continuous with the present streams. Overlying these beds are others of alluvium, or sandy silt, often in large, broad valleys of wide extent.

Along the coast, sand-dunes have been formed by blown sand. Elsewhere beaches of shingle have been formed by the drift of shingle along the coast.

There is a considerable depth of peat in some of the lowland valleys, in areas contiguous to rivers, where marshes and fens have developed. This is black and amorphous and alkaline.

At higher altitudes, a brown peat of an acid (sour) nature is formed on hills, resulting in the development of moors and heaths, where the soil is dry, and of bogs where the peat is undrained and wet. Large peat bogs are formed in Scotland and Ireland.

In Scotland the rocks are mainly of older age, Palæozoic, and siliceous, consisting of metamorphic, volcanic, and igneous rocks or schists, tuffs, slates, grits, sandstones, shales of Archæan, Precambrian, Silurian, Ordovician, Devonian, Carboniferous age, in the main. Little limestone is developed, though some bands occur. Later rocks are made up of rocks of Triassic, Liassic, Oolite age, and a small area of Tertiary beds (Mull, etc.).

Overlying these is a mantle of till of glacial drift. This gives rise to moorland and peat. At high altitudes the older rocks support an arctic alpine vegetation. As elsewhere there occur alluvium and river gravels in the British Isles, in river valleys, and maritime deposits along the coast.

The main area in Ireland is made up of Carboniferous limestone, forming a central plain. Hilly ground in the west and north, as well as on the east, is formed of metamorphic and igneous rocks. In the south-west Millstone grit, and in the south, Old Red Sandstone help to form features. Some Silurian and Ordovician rocks occur in the north-east and south-east, with granitic masses intruded into them. Some newer Triassic and Cretaceous rocks occur in Antrim, with basalt beds above. In many parts, the solid rocks are overlaid by boulder clay with eskers, as in Scotland, but more calcareous. Compared with Scotland, where siliceous rocks cover a large area, the Irish rock-formations are predominantly calcareous, and this has a marked effect on the flora. Some peculiar plant formations occur in the south-west and south-east, consisting of southern plants, as noted on p. 66.

The limestone may weather down to a sort of clay, and much detrital sand is developed. Limestone pavements occur in the west, as on the Pennines. Much of this area has been deforested, and is barren, with little tree growth.

Much heathland and moorland is developed on the Old Red Sandstone and granite, as well as on the Carboniferous Limestone. Loamy soils are developed on the Ordovician and Silurian areas, and on mica schist.

A large area over the quartzites, metamorphic rocks, and granite is filled in with acid peat, and the peat is often very thick, 30 feet or more. When dug for fuel or turves it gives rise to poor rush-pastures.

A further discussion of soils and their bearing on vegetation will be given under another section. The foregoing summary shows the wide variety of soils or rocks to be met with in the British Isles, explaining the diversity of the scenery in some areas, its uniform character in others.

In dealing with the general conditions of plant life, we have to consider the part played in the life of the plant by such main factors as air, water, heat, soil, light, wind, etc.

Air is a very important factor. Without it plants cannot obtain carbon dioxide or oxygen to form starch.

The amount of carbon dioxide varies from ·02 to ·04 per cent., whilst that of oxygen is 20 per cent. The amount is more or less constant in all areas. The air varies in the amount of humidity, and so of heat, which affects transpiration.

In water and in the soil the amount of oxygen varies. Some soils contain less air than others. In any case the soil contains less oxygen than the air. Stiff clays and peaty soils are poor in oxygen, and the root-system suffers thereby.

Some plants are mainly, or partly, air-plants, or Aerophytes, such as most Lichens, many Mosses, and amongst those Orchids that are termed Epiphytes food is obtained from the rain or dew. There is a pressure exerted by the atmosphere, which increases with altitude; hence mountain vegetation is affected thereby, and as they transpire freely, the plants are xerophytic and adapted to control their water-supply and loss. If the air-pressure is reduced, the absorption of oxygen and carbon dioxide is conversely affected or reduced, and if it is decreased the rate of absorption increases. Alpine plants would suffer from difficulty of absorption (they transpire too freely), but the light intensity at high altitudes assists the rate of absorption. There is relatively also more carbon dioxide at high than at low altitudes. But the intense light, cold, and exposure produce a dwarf vegetation.

Water is necessary for all plant growth. The amount required varies; hence the different adaptation of different groups of plants to this factor, giving us such divisions as land plants, water plants, Hydrophytes, Xerophytes, Mesophytes (*cf.* p. 44). Some live entirely in water, some are only partly submerged, partly floating, others are amphibious. These may be contrasted with woodland or meadow plants, the latter with desert types. Each type has different adjustments to its water-supply.

The water-supply may vary for the whole year, depending on rainfall. It may vary periodically. In some areas there is a regular wet and dry season. In other cases drought occurs irregularly. The source of water may be rainwater, or dew, or atmospheric moisture. It may be from a subterranean source. In soils there may be a water-level which varies in depth, and this affects the growth of plants. It may lie near the surface as in marshes, or in clay soils, or at a depth on sandy soils. On rocky soils, or where springs issue from the outcrop, rock surfaces may stream with water continuously.

The composition of the water varies, or, rather, the amount of substances in solution may vary, and the character of the solutes may vary. The water may be alkaline or acid. This will depend on situation, or the character of the rocks from which water is derived, or the nature of rock fragments dissolved in water.

In limestone areas the water will be rich in lime salts. Where peat is formed the water will be charged with humous acids.

The rate of flow of water is also important, as this may be stagnant, slow, or quickly flowing, and in each case the vegetation varies.

Water is the source of oxygen and hydrogen, and this affects plant growth, for the water-supply affects aeration. As food from the soil enters by aid of the water-supply, the amount of the latter determines the well-being of a plant. In the case of water plants the depth at which they grow varies, and so does, therefore, the supply of light. Water retains heat, and thus water plants have a more uniform supply. Frozen water has an effect on plants, as expansion may cause strain or cracks in the tissues. In aquatic habitats the surface layer is warmer than the lower layers. Water takes longer to heat and longer to cool than the soil.

In water there is more carbon dioxide than in the air. Aquatic plants get theirs from the water, and are adapted to this end. In aquatic plants the water serves to support the plants, and such types do not need mechanical tissue. The uniform characters of aquatic habitats result in the extensive range of many species. Some plants are adapted to live half in water, half in air, or even on land, as the Amphibious Knot Grass. In peaty soils the water is inaccessible to plants, so they are xerophytic.

Large masses of water, oceans, and seas affect climate, making it moister and more uniform and equable. Ocean currents modify temperature, warm currents from the tropics flowing northward, as the Gulf Stream, affecting climate, though its effect has been discounted in recent years.

Soil water may be free, or capillary (adhering to the soil particles and capable of being withdrawn), or hygroscopic, and only moved by heating to 100° C.

In a variety of ways temperature affects plants. It does not vary like the water-supply. Plants can develop and grow between 0° and 53° C. and are not killed within those limits, but above this as a rule they are inactive and die. Plant life is most active between 20° and 30° C.

Plants in hot springs are adapted to higher temperature. Plants may live in a passive condition at lower or higher temperature. In winter, temperature is often below zero, and plants are not affected, because they are dormant, and have adaptations, corky tissue, etc., to resist cold. Much depends, of course, upon the place of growth. Tropical plants require a greater amount of heat continuously than arctic plants, which can live unchecked at very low temperatures. There is a point below which plants cannot exist, or their zero point. Each plant requires a certain amount of heat before it can germinate, open its leaf or flower-buds, or flower and fruit, and this point is called the thermal constant, consisting of the number of degrees of temperature required before each operation is possible.

The annual temperature is an important factor, but so is the distribution of heat, whereby there are zones of temperature according to latitude. The amount of annual temperature is less important than the area of distribution. Even where the temperature is uniform there are various groups of plants that flower and develop at different periods, as in spring or summer, when different thermal constants obtain (see Ch. V.). The temperature of the soil differs from that of the air, and is important, affecting absorption.

High temperature inereases transpiration, so that, if absorption is not adequate, plants so situated are obliged to adapt themselves accordingly.

Moisture retards transpiration, though the temperature may be high. Some plants are adapted to high temperatures and so heat-lovers, which are frigophobes and are adversely affected by cold. Some are able to withstand cold and are frigophiles, as arctic plants.

According to temperature the vegetation of the earth is divided into zones, *e.g.*, the tropical zone, with average annual temperature of 26° to 32° C., where palms flourish. The warm temperate zone has an average annual temperature of 13° to 25° C., and in winter this is maintained at 5° C. Many of the plants are Xerophytes, and deciduous.

The temperate zone includes the tree zone with a few evergreens. The lowest extreme of temperature is reached by the arctic and alpine zone. The arctic plants live under much the same conditions as the alpine. The whole vegetation, being upland, is dwarf, and consists of many rosette or cushion plants, adapted to resist cold. There is an absence of trees.

Not only is the chemical character of the soil an important factor, but the physical character also largely determines the water-content. On the size and the number of the particles, and their arrangement depends the water-supply; a soil may readily absorb water but not retain it. The chemical character of the soil determines the nature of the nutrient solution it affords.

As regards the chemical character of the soil, it may be rock, with little or no soil. This affects the water capacity, and rock plants are largely Xerophytes. Sand soil readily absorbs water but does not retain it. Limestone and chalk afford a lime soil. Clay and loam receive water and retain it. On many soils the decay of plants and animals yields a humus, and in suitable regions peat forms. Such soils are rich in certain mineral salts, and where wet this may cause the water to be unavailable to the plant, which must adopt xerophytic characters. Salt soil is formed in the coast region and some inland areas. The soil-water here, again, is unavailable. The depth of soil is an important factor. In some areas more than one soil occurs, or the subsoil may be clay, the topsoil sand. This alters the normal water-supply to the latter. The manner in which a soil is covered by vegetation, humus, etc., also determines the water-supply.

When a soil consists of large particles of sand or similar sterile constituents this affects its fertility, which, however, may be modified by the nature of the water-supply, which may contain nutrient salts. In such soils there is calcium, magnesium, and potassium, and with the addition of nitrates and phosphates such a soil will become fertile.

In clay soils there is much potash, magnesia, and phosphoric acid, and the water-content is high. Chalk soils have a high percentage of calcium salts. Peat soils are rich in nitrates, but these are not available to plants, as a rule, since the soil is not properly aerated.

The relative proportion of sand alters a clay soil into a loam, the proportion of clay being in such case from 40 to 70 per cent., whilst if there is only 10 per cent. of clay the soil is sandy. Loam with 70 to 85 per cent. clay is a clayey loam. Marls contain some 20 to 25 per cent. of calcareous matter, and if there is more calcareous matter it is a calcareous marl. Soils with 20 per cent. of humus are humus soils.

Loamy soils are more fertile than clay or sand, especially if there is a certain amount of humus.

Chalk soils are usually dry. Clay soil, though retaining water, becomes very hard when dry, cracks forming. Even when wet the roots with difficulty absorb moisture. Clay soil mixed with sand, lime, or humus is, however, much improved.

Sandy plants occur inland on heaths, etc., and along the coast. Such coastal sand formations are generally saline. Sand soil plants are adapted to drought, and, while capable of growing in other soils, generally become altered by the different conditions of water-supply. Salt soils also demand xerophytic adaptations. The vegetation is dwarf. In salt-marshes the water is unavailable, as the plant absorbs as little as possible, owing to the high proportion of sodium salts in solution.

In the case of humus soils the plant uses the humus as a medium. Some plants live on the decaying matter and are Saprophytes. Mycorhiza serves as root-hairs to supply nutrient matter and the Saprophyte receives its supply of carbon already made. Others are provided with nitrogen in the same manner. These have no green leaves. In the case of peat, the plants that live in bogs and on moors demand water, not food, from the peat.

Soils are produced from the rocks which form the crust of the earth. This is about ten miles in thickness. The interior is denser, and consists of rocks in a different state, the exterior being cooler. The crust is made up of rocks formed either by the cooling of molten masses, and their intrusion through others, causing them to reach the surface, or igneous rocks, such as granite. Many rocks are of volcanic origin. Other rocks are of aqueous origin, laid down under water, and occurring in layers, or strata, being made up (as to-day) of sediment brought down by rivers, accumulated in oceans, lakes, etc. Such rocks consist of clay, sand, etc., compacted into shales, sandstone, etc.

Some of the water-formed rocks, as sandstones, owing to pressure, intense heat, etc., have become much altered, and so are metamorphic, and are then quartzites, whilst muds may become slates.

The rock-forming minerals found in these rocks include quartz, felspar, mica, hornblende, augite, olivine, calcite, gypsum, iron ore, etc. The elements which enter into their composition (as they are compounds) are oxygen, silicon, aluminium, iron, calcium, magnesium, sodium, potassium, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine.

Few occur in a free state. Most are found combined. It is these main elements that furnish the plant with food.

From the rocks thus composing the crust, the surface soil is produced by a variety of processes, which help to break it up, or decompose it and to denude it.

The soils formed are sedentary (formed in their present position) or transported (formed by being transported from elsewhere by water, ice, wind, etc.)

Sedentary soils have the same colour and characters as the underlying rock, but humus helps to darken them. In between the rock and the soil is the subsoil, intermediate between the two and in the process of being formed into soil. The texture differs, as does the colour.

The texture of the rock varies. The constituent particles may be close or distant. They may be cemented together by a cement, or compacted by being crystalline. The process of weathering helps to break down rocks.

The agents of denudation are rainwater, temperature changes, frost, atmospheric changes, earthworms, and plant roots.

Rainwater contains carbon dioxide, and this has the power of dissolving out carbonates, etc. Water also wears down rocks, especially soft rocks. Hill and valley structures are examples of the effect of water on the crust. The valleys are often formed of soft strata, the hills of hard strata. Other effects of water are seen when it freezes in the ground, and expanding causes the breaking-up of rocks. Water in crevices when frozen causes large rock masses to be broken up.

Alternate heat during the day, causing expansion, and cold at night, causing contraction, produce the breaking-up of rocks.

Atmospheric changes affect the soil by the oxidation of the rock, breaking hard rocks up into soft masses. Wind wears away rocks, and carries loose material to a distance. Worms aerate the soil, and bring to the surface during the year a fresh layer from below.

Roots act on the soil, the root-hairs dissolving the soil constituents by means of an acid excretion.

According to the character of their soil requirements we may distinguish clay plants or pelophilous plants, sand plants or arenophilous plants, limestone or chalk plants or calciphilous plants, water plants or hydrophilous plants, peat or humus-loving plants or turfophilous plants, and saline-soil-loving plants or halophilous plants. Rock-loving plants are lithophilous or saxicolous plants.

Light is essential to plant growth. Few, if any, plants grow in the dark, if they are green plants. Fungi can grow in the dark. Ferns may be found in very badly lighted caverns or rock-crevices. But all green plants need light for carbon assimilation. The different light conditions in a wood are a measure of the different requirements of different types of plants. There are three or more layers, a tree zone, a shrub zone, and a third zone of herbaceous plants, with a fourth of cryptogams, mosses, etc.

The shade of woods varies in degree. In some woods, as beech woods, where the light is very poor, there is no shrub zone, and only a few orchids occur in the ground flora. Many of these are saprophytes and are not green plants, as Bird's-nest Orchid.

According to their relative light requirements, plants may be distinguished as sun plants that grow in the open, as meadow plants, heath plants, etc., and shade plants such as woodland plants. In the latter the leaves are broad and the internodes long; in the former the leaves are narrow and the internodes short.

The leaves of trees and other plants are arranged on the stem relative to the securing of the best conditions of light. Sometimes they are arranged in a mosaic, in other cases they are vertical. Climbing plants arrange their leaves so that they are in one plane and the leafstalks form a spiral. Trailing plants have the leaves all in one plane, and alternate, spreading them out so that each leaf is exposed, so that there is no overlapping. Plants exposed to intense light, as on mountains, arrange their leaves to prevent too rapid transpiration, and are otherwise adapted to prevent this.

Water plants get their light indirectly, in the case of submerged plants, from the water, which causes the rays to be deflected at the surface, and the light is thus diffused and weak. Many plants endeavour to put forth floating leaves so that they may compete as favourably as land plants in their endeavour to assimilate. The zonation of water plants at different depths may be compared with that of woodland plants in different tiers.

Cloud and mist on mountains affect the light intensity. The angle at which light rays reach the earth varies with the seasons and with latitude. The length of the day also affects the amount of available light. A summer day is longest in the temperate regions, and in the arctic regions there are long periods of darkness, but the light is continuous in the summer. Too intense light affects growth, and alpine plants are often dwarf in consequence.

Wind is a factor which influences the growth of plants. In this way plants choose a particular aspect where this is possible. In the garden this fact is familiar. Plants growing on the north side of a house or wall do not bloom so soon, or so soon go out of bloom, as plants on a south wall, and so on. This applies to light and sun requirements as well as to the prevalent wind.

Wind is most marked in exposed situations. Plants that grow on hills are much exposed to wind force.

They are frequently, in the case of trees, dwarf, and the growth may lend itself to the direction of the wind, growing in the opposite direction—to the north-east in the case of a south-west wind. The vegetation on a hill differs on the south-west and the north-east sides owing to the effect of the prevailing winds.

The region of the coast is generally devoid of trees on account of the intensity of the wind force. There are land breezes and sea breezes. In high gales saline solutions may be present in a misty atmosphere, and affect the growth of plants. Trees, if able to exist along the coast, are dwarf, and usually grow landward.

Hedgerows are the retreat of former woodland plants in areas where the woods have disappeared. Intermediate conditions are afforded by the banks, and the ditch itself again affords shade conditions for land plants when dry, for aquatic plants when water lies in it.

The foregoing factors are such as operate naturally. There are some other causes of an artificial character that are responsible for some changes in the character of the flora.

The initial stage of a large proportion of the vegetation of the country is woodland, and at one time a large (or major) area was woodland. Much of this has, however, disappeared owing to tree-felling. Large areas of forest were destroyed in the Conqueror's time. In Alfred's day wood was required for the building of ships, and prior to this, as well as subsequently, wood was extensively used for fuel, for building, and other purposes. It was not, however, till corn was grown on a large scale, and land brought under cultivation, that large areas were cleared. In Domesday Book we have an estimate of the acreage under the plough, revealing a good deal of clearing of woodland and reclamation of waste. This area is insignificant compared with the acreage now given over to arable land. The amount has decreased, owing to the large increase in imported grain, and there is much grassland now that was once arable. Land showing ridge and furrow denotes land under the plough in early Saxon or Norman times. The increase in wooden ships may have contributed towards the cutting down of woods in Elizabeth's day. The replacement of wooden ships since Nelson's time has lessened the demand for timber on this head. Much of the timber used to-day is foreign timber. Forestry until recently was in a backward condition, trees being felled and not replaced by young trees. Afforestation is, however, again being encouraged.

The great effect of tree-felling, apart from the alteration of the vegetation, is in the manner in which the atmosphere becomes much drier. This is deleterious to the fertility of the soil.

By a natural process woodland becomes scrub, and scrub may become pasture or meadow, or, where conditions are wet, marsh, or if peaty, moorland. But the artificial felling of woods is a sudden and more rapid process, and rainfall is at once affected. In any area a comparison between former and present extent of woodland is an interesting object of research. The planting of trees on areas not previously woodland conversely upsets the character of vegetation.

Next to tree-felling, drainage, which follows the cutting down of trees for cultivation of land, has a great effect upon natural vegetation. As a result of drainage a wet area is transformed into wet meadow or pasture, or even dry meadow or pasture. Drainage is of course natural, owing to slope; but artificial drainage interferes with natural conditions, though natural slopes may be utilized to attain the desired end.

That drainage has altered the face of the country is clear from the disappearance of former bogs, marshes, moorlands, and other moist habitats. The fens of East Anglia, now reduced to a very small acreage, were formerly very extensive. But to-day they form fertile arable land or pasture, and the peculiar plants and animals that were found there have gone.

Allied to drainage are the kindred processes of irrigation or systematic watering of dry lands, and the forming of reservoirs for water-supply or for the feeding of canals, etc., and the construction of the latter. So that where we have lost some bog plants and aquatic plants by drainage, we have conserved or introduced them in other areas by these latter operations.

As soon as an area has been drained it becomes suitable for cultivation. Where this is possible, indeed, it has always been done. By the process of cultivation land that has been drained may be converted into pasture or meadow. In the former case, animals browse and regularly prevent the growth of certain plants. Plants not palatable to animals are left, and so survive. The grasses are encouraged artificially as a stable fodder, the thistles, nettles, etc., are discouraged and eradicated, or left only where they can manage to continue a hazardous existence. In the case of pasture the type of animal browsing affects the character of the vegetation.

Formation of meadow produces a similar radical change upon the nature of vegetation to that of pasture. Generally meadow and pasture are interchangeable, for the latter may be treated as meadow. But there is a type of grassland that one may call meadow from its situation, whether pasture or not, which is usually moist and lowland. Pastures, again, may be treated in the same way, and such grassland is usually upland, and has a different flora from a natural meadow.

In meadows the plants grow to perfection till mown. In this way all the components have an equal chance of survival, whereas in a pasture this is not so. Dispersal of fruit or seed from meadows is indeed normal, whereas in a pasture this is not the case.

Apart from the actual formation of grassland which is not natural, but artificially produced, the various operations of cultivation have a marked effect upon vegetation. Thus, ploughing introduces the possibility of arable land. In this case the entire natural vegetation is replaced by cultivated cereals, which are artificially improved grasses; and the introduction with these of a number of plants that are not native to the soil, called colonists, such as poppies, or aliens, such as hemp. These sow seed and persist and spread from one area to another, so that the flora is being continually augmented by a yearly crop of fresh aliens, and the colonization of plants that demand open soil conditions such as arable.

Owing to the rotation of crops, however, this cornfield flora is always changing, the weeds of the corn differing from those of a root crop, or of tares or clover, etc. Thus, man's entrance into the field introduces many complications, and if it adds to the interest of the flora by the introduction of new plants it brings in a state of instability wholly foreign to natural conditions of plant life.

Along with cultivation, where fences are formed, and especially since the enclosure at the beginning of the nineteenth century, much artificial planting of trees has taken place, apart from such semi-natural areas as park, etc. Along the hedgerow in fields the trees are largely planted ones. The very hedgerows are artificial, being the result of planting. The hedgerow to-day affords a retreat for shade plants, and those others that suffer from browsing. Hedgerows act as barriers to dispersal, or as a means of dispersal by birds which follow the hedgerow in wandering about.

The enclosure of land causes browsing to be more intense, and the effect on meadow and pasture more marked, owing to restriction of range. No spot in a pasture is left unbrowsed, untrodden, untouched.

The introduction of trees and hedgerow plants may also help to introduce other plants that grew naturally elsewhere where the trees or shrubs originated, brought in the soil or roots—*e.g.*, ferns or woodland plants.

Roads are artificial and, again, are lined with hedges and trees. They have special conditions of their own. Even the macadam introduces special features, gritty soil, etc., at the margin. Drainage of the road causes aquatic vegetation to develop in the ditches (which applies also to fields). A roadside is frequently little browsed, often treated as laid grass, and a greater variety of plants may be found on some roadsides than in meadows.

Some subsidiary artificial causes affect vegetation in addition to the foregoing major ones, of which a few only need be mentioned. Thus, industrial factors introduce the effect of smoke, which is very deleterious to most plants. The smoke and fogs of London which operate on a large scale form an empiric example of their effect, for it is well known that save on the outskirts—and chiefly there to the south-west or north-west—plants are poorly developed, especially trees. Parks are exceptions, and though here and there there are areas in the heart of London where a truly astonishing number of plants may spring up on waste ground, they are mainly ephemeral, or plants accustomed to live in impure atmosphere. The effect of smoke elsewhere is seen in large manufacturing regions—Lancashire, Yorkshire, the North of England generally—where a great smoke-cloud obscures the sun and vitiates the atmosphere; and in the neighbourhood of coalfields, where, to the north-east especially, vegetation is stunted, poor, and devoid of variety.

As a special factor in certain areas, such as the coast, heaths, etc., golf, by the formation of artificial links, is responsible for the decrease in area of natural vegetation of an interesting and rather restricted character. Sand-dunes or sandy wastes, and heaths or moorland, are especially selected for this purpose. The area is mown till a soft, springy turf forms, and all the natural vegetation on the lawns or holes disappears, whilst the rest of the golf-course undergoes modification.

Building operations, in like manner, though not in the same way, may, by a fortuitous chain of circumstances, result in the eradication or destruction of a habitat for rare or uncommon plants, or lead to the alteration of the vegetation on a wider basis, as the town or city extends. This result is inevitable, but none the less needs to be considered. The Mousetail once grew near St. Pancras, but who would look for it there now?

In heath-like regions, hills, the burning of furze may disturb natural conditions. When the furze is burnt down, plants new to the district spring up. Some plants in the same way may disappear. The same applies to the cutting of bracken in other areas.

Peat-cutting has a still more marked effect. All the bog plants go when the peat is cut down to its full depth. In their place spring up plants that grow in wet meadows or rush societies, or corn may be cultivated in their place. In Ireland this has gone on on a large scale.

as the British Isles could not be studied upon the basis of climate. They all come into the north temperate region, and this is the broad region of deciduous forest trees. But though this broad basis of classification serves to distinguish the floras of this zone from the tropics or subtropical regions, where palms, bamboos, etc., are characteristic, it is not even so definite a summary of vegetation types as the physiognomic divisions—wood, meadow, etc. These, again, are only features of a landscape: they do not define the nature of the vegetation minutely enough. We have not yet got down to the habitat, but are studying plants from a panoramic view-point. It is the purpose of ecology to more accurately define the communities of plants, in popular parlance termed wood, marsh, etc., by ascertaining their constituents, and by studying what conditions cause definite communities to arise and to grow under exactly similar conditions. As the conditions vary, so do the communities or their constituents, the percentage of species, and the frequency of individual plants.

In contrast to systematic botany, where the species is studied, and independent of the habitat, the *motif* of ecology is to study the habitat and the plant community of each habitat as well as to establish the relationship existing between the two.

Not one, but all the factors of the environment have to be considered. It must also be recognized that plant communities are not in every case distinct, but dovetail into each other. One type of formation gives rise to another. One type may become degenerate, or return to an earlier stage.

On a broad basis the physiognomic types of vegetation may be studied as an introduction to a closer analysis of ecological divisions.

These may be defined thus:

Woodland,
Grassland,
Heaths,
Moors,
Bogs,
Marsh,
Fens,
Aquatic vegetation.
Salt-marshes,
Sand-dunes,
Shingle-beaches.

Woodland cannot exist unless there is a definite amount of rain. Also it is restricted to altitudes below 2,000 feet. Mountain regions are clothed with woodland to-day around the slopes. Formerly the summits may have been wooded, as remains of pine and birch occur in moorland peat. Forests are deciduous or evergreen. Most of our forests are deciduous.

Woodlands (Figs. 11-14, *post*) are developed on soil rich in humus, and cannot exist where the soil is sour or acid, where peat forms, but develop into heath or moor. In this country most of the woodland is semi-natural. A large part is coppiced periodically, whereby light is let in and the ground flora thereby affected.

In natural woods the trees are usually few in number. Seedlings of these types are able to develop. In artificial woods or plantations the trees are of numerous types, with a proportion of conifers, obviously planted. Copses are artificial, and may consist of one tree, as the ash, or of several, all being felled at one time.

Distinct from woods and copses are the natural areas of scrub that develop in some parts of the country, on waste ground, wood-borders, hillsides. Often the soil is too shallow for tree growth. Large areas are covered by hazel, hawthorn, blackthorn, etc., or even roses and brambles, with a small proportion of naturally sown trees or saplings.

Grassland, moreover, like woodland, may be natural or artificial. Some parts of the country that have never been woodland have always formed natural grassland, as where the soil is shallow, or on peaty soils, moorlands, heathy tracts. On the chalk, trees do not develop on the summit, and much chalk grassland is natural pasture. Pastures are usually dry tracts, meadows moister, when spoken of apart from agriculture. Salt-marsh pasture or heath pasture is natural. Elsewhere woodlands have given way to grassland, as the trees have been felled or as forest has degenerated. In some cases pasture has followed arable land. As grassland is left to establish itself the natural flora may reassert itself, and artificial influence may become obliterated. Water meadows and lowland valley plains, unless covered originally by alder willow thickets, have in many cases originated naturally.

Natural pasture is largely found on hillsides, on limestone soils or siliceous soils. Sandy soils less frequently are dominated by pasture.

In grassland the dominant types are the grasses. Other herbaceous plants tend to disappear under cultivation, except the fodder plants, such as Black Medic, etc., that are encouraged.

In dry pastures turf is formed, chiefly of dry-soil grasses, together with some other herbaceous plants that are able to contend with the dominant grass type and the dry conditions.

The grasses are preyed upon by such hemiparasites as Red Bartsia, Yellow Rattle, etc. Other plants besides the grasses develop the grass habit, as the Flaxes. A large number, where the soil is more open, are rosette plants, as the Longrooted Cat's Ear and Hawkbits.

Heaths (Figs. 16, 17, *post*) are developed on sandy soil of a generally barren character, exposed to physical drought. Frequently such soils bear a fair proportion of humus in which the heaths are rooted, and where mycorhiza develops and performs the function of root-hairs. Heaths may be original or derived from former woodland. They are characterized by a well-drained soil in all cases. Wet heaths, however, occur, associated with dry heaths or other types of vegetation, and owe their origin to the natural formation of the surface.

In some sense the word "moor" has been applied to all peat-covered areas, low moors being reserved for marsh, whilst high moor is applied to bogs. The relative amount of peat (or humus) determines the question as to whether an area may be regarded as a heath or a moor (or bog or marsh). Heath is formed on shallow peat overlying a porous sandy or gritty soil. Peat or humus cannot develop where bacteria can exist, for these decompose it. Thus, peat is not found on limestone soils. If it does, it implies that there is an intervening layer of sand or clay, as on some parts of the chalk.

Moors, in contrast to heaths, as used in the ordinary sense, are found at high altitude, as a rule, where the peat is thick, and there is not a large percentage of mineral salts in the soil-water. Generally peat is found on the older rocks, where, again, the greatest rainfall is registered, as a rule. Moors are either, again, of upland type and developed on the summits or slopes of hills or mountains sometimes in subalpine or alpine zones, or they may be lowland and formed where a marsh has become less alkaline, and where peat has become thick and the soil-water sour or acid.

This last factor is the most important one in determining the origin of moorland vegetation. The lowland moor is a bog, the upland moor is drier, and more strictly moor.

In some cases the latter may succeed an area of former woodland. Moors and heaths may develop also in succession to each other as peat increases in depth, or becomes denuded or thinner. As in the case of heaths, moors are characterized by plants with xerophytic adaptations, as both are subjected to dry conditions, or physical or physiological drought. The moorland plants are exposed to wind and insolation. Heath plants are less exposed in this respect than moorland plants in respect of wind, but heath plants are equally subjected to intense illumination.

Bogs (Fig. 18, *post*) are really moors, lowland or highland, where the soil is acid (sour) peat, and where the water-level is at or near the surface. Moors in which there are hollows generally have some areas of bog in such parts. Bogs also occur on the former sites of marshes. Since the water of bogs is largely derived from dew and mist, it is less rich in mineral salts than marshes fed by telluric water.

It is in bogs that Bog Mosses or Sphagna grow. The plants are also largely assisted by mycorhiza in obtaining nutriment. The Sundew and Butterwort are carnivorous. There is often a mixture of bog and marsh plants in a bog. The bog may develop from a marsh by the accumulation of peat, and there may be a change from an alkaline to a sour or acid type of water.

Like moorland plants, bog plants are adapted to dry conditions and physiological drought, and are Xerophytes. The humous acids of a bog (or moor) allow all the plant remains that accumulate to be preserved as peat, owing to the absence of oxygen. Heaths, Ling, etc., commonly occur with Cotton-grass, etc.

In contrast to the bog, marshes (Fig. 19, *post*) are developed on thin, black peat, wet, and fed by water containing a relative abundance of mineral salts, lime salts, etc. An entirely different association of plants characterizes it. Marshes develop on the margins of rivers, lakes, etc., where water continuously feeds the soil to within a few inches of the surface (or even above). Sometimes a marsh is formed on the slope of a hillside where two formations crop out, and a spring (rich in mineral salts) issues from their junction. One difference between a marsh and a bog lies in the nature of the peat. It is black and amorphous in a marsh, because it can be easily decomposed by bacteria, though the soil-water and soil are not well aerated. Oxygen is poison to some bacteria.

As a rule, the proportion of humous acids is not so great as in a bog. Hence the soil-water is more available to marsh plants, and though some types have reduced foliage and other xerophytic adaptations, the bulk of the marsh plants have broad leaves and long internodes, the vegetation being luxuriant and shaded in some cases by taller plants, Grasses, etc., Willows. There may, however, be a large proportion of narrow-leaved types, and in some cases some of these may predominate and help to form a particular association—*e.g.*, Spike Rush, various Rushes, Cotton Grass, Sedges, or even Purple Moor-grass.

Marsh differs from fen in the fact that deep peat is developed in the latter, though the water is of the same type, and thus differs from bog or moor where the water is acid or sour.

Fens are formed on thickish peat, and the area known as the Fens is characteristic of this type of vegetation, though some part of the Fens is formed of marshland, or salt-marsh, or true bog, and much is aquatic vegetation. It is the marginal reed-swamp that helps to form the fen, and the existence of Broads, as in Norfolk, or shallow lakes, invaded by reed-swamp, allows deep peat to form. Usually, fen forms on lake borders, or at the margins of rivers, regions liable to silting, or even deepening. Some plants found in bogs grow here, as Purple Moorgrass, Mat Grass, Bog Myrtle, etc. The typical fen consists of fenland and fen carr, the latter a type of woodland. The dominant tree is Alder. Much scrub is formed by Willow, Bog Myrtle, Birch, etc. Where the vegetation is fen simply, the predominant plants are Sedges, Grasses, etc. Prickly Twig Rush is a characteristic sedge type.

Already a fairly full description has been given of aquatic vegetation as a whole. It consists of plant communities that live, more or less, wholly submerged in water. But as water varies in depth, from the margin to the centre or deepest part, so there are adaptations to meet this, and several types of aquatic plants, as the submerged leaf type, floating leaf type, closed reed-swamp, and open reed-swamp (Figs. 20-22, *post*), may be distinguished, the last two in the case of rivers and streams being treated as one. In a lake or Broad there may be either of the latter.

Aquatic vegetation is wholly adapted to its environment, and these adaptations have been mentioned. The different types of aquatic vegetation depend upon the rate of the current or the composition or mineral content of the water. As regards the first it may be stagnant, slow, swift-flowing; as regards the second, poor or rich in mineral salts. These factors affect the distribution of aquatic plants, as soil does in the case of land plants. The marginal or open reed-swamp helps to convert aquatic vegetation into land vegetation, or marsh or fen vegetation.

Altitude, to some extent, affects the area of aquatic vegetation, and, of course, the existence of watersheds and river-systems is essential. Lakes develop in certain areas owing to the damming-up of river-courses or of valleys. Aquatic vegetation is normally lowland, since water accumulates in such areas more readily than at higher levels, where bogs are more prevalent. There are, however, upland streams, often torrential, and these are the habitat of certain alpine types of moisture-loving plants. There are also mountain tarns, or lakes, and these contain a vegetation of a particular type.

Water plants are, when submerged, like woodland plants, shade plants. They get all their nutriment from the water, little or none from the soil; hence the nature of the salts in the water in solution is important, and varies according to the current of the water and the area from which the salts are drawn.

Some water plants may, in case of necessity, fit themselves for life on land, as Water Plantain, Yellow Flag, etc. Having rhizomes, they can spread extensively in the soil-stratum. Such plants are members of the reed-swamp, and are more naturally terrestrial. But others, as Water Buttercups, are amphibious, and, though submerged or floating, may on occasion establish themselves, when the water-level demands it, on soil. Water plants have the stomata on the upper surface of the leaf. A few land plants exhibit this character, as the Lesser Celandine, a Geophyte which has adopted this latter habit on again becoming terrestrial. It is probable that many water plants are derived from land plants, since they are adapted mainly to land conditions, especially in floral structure, being capable of pollination by insects.

Maritime vegetation (Figs. 25, 26, *post*) is distinct from that of other types, for in the case of land plants the soil-water is saturated with sodium chloride, which is inimical to plant growth as a rule, save in small quantity. In the case of aquatic types, maritime vegetation differs again in that the water is not fresh but salt.

Maritime vegetation consists of formations termed salt-marshes, sand-dunes, or shingle-beaches.

Maritime vegetation is typically xerophytic. The soil is sandy or shingly, and physical drought results. The soil-water is saline and physiological drought contributes to produce the same effect. A large part of the shore is made up of sand, and few plants grow exposed to high-water level. In estuaries the soil is muddy. In the case of rocky coasts the soil varies, and everywhere the area is exposed to wind-force; only in a few sheltered bays do trees flourish.

Of aquatic types, the only ones, except Algæ, are Sea Wracks, Horned Pondweed, or Tasseled Pondweed, and in brackish water a type of Water Buttercup.

It is along the coast that one has an opportunity of studying an open association, as opposed to closed formations, such as inland types, where the soil is covered with vegetation and incapable, save in the case of aquatic vegetation, of invasion. In closed formations there has been in the past a series of changes following a normal order of succession, but only the last is seen, unless, at the margin, two phases can be studied in process of change. An open association enables one to study the order of succession, and the character of each phase for this is actually going on at the present time. A large number of maritime plants are annuals, the open soil favouring their chance of survival.

Salt-marshes (Fig. 25, *post*) are usually situated where an estuary has formed at the mouth of a river issuing at the sea margin. The soil may be mud, as it is initially a mud flat. This in time becomes saline, and pasture vegetation or marsh vegetation arises. It is of a particular type, owing to the necessity of adaptation to saline conditions which only salt-marsh types can stand, though usually some inland types invade the salt-marsh, and continue to lead a protracted existence, a few meadow types becoming dominant. The vegetation has a zonal arrangement, since the amount of salt decreases from the sea towards the land. Usually there is a much wetter region on the seaward margin. Samphire generally forms an external zone. This area is exposed to salt water and high tide. Where the tide does not reach so far the sand or mud is silted up and marsh vegetation is developed with other types, which help to stabilize it. Farther inland the salt-marsh consists of Rushes, Sedges, Sea Clubrush, forming a sort of reed-swamp in drains and dykes and on drier land, but still often on the mud-flats grow other plants, Sea Aster, etc. This may form pasture, and be of agricultural value.

On the margin of salt-marshes or on sandy shores a different type of vegetation, or even zones with pasture, zones of coarser Grasses, Sedges, and open soil types, such as Sea Kale, Sea Rocket, Sea Purslane, etc., may develop in clumps. This type is called strand vegetation.

When the sand is blown into mounds by a sea breeze and a liberal supply is forthcoming, it forms dunes. These are moving dunes or fixed dunes. Such a flora is really a desert flora. The seaward dunes are moving, and generally the seaward side is bare. This causes dunes of this type to be known also as white dunes.

It is, however, covered by long-rooted Grasses, Lyme Grass, Marram, etc., on the landward side. These mounds may have originated on a sandy shore by the growth of the coarse Grasses on the fringe of pasture, above the highwater-level.

The white dune grows landward. At first colonized by Marram, or Lyme Grass, gradually other plants occur, and as the dune grows inland it becomes a fixed dune, after it has become stabilized by the growth of such plants as Seablite, etc., for when it has become consolidated the Lyme Grass, etc., disappears. Finally a sort of pasture forms, and the formation is changed from an open formation into a closed formation. Heath may form, or the Creeping Sallow may become dominant.

In hollows in the dune there may be marsh, with freshwater types.

Shingle-beaches (Fig. 26, *post*) are formed at some distance from the shore. The shingle is large with spaces between, and either filled with sand blown from the sea up to the surface or in the interstices. Shingle plants have long rhizomes, which reach down to the soil below, or are rooted in the sand. Zones of different species may be noted at varying distances from the sea. Oraches may form an external zone. Many land plants grow here, as *Rumex crispus*, *Anagallis arvensis*, *Bellis perennis*, etc.

Still differing from this type of vegetation is that of rocky cliffs and shores. They are exposed to surf, and so nourish a flora addicted to saline soil. Samphire, Thrifts, Sea Lavenders, etc., are common. On some cliffs Woad, Sea Cabbage, Cotoneaster, Asparagus, etc., occur.

Such in brief is the character of the different physiognomic types of vegetation. Each of these can be divided up on a more exact basis, or otherwise denominated. These ecological types may be briefly enumerated. The reader can study some of these in his or her own area, and pay visits to various parts of the country in order to study others. It is advisable to obtain a practical knowledge of each type in the field.

G. B. Dixon.

FIG. 11.—OAKWOOD, WITH BLUEBELL ASSOCIATION.

G. B. Dixon.

FIG. 12.—SESSILE OAKS, CHARNWOOD FOREST.

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From an ecological standpoint soil primarily determines the plant formation in the British Isles, or water; and subsidiary causes are light, temperature, rainfall, etc.

Woodland is the initial stage in most cases, except in the case of aquatic and maritime vegetation.

On clay or loam the typical woodland is a damp Oakwood (Fig. 11). It is also found on moist sand and gravel, and on clay-with-flints on the chalk. Usually it is of lowland type, and occurs in valleys and on alluvial plains. A thin layer of humus accumulates.

Other trees on such soils include the Ash, Hornbeam, as in Epping Forest, and the Birch. The Oak is usually the pedunculate type, but some few examples of the Sessile Oak may occur here and there. A few Beech may be present. The Elm, Lime, Horse Chestnut, Sycamore are often planted. In the shrub zone the Hazel is the chief type. Other shrubs are Hawthorn, Sloe, Elder, Maple, Holly, Sallow, Dogwood, Guelder Rose, Rose, and Bramble. In the ground flora occur Bluebell, Wood Anemone, Primrose, Dog's Mercury, Lords-and-Ladies, Lesser Celandine, Greater Stitchwort, Wood Violet, Sanicle, Weasel Snout, Bugle, Ground Ivy (on loamy soils), Selfheal, Red Campion, Millet Grass, Giant Brome Grass, Melic Grass, Sylvan Brome Grass, etc. This type of woodland is found up to altitudes of 600 feet. Bracken occurs in the ground flora.

On sandy soils the Oakwood is upland, or dry Oakwood (Fig. 13) extending from 500 to 1,000 feet. The vegetation is less varied and not so luxuriant except where the wood is more open.

There is less humus than in the damp Oakwood. Heath plants occur in this type of wood. Bracken, Ling, Gorse are often dominant. Above the Oak zone the Birch becomes dominant. With the Sessile Oak

(Fig. 12), more dominant on strictly siliceous or older sandstone soil, the pedunculate Oak occurs. The Ash is rare. The Beech is not uncommon.

There is often a fair proportion of conifers which are usually planted. There is rarely any Hazel, Sallow, Guelder Rose, or Dogwood. The Holly is common and the Rowan.

The ground flora may be dominated by Bluebell, to be followed by Bracken, and this in turn by Soft grass, forming a complementary association. In some areas, where the soil is rocky, Wood Sage, White Climbing Fumitory, and in open spots Sheep's Sorrel, Ling, Whortleberry occur. Brambles may form a continuous ground flora, consisting of numerous species. Roses are not uncommon. In open places the Foxglove occurs, with Golden Rod on rocks, and various Hawkweeds, also Rosebay giving a show of colour.

Grass types include Heath Hair Grasses. Low herbaceous types include Heath Bedstraw, Tormentil. Wood Sorrel and Wood Anemone are frequent. Siliceous soils are characterized by the dominance of Whortleberry, Heath Hair Grass, Ling. Honeysuckle grows as a trailer or climber.

On some heathy soils, where the soil is sandy, coarse, or where dry peat forms, an Oak-Birch-Heath type of woodland or heath (Fig. 14) is developed, or dry heath and commons on Millstone Grit, Coal-measures, etc., and on the more sandy Tertiary beds, in Surrey, East Anglia. The Birch is dominant with Oak, Bracken, and Heath Hair Grass, Ling, Whortleberry. Brambles may become dominant. Mountain Ash, Holly, Alder Buckthorn may form a scrub. White Beam and Juniper, Woodsage, Tormentil, and Heath Bedstraw, Purslane, Rosebay, Foxglove, Centaury occur in the ground flora, with Sedges.

Above an altitude of 1,000 feet, on sandy or siliceous

G. B. Dixon.

FIG. 13.—A DRY OAKWOOD WITH BRACKEN.

G. B. Dixon.

FIG. 14.—OAK AND BIRCH WOOD.

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soils, the Birch becomes dominant and the Oak disappears. Where it is discontinuous it is replaced by Heather or Whortleberry, or moorland in general.

On marly soils or calcareous sandstones, where the proportion of lime salts is not more than 25 per cent., the woodland is Ash-Oakwood, the Ash being as frequent as the Oak. Otherwise the flora resembles in some respects that of the damp Oakwood. The shrubs include Spindle Tree, Wayfaring Tree, and, as a climbing plant, Clematis. Dogwood, Privet, Sloe, Hawthorn, are common. In the ground flora Pencilled Wood Vetch, Nettle-leaved Bellflower, Dog's Mercury, Herb Paris, various Helleborine Orchids, etc., occur.

On limestone soils the wood is dominated by the Ash. Little humus is found on such soils. With the Ash occurs the Wych Elm and the Yew; White Beam, and Spindle occur in the shrub zone. The Hawthorn is an abundant shrub and may form a scrub. In the ground flora the Moschatel, Dog's Mercury, Garlic, Archangel, are common, also Solomon's Seal, Yellow Star-of-Bethlehem. Ploughman's Spikenard, Marjoram, Woolly-headed Thistle, Bee Orchid, Hairy Violet, occur in the ground flora, or in the scrub where the wood is thinner.

On Chalk the woodland is Beech, but, as on Oolite, this may be replaced by Ash. The Beech casts a deep shade, and therefore the shrub zone and ground flora are limited. Often only a carpet of dry leaves is present below the Beech-trees. Where light conditions are better the shrubs include Spindle Tree, Wayfaring Tree, White Beam, Yew, Box, Juniper, Hawthorn, Elder, Buckthorn. In the ground flora occur Green Hellebore, Sanicle, Wood Violet, Dog's Mercury, Enchanter's Nightshade, Orchids, such as Helleborines, Fly Orchid, Bird's-nest Orchid, Bird's-nest. The Spurge Laurel, Butcher's Broom, Deadly Nightshade, are undershrubs.

In some parts there are extensive woods of evergreens, such as on the Chalk, of Box and Yew. Elsewhere the Pine grows on heaths, as in Scotland and East Anglia. The Larch and other conifers are planted to-day and form large woods or forests in the North, and at high altitudes. The Pine is native in Scotland. It casts a deep shade, but several peculiar northern types occur in the ground flora, as the Winter Greens, Linnæa, Small Tway Blade, Coral Root, Chickweed Wintergreen, Bird's-nest.

When woodland is cut down or becomes degenerate grassland is formed, or heath, or moorland. Of grassland, the type found on clay or loam is called neutral grassland, and includes the ordinary meadow plants of the Midlands, such as Buttercups, Cuckoo Flower, Milkwort, Mountain Flax, Meadow Crane's-bill, Red Clover, White Clover, Bird's-foot Trefoil, Meadow Vetchling, Tormentil, Agrimony, Pignut, Lady's Bedstraw, Moon Daisy, Marsh Thistle, Dandelion, Cowslip, Yellow Rattle, Selfheal, Sorrel, Spotted Orchid, Green-veined Orchid, Sedges, and various Grasses, such as Rye Grass, Cock's-foot Grass, Sweet Vernal Grass, etc.

When ground is low-lying or wet, a rush association forms with Rushes, Lesser Spearwort, Marsh Marigold, Cuckoo Flower, Ragged Robin, Bog Stitchwort, Meadowsweet, Marsh Bedstraw, Creeping Jenny, Spotted Orchid, Spike Rush, various Sedges, Manna Grass, Tussock Grass, etc.

On sandy soils the grassland is a grass heath, with or without Heaths. Where the soil is dry the following are characteristic: Whitlow Grass, Wood Violet, Milkwort, Mouse-ear Chickweed, Upright Chickweed, Red Sandwort, Pearlworts, Grassy Stitchwort, Dove's-foot Crane's-bill, Stork's-bill, Gorse, Broom, Slender Trefoil, Yellow Trefoil, Bird's-foot, Brambles, Tormentil, Rue-leaved Saxifrage, Parsley Piert, Heath Bedstraw, Least Cudweed, Heath Ragwort, Smooth Cat's-ear, Carline Thistle, Sheep's-bit Scabious, Harebell, Ling, Dwarf Forget-me-not, Harlequin Weed, Knawel, Buckshorn Plantain, Squill, Early Sedge, Bent Grasses, Sheep's Fescue, Bracken, etc.

On siliceous soils there is a grassland called "siliceous grassland," which is characterized, when dry, by the abundance of Mat Grass, when wet by Purple Moorgrass. The former may have Heath Hair Grass almost subdominant, and locally Bracken, whilst locally abundant types include Dwarf Furze, Heath Rush, Bent Grass, Sheep's Fescue, and other plants, such as Heath Milkwort, Broom, Greater Bird's-foot Trefoil, Tuberous Vetch, Tormentil, Heath Bedstraw, Harebell, Sheep's-bit Scabious, Fine-leaved Heath, Ling, Common Speedwell, Sheep's Sorrel, Crowberry, Sweet Vernal Grass, Sedges, Rushes, Hard Fern, etc.

Where the Purple Moorgrass is dominant, other types include Lesser Spearwort, Marsh Violet, Sundew, Penny Wort, Cross-leaved Heath, Ling, Marsh Dandelion, Crowberry, Spotted Orchid, Rushes, Cotton Grass, Sedges, Heath Hair Grass, Mat Grass, etc.

Where the soil is derived from limestone, and calcareous, the grassland is of an entirely different character (Fig. 15). The dominant grass is Sheep's Fescue. Many herbaceous types occur amongst the short turf formed by this grass and others. Such are Hairy Violet, Lady's Fingers, Horseshoe Vetch, Salad Burnet, Rockrose, Squinancy Wort, Clustered Bellflower, Lamb's-tail Plantain, Fly Orchid, Burnt Orchid, Pyramidal Orchid, Downy Oat Grass, Smooth Oat Grass, Erect Brome Grass, False Brome Grass, etc.

In some areas the range of species is wider. They may include also, Bulbous Crowfoot, Whitlow Grass, Shining Crane's-bill, Milkwort, Great Bird's-foot Trefoil, Rue-leaved Saxifrage, Biting Stonecrop, Hairy St. John's Wort, Crosswort, Pearl Everlasting, Milfoil, Dog Daisy, Knapweed, Hawksbeard, Hairy Hawkbit, Autumnal Hawkbit, Mouse-ear Hawkbit, Cowslip, Autumn Gentian, Marjoram, Wild Thyme, Eyebright, Ribwort Plantain, Green-veined Orchid, Frog Orchid, Field Wood Rush, Early Sedge, False Oat Grass, False Brome Grass, etc.

On the Chalk, the dominant grass is also Sheep's Fescue. Other plants of common occurrence are Pasque Flower, Dyer's Weed, Wild Mignonette, Hairy Violet, Milkwort, Bladder Campion, Nottingham Catch-Fly, Sandwort, Mountain Flax, Black Medick, Hop Trefoil, Lady's Fingers, Bird's-foot Trefoil, Horse-shoe Vetch, Sainfoin, Dropwort, Salad Burnet, Squinancy Wort, Small Scabious, Ploughman's Spikenard, St. James's Wort, Carline Thistle, Musk Thistle, Dwarf Thistle, Greater Knapweed, Bristly Ox Tongue, Autumnal Hawkbit, Dandelion, Clustered Bellflower, Yellow Wort, Autumn Gentian, Field Forget-me-not, Dwarf Forget-me-not, Mullein, Toad-flax, Eyebright, Marjoram, Wood Basil, Basil Thyme, Calamint, Ground Ivy, Selfheal, Wood Sage, Scented Ribgrass, Ribwort Plantain, Lady's Tresses, Pyra-midal Orchid, Spotted Orchid, Man Orchid, Bee Orchid, Musk Orchid, Fragrant Orchid, Field Wood Rush, Glaucous Sedge, Shining Oat Grass, Erect Brome Grass.

On marls and calcareous sandstones, the grassland is somewhat intermediate between that of neutral grassland and limestone pasture. Some areas of marsh may become pasture which resembles inland, that of wetter pasture with a greater proportion

G. B. Dixon.

FIG. 15.—SCRUB AND ROUGH PASTURE OCCUPIED BY RAGWORT.

G. B. Dixon.

FIG. 16.—HEATH DOMINATED BY BRACKEN AND FURZE.

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of marsh types, and near the coast consists of fen pasture with salt-marsh types. Fen pasture or grass fen occurs in the fen formation.

Moorland formations are dominated by such Grasses as Mat Grass and Purple Moorgrass in some places, but the bulk of them are characterized by heath or moorland plants.

At alpine and subalpine altitudes of about 2,000 feet a grassland forms, which is characterized by highland species in the former case, and more lowland types in the latter. The subalpine pasture is characterized by such Grasses as Sweet Vernal Grass, Bent Grass, Sheep's Fescue, Waved Hair Grass, and also Mat Grass, which increases in an upward direction, the others in an opposite direction. Other grass types include Tall Meadow Grass, Heath Grass. Amongst other plants are Mouse-ear Hawkweed, Milfoil, Sheep's Sorrel, Carline Thistle, Field Wood Rush, Devil's-bit Scabious, Harebell, Burnet Saxifrage, Dutch Clover, Yellow Trefoil, Bird's-foot Trefoil, Heath Bedstraw, Lady's Bedstraw, Wild Thyme, Mountain Flax, Milkwort, Gorse, Whortleberry, Ling, etc.

Amongst alpine grass land occur Mat Grass, Viviparous Sheep's Fescue, Alpine Lady's Mantle, Alpine Meadow Grass, Alpine Cinquefoil, Alpine Mouse-ear Chickweed, Mountain Spurrey, Purple Oxytropis, Small Scotch Gentian, etc.

Heath formations (Figs. 16, 17) on dry sandy or even clay soils are largely dominated by heath plants, such as Ling, Heaths, Whortleberry. In addition to these dominant types, there also occur Wood Violet, Heath Milkwort, Pretty St. John's Wort, Mountain Flax, Furze, Dwarf Furze, Broom, Bird's-foot Trefoil, Tormentil, Heath Bedstraw, Saw Wort, Harebell, Common Speedwell, Redrattle, Eyebright, Cow Wheat, Wood Sage, Juniper, Spotted Orchid, Bent Grass, Mat Grass, Bracken, etc.

Such in general is the composition of a dry heath, with a peaty soil overlying sandy soil or moorpan. Sometimes the heath is of a wet type, and the flora is then somewhat different, since the soil is acid, and therefore moorland conditions prevail on a limited scale. We may find here Sundew, Cross-leaved Heath, Dwarf Sallow, Bog Myrtle, and Lesser Jointed Rush, Oval Sedge, Purple Moorgrass, Bog Mosses, etc.

Moorland formations are characterized by a considerable depth (Fig. 18) of peat, with soil-water of a sour or acid type. They may be lowland or upland.

Lowland moors are developed on estuarine or lacustrine silts, and along the borders of river mouths or lakes.

The estuarine moors exhibit a zonal arrangement, showing that they were initiated from marsh or fen, and, following a moor formation, the vegetation passed into the stage of Sphagnum moor.

A typical estuarine moor is characterized by such plants as Hair's-tail Cotton Grass, Deer's Grass, Ling, Cross-leaved Heath, Marsh Andromeda, with Narrow-leaved Cotton Grass, White Beak Sedge, Cranberry, Bog Asphodel, Sundew; in wetter spots with Bog Mosses. When the surface becomes drier, Birch and Pine invade the moor, and a scrub forms, with Rowan, Yew, Alder, Willows. In some parts Purple Moor-grass, Ling, and Whortleberry develop at this later stage.

Along the margin, Alder wood develops with other trees and shrubs—*e.g.* Sessile Oak, Bogbean, Marsh Cinquefoil, Tussock Sedge, Water Violet, etc.

Lacustrine moors are represented by the remains of former vegetation in basins of old lakes, with a succession of lake mud, shell marl, amorphous peat

L. R. J. Horn.

FIG. 17.—A SANDY HEATH, WITH PINES, IN EAST ANGLIA.

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Hypnum peat, with drifted Birchwood peat of Birch in places, mixed brown peat with Cotton Grass, Ling, Bog Moss, and an upper grey spongy Bog Moss peat.

Valley moors and springs show a fourfold series of communities: Alder thicket, reed-swamp, Purple Moorgrass association, Bog Moss moor or moor formation.

In Alder thickets there are several types of Cotton Grass. The reed-swamp is characterized by Reed, Sweet Reed Grass, Reed Mace, Bur Reed, in deeper water, and on the margin Fox Sedge, Bottle Sedge, Panicle Sedge, Bulrush, Marsh Horsetail. Here also grow Bogbean, Marsh St. John's Wort, Marsh Cinquefoil, Marsh Lousewort, Smaller Bladderwort, Pillwort, and marginal to the submerged vegetation grow Ling and Bog Myrtle.

In the Purple Moorgrass association the Purple Moorgrass forms tussocks and is dominant, with Black Bog Rush, and in hollows Ling, Cross-leaved Heath, Tormentil, etc., and Bog Moss in pockets.

The Bog Moss moor is dominated by Bog Mosses, and here also grow Cotton Grass, Many-stalked Club-Rush, Jointed Rush, Butterwort, Bog Orchid, Sundew, Bog Asphodel, White and Brown Beak Rush, with Bladderwort. Where the surface is drier there is a good deal of Ling, and a scrub may be formed by the Birch.

On upland moors there may be a layer of peat from a few inches to as many feet in thickness. Usually it overlies sandy, gritty, or siliceous rocks, and is well drained, rising from 1,000 feet (or lower in the Charnwood Forest area) to 2,000 feet or more.

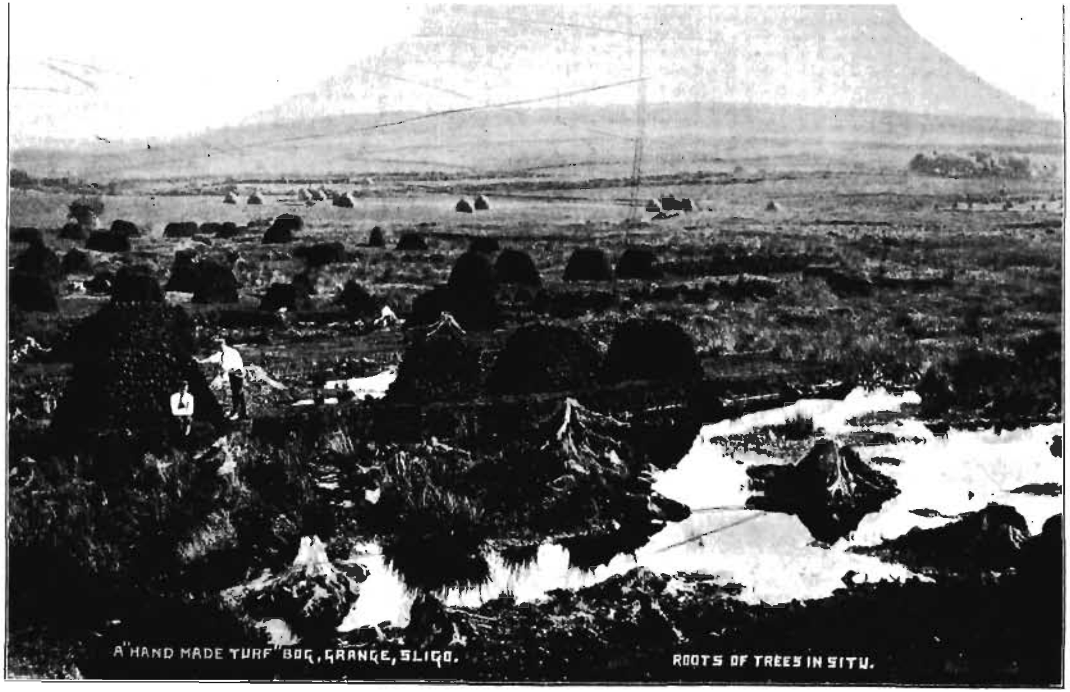
Several associations may be distinguished dominated by different species, and the later stages may be regarded as having passed through an earlier stage. The different formations depend on slope, aspect, soil or soil-water, and relative humidity, one association also giving place to another by invasion, thus forming a succession. Intermediate stages may be recognized.

In the upland moorland there is an initial Bog Moss association or Moss moor, with Cloudberry, Cross-leaved Heath, Cranberry, Cotton Grass, Crowberry, Ling.

Successional to the Moss moor we have Cotton Grass moors, with Hare's-tail Cotton Grass and other species. They are sometimes very extensive, and on slopes of uplands may ascend upward from 1,200 feet. They were formerly more extensive, as is denoted by place-names compounded of the word "moss" where they are not to be found to-day. Peat from 5 to 30 feet deep is developed. Where the soil is drier Mat Grass intervenes. That this type of association was formerly wooded is shown by the remains in the peat of Birch, Sessile Oak, Alder, Willows, Pine, etc. Formerly Arctic Willows grew in such habitats. Other plants that now form the somewhat restricted flora of the Cotton Grass moors are Cloudberry, Whortleberry, Ling, Crowberry, Cross-leaved Heath, Deer's Grass, Bog Asphodel, Marsh Andromeda, Cranberry, Butterwort, etc.

In some parts at about the same level as the Cotton Grass moor, a Deer's Grass association is formed, characterized by the dominance of Deer's Grass, and many of the other plants of the Cotton Grass association, Ling being frequent. Also one finds Sundew and Fine-leaved Heath.

On hill slopes below Heather moorlands, a Bilberry moor association is frequent on some of the uplands where the soil is drier than in the previous associations. It may form a summit flora, reaching an altitude of 3,000 feet. Elsewhere it covers sandstone slopes and scree, and here grow Fine-leaved Heaths, Bearberry,



R. Welch.

FIG. 18.—AN IRISH PEAT BOG, WITH PEAT AND TURVES CUT.

To face p. 112.

and Bracken, with Cowberry locally dominant. Frequently Ling and Whortleberry are equally dominant. This type often follows a Cotton Grass association. Cloudberry is a frequent plant, and also Crowberry and Ling. Other associates are Mat Grass, Waved-hair Grass, Sheep's Fescue, Cotton Grass, Heath Rush, Sheep's Sorrel, and Hare's-tail Cotton Grass.

Heather-moor associations are widespread on upland moorlands in the hilly districts of this country. The peat is dry and shallow on siliceous soils. Such associations may develop at altitudes of 600 to 700 feet, and rise to 2,000 feet. They are developed mainly on the eastern slopes. They were formerly partly woodland, remains of Birch occurring in the peat. The flora includes Ling, Heath Milkwort, Dwarf Furze, Heath Bedstraw, Whortleberry, Cowberry, Fine-leaved Heath, Crowberry, Heath Rush, Bent Grass, Waved-hair Grass, Bracken, etc. In wet hollows a Rush society occurs, where the soil is wet, with Rushes, Bog Stitchwort, Lenormand's Crowfoot, Water Blinks, Marsh Bedstraw, etc.

Bogs are really included in moorland, but are often more lowland in character, differing from marshes in that peat is formed and the water is of an acid nature. Usually they occur on the borders of highland lochs or moorland. Bog Mosses are usually present. In some areas the bog is dominated (Fig. 28) by Rushes, as Common Rush, Lesser Jointed Rush, Jointed Rush, Obtuse-flowered Rush, etc. Where they are discontinuous other plants occur, as Lesser Spearwort, Marsh Cinquefoil, Pennywort, Bog Stitchwort, Bog Pimpernel, Bog Bean, Grass-of-Parnassus, Marsh Orchid, Sundew, Butterwort, Cranberry, Marsh Andromeda, Cross-leaved Heath, Dwarf Willow, Bog Asphodel, Purple Moorgrass.

In contrast to bogs marshes occur mainly in lowland regions in association with aquatic vegetation. The water-level is at or near the surface. Marsh vegetation develops from aquatic vegetation through the reed-swamp (Fig. 19). There is a thin layer of peat; this is black, amorphous, and it is not possible to distinguish the remains of plants in it. The water is alkaline, and contains lime-salts. The texture is close, and though humous acids develop they are not in sufficient quantity to induce xerophytic adaptations in the plant. In this way the vegetation differs from bog or moorland vegetation in being more luxuriant, many types having large or broad leaves. Moreover, there is a typical woodland developed in connection with the marsh formation forming an Alder-Willow association (Fig. 20). The chief tree is the Alder, and with it grow Willows, and the Ash, as well as the Oak. Rarer plants are the Black Poplar and the Grey Poplar. The Osier, Purple Willow, Goat Willow, White Willow, are frequent. Occasionally a Birch may be found. The shrubs include Guelder Rose, Field Maple, Hawthorn, Sloe, Elder.

Amongst other herbaceous types the following are common: Lesser Celandine, Marsh Marigold, Water-cress, Cuckoo Flower, Red Campion, Ragged Robin, Square-stalked St. John's Wort, Golden Saxifrage, Great Hairy Willow Herb, Small-flowered Willow Herb, Water Parsnip, Wild Chervil, Angelica, Marsh Bedstraw, Cleavers, Valerian, Teasel, Marsh Thistle, Creeping Loosestrife, Comfrey, Tufted Scorpion Grass, Scorpion Grass, Bittersweet, Water Betony, Brooklime, Skullcap, Woundwort, Nettle, Hop, Marsh Helleborine, Marsh Orchid, Yellow Flag, Wood Club Rush, Panicled Sedge, Pendulous Sedge, Reed Grass, Tussock Grass, Yorkshire Fog Grass, Flote Grass, Manna Grass, Horsetails, etc.

Fen vegetation is related to marsh vegetation, the

T. R. Goddard.

FIG. 19. (2)—MARSH, WITH DEEPER PEAT, FOLLOWING BOG PHASE.

FIG. 20. (1)—ALDER WILLOW AND REEDSWAMP, DEVELOPING A KIND OF FEN FORMATION AND GRADUALLY GIVING RISE TO MARSHLAND AT THE EXPENSE OF THE AQUATIC VEGETATION.

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ground water in both cases being alkaline, but the peat is thicker than in the case of a marsh. The fens or fenland in East Anglia cover a large area where the conditions are on a larger scale and have been more permanent than in the more generally distributed marshland, which occupies small areas in association likewise with river valleys, but in areas more subjected to desiccation. The fen is a further stage of marsh, with a greater preponderance of plants common to bog or moorland vegetation. Both marsh and fen may give rise to bog or moorland, and originate from aquatic vegetation through the intermediate reed-swamp. Lowland moors are likewise related to fen, if not in some cases identical, though topographically distinct.

Allied to fen associations is the carr association or fenwood, the former usually without woodland, the latter mainly dominated by woodland.

Fen associations are characterized by the dominance of Sedges and Grass types. Trees such as Alder, Birch, Willows, Bog Myrtle may occur. As the surface, which is continually changing, by the invasion of reed-swamp by land, is uneven, the vegetation is varied. Therefore there are several types of fen association. Sometimes the Reed is dominant, sometimes Obtuse-flowered Rush, or Manna Grass, or Reed Grass, or Prickly Twig Rush.

Amongst the typical plants found in the fen association are Marsh Marigold, Ragged Robin, Square-stalked St. John's Wort, Meadow Vetchling, Meadowsweet, Angelica, Water Dropwort, Tormentil, Pennywort, Marsh Bedstraw, Purple Loosestrife, Rough Bedstraw, Marsh Valerian, Great Valerian, Scorpion Grass, Bog Bean, Marsh Helleborine, Marsh Orchid, Obtuse-flowered Rush, Prickly Twig Rush, Purple Moor-grass, Reed, Wood Reed Grass, Sedges, Carnation Sedge, and Bog Mosses. Moor with Ling, etc., may develop upon fen.

As a rule carr or fenwood follows such an association. Bog Myrtle, Dwarf Willow, form a scrub. Carr may be either fen-carr or swamp-carr. The former occurs in the fen association which it succeeds. Swamp-carr occurs on the margin of open water, being a swamp-wood in water, with sometimes shallow peat and sand. The peat becomes drier eventually, and fen and swamp-carr merge.

In swamp-carr Alder, Grey Sallow, Tussock Sedge, Marsh Fern, grow, and in early fen-carr one finds Buckthorn, Alder-leaved Buckthorn, Guelder Rose, Alder, Grey Sallow, Bog Myrtle, Dwarf Sallow, Privet, Black Currant, Ash, Birch, Oak.

The ultimate type of carr developed includes Alder, Grey Sallow, Buckthorn, Alder-leaved Buckthorn, Guelder Rose, Ash, Privet, Oak, Birch, and Marsh Marigold, Meadowsweet, Red Currant, Black Currant, Gooseberry, Nettle, Yellow Flag, Panicled Sedge, Marsh Fern, etc.

Aquatic vegetation is for the most part of freshwater type. Only a limited amount of maritime aquatic vegetation exists. The latter is confined to a few plants, such as Grasswracks, in sea water, and in brackish water to a few Pondweed types, Samphire, Saltwort, etc.

As regards freshwater aquatic vegetation it consists of all plants that grow submerged more or less in water, either rooted in it or floating.

The constancy of such types almost universally is due to the uniform character of the conditions in an aquatic environment. Some plants, such as the Water Buttercups, Duckweeds, and Pondweeds, are found all over the globe.

Possibly the migrations of wild fowl have to do with this general occurrence of common types in no small degree. Nevertheless, the greater factor is no doubt the fact that the power of regeneration or propagation of water plants is very great; and the extensiveness of the habitat ensures that such parts are liable to be distributed by the mere agency of the current, and to establish themselves when sooner or later such fragments come to rest. Even seeds may be distributed from one continent to another, by travelling across the ocean, the adaptations of such seeds to resist the effect of long immersion in sea-water enabling them to germinate when cast up on the shore. Shipping, canal traffic, and a hundred other human agencies, also contribute towards the same end—the internationalization or intercontinentalization, to coin long words, of species.

One feature of aquatic plants is the large proportion of Monocotyledons that are aquatic in habit, amounting to some 30 to 40 per cent.

Very quickly spreading are such plants as the Canadian Waterweed, which was introduced from America into the British Isles in 1839, and has now penetrated to almost every little pond in this country.

Contrasted with terrestrial plants, aquatic associations are open as a rule. The reed-swamp, an intermediate type, may, however, become closed, as it transfers an area to land conditions.

Several different factors determine the nature of aquatic associations, which may be very distinct. These are mainly the aeration of the water, the rate of the current, the proportion and character of the mineral salts in solution, the depth of the water, and the altitude of an environment.

Aquatic plants grow in ditches, pools, streams, rivers, canals, reservoirs, and lakes. Even torrents and waterfalls have their special flora.

Initially we may have a state in which the water, so far as freshness is concerned, is foul, or stagnant. In this condition few or no Phanerogams can exist, and the water is colonized by Blue-green Algæ as a rule. A cow pond in which the water is much polluted may contain no flowering plants save the Lesser Duckweed. Where this little free-floating plant occurs in great abundance indeed scarcely any other species exists, unless it be a Water Buttercup. But at the margin, where aeration is better, other plants may thrive in the reed-swamp.

In each type of association it is possible to distinguish, so far as depth is concerned, a zonal arrangement of aquatic plants. The lower regions are occupied by submerged plants, whilst above come floating-leaf types, and along the margin, or in not very deep water, scattered about or forming small societies, come the plants of the reed-swamp, which are partly aerial.

In some cases a zone may be made up of a single species—*e.g.*, Bulrush or Reed, or below water of Horned Pondweed, or Floating or Water Buttercup. Usually non-vascular plants, such as the Stoneworts, grow at the bottom.

In shallow water one may note the large subterranean colonies formed by the Canadian Waterweed, and others of the Pondweeds or Water Milfoils. Some of these two last may be entirely submerged or partly so, and having in addition some floating leaves. Floating-leaf types are exemplified excellently by the Water Lilies (Fig. 22). Interspersed with the latter may be various types of Water Buttercups, with some submerged and linear, some floating (peltate or fringed) leaves.

In the reed-swamp grow such types as the Reed, Bulrush, Sedges, Manna Grass, etc. (Fig. 21). Such

G. B. Dixon.

FIG. 21.—AQUATIC VEGETATION WITH MARGINAL REEDSWAMP.

G. B. Dixon.

FIG. 22.—REEDSWAMP INVADING AQUATIC VEGETATION.

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is the general character of aquatic vegetation in still water, where there are abundant salts. Amongst other types, Mare's-tail may sometimes become more or less dominant and be either submerged or half-aerial. A similar habit is assumed by the Water Violet. The Starworts are generally submerged, and so is Pillwort.

Some types are free-floating, as the Duckweeds, Hornwort (submerged), and Frogbit (with floating leaves). Amongst other submerged types are Milfoils, Bladderworts (only the flowers being aerial), Water Soldier (sometimes floating), Pondweeds. The *floating-leaf* types include Water Lilies, Amphibious Knot Grass, Arrowhead, Duckweeds, Common, Large, Waved Pondweed, Flote Grass.

In the reed-swamp one finds Reed or other types dominant, Purple Loosestrife, Great Hairy Willow Herb, Water Parsnip, Water Dropwort, Great Yellow Loosestrife, Comfrey, Marsh Woundwort, Great Water Dock, Whorled Dock, Rushes, Reed Mace, Bulrush, Pond Sedge, etc. (Fig. 22).

Where the current is slow, the flora may vary somewhat, as in rivers and streams, and there are not so many marsh plants, save at the margin. Few, or none, are free-floating, but most are submerged types, and a ribbon-growth is a common form of adaptation. Typical of this aquatic association are *Ranunculus circinatus*, Water Dropwort, Canadian Waterweed, Bur Reed, Arrowhead, Pondweeds, Bulrush. In shallower parts Brooklime, Scorpion Grass, Marshwort, Great Hairy Willow Herb, develop. Submerged types, and Starworts also occur. Similar vegetation is seen in canals, where a slow flow is caused by the traffic periodically. In the shallow parts, away from the current, grow Duckweeds and Water Lily.

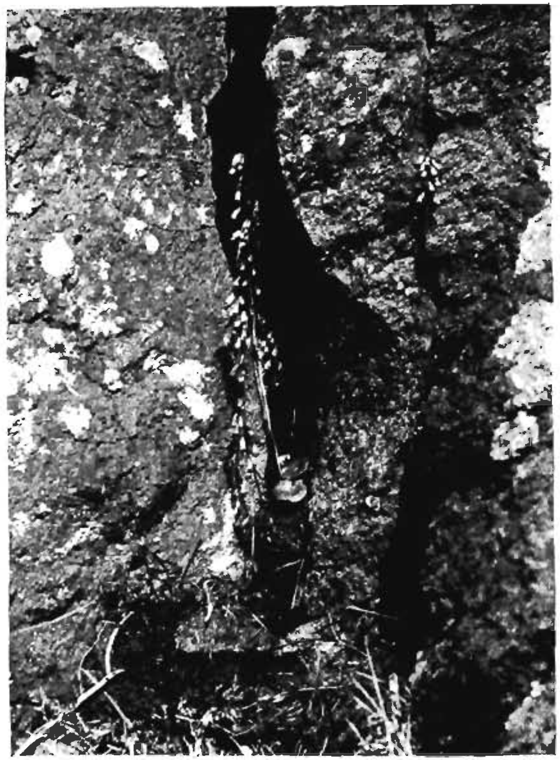
In the reed-swamp grow Rue, Winter Cress, Meadowsweet, Great Hairy Willow Herb, Great Yellow Loosestrife, Scorpion Grass, Brooklime, Reed Mace, Bur Reeds, Yellow Flag, Water Plantain, Fox Sedge, Pond Sedge, Reed Grass, etc.

When the water is poor in mineral salts, in lakes and tarns, in regions where the rocks are hard and siliceous, either in upland or lowland areas, the plants are quite different and include Awlwort, Milfoil, Starwort, Water Lobelia, Bladderwort, Lakeweed, Lesser Jointed Rush, Pondweeds, Spike Rush, Floating Spike Rush, Pillwort, Quillwort, etc., of submerged types. The floating-leaf types include Water Lilies, Procumbent Marshwort, Amphibious Knot Grass, and several Pondweeds. In the reed-swamp grow Bog Bean, Floating Bur Reed, Common Spike Rush, Many-stemmed Spike Rush, Bulrush, Prickly Twig Rush, Sedges, Reed, Floating Manna Grass, Marsh Horse-tail, etc.

In rapid streams, where there are no lime-salts in the waters, and the water is well aerated, Lenormand's Buttercup, Ivy-leaved Water Crowfoot, Floating Manna Grass, Starwort, Water Blinks, Bog Stitch-wort, are found.

In streams that are quickly-flowing, where the water is alkaline in reaction, *Ranunculus fluitans* occurs.

Altitude regulates the occurrence of a certain class of plant formations which may be called arctic-alpine vegetation. Some of this is grassland, some moorland, whilst there are further associations that flourish on shelving rock faces or in their crevices (Figs. 23, 24). This kind of vegetation is restricted to hills of considerable altitude in Scotland, Wales, north of England, and Ireland. Snow lies on some of the summits. In most cases the plants are subjected to great wind force, and are dwarfed. Shelter is afforded alone by ravines and rock fissures.



C. A. Allen.

FIG. 23.—CREVICE PLANTS: NAVELWORT.

G. B. Dixon.

FIG. 24.—ROCK SURFACES AND CHARACTERISTIC VEGETATION.

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Where the ordinary moorland ends, as a rule, or at 2,000 feet, this arctic-alpine vegetation begins. Characteristic plants are Dwarf Campions, Stonecrops, Saxifrages, Willows, etc. The vegetation is the relic of the arctic plants that travelled south in the Ice Age, and ascended hills to live as alpine plants on the return of warmer conditions. Much of the vegetation is, as in true arctic areas, confined to the lower plants forming a zone of Mosses and Lichens.

Trees do not ascend beyond the lower limits of this zone, though they may have existed formerly. Ling decreases, and the Whortleberry becomes more abundant. In the case of grassland, the lowland types associated with the Grasses disappear and northern types take their place. The Grasses themselves differ and viviparous types replace lowland forms. Though altitude plays a part in the distribution of these types of vegetation, it is not the sole factor. Similar types in Ireland are to be found near sea-level.

Owing to the exposed character of the vegetation, typical growth forms occur, such as the Cushion, Mat, Rosette habits.

The vegetation belongs to the group known as Highland, as defined by Watson, and in Scotland as Scottish. Such types include Globe Flower, Rock Pansy, Wood Crane's-bill, Stone Bramble, Linnæa, Lesser Wintergreen, Crowberry, and the small Twayblade.

The Highland type includes such plants as Moss Campion, Saxifrages, Herbaceous Willow, Mountain Wood Rush, Rigid Sedge, and Viviparous Sheep's Fescue. These plants are native of the Northern Palæarctic region, and in South or Central Europe occur on the Alps.

The vegetation as a whole is not varied, though characteristic. It differs on different mountains. The number of species barely amounts to one hundred.

At the base of most of these mountains below the arctic-alpine zone cultivation is possible up to 1,500 feet. Much is pasture which may have been derived from moorland, and originally ploughed up. In place of hedges, as in England, walls serve as boundary fences. Barley and Oat growing are carried on more extensively, as such crops do well in northern latitudes. On such land the ordinary plants of arable soils flourish, and in the pasture the Grasses and other herbaceous types are such as occur in lowland pastures, on sandy or other soils. Few remains of moorland or heath persist. Elsewhere a natural grassland develops, but this is greatly modified by sheep-grazing, as elsewhere. Remains of Ling occur, and the bracken may also be dominant in places. Much depends on the extent of the enclosures.

In some parts, where streams run down, and Rush associations form, the vegetation is somewhat more diversified, with marsh or bog plants, such as Marsh Marigold, Lesser Spearwort, Marsh Violet, Water Blinks, Ragged Robin, Marsh Cinquefoil, Grass-of-Parnassus, Marsh Bedstraw, Butterwort, Bog Asphodel, Arrow Grass, etc. On the dry banks Globe Flower, Wood Crane's-bill, Stone Bramble, Angelica, Northern Bedstraw, Golden Rod, Wild Thyme, Eared Sallow, etc., occur. Still more alpine types may descend by the same means, such as Saxifrages, Tofieldia, Alpine Lady's Mantle, Viviparous Knot Grass, Mountain Sorrel, etc.

Above this zone of cultivation comes one of moorland associations. This may consist of grass moor, heath, or moor dominated by Ling and Whortleberry. They are subalpine and akin to the upland moors as a whole. They develop on the glacial terraces made up of successive sheets of moraine matter left by the ice sheet. The top of the terrace is wet, the slopes dry. On the wet parts Mat Grass, Heath Rush, Deer's Grass, are common, with Waved-hair Grass, Sweet Vernal Grass, Purple Moorgrass, Cotton Grass, forming a Grass moor on wet black peat; whilst on the slopes grow similar types, but bog mosses do not develop. Where peat is thick the vegetation is a Whortleberry-Ling association, with also Cowberry, *Crowberry, Hare's-tail Cotton Grass*, Cloudberry, Bearberry. Such formations are closed, except on the stream side, so that the more open associations of the arctic-alpine zone do not develop.

The zone of arctic-alpine vegetation consists of arctic-alpine grassland formation, and an upper arctic-alpine formation, which is formed on mountain-top detritus, or as a chomophyte formation of crevice plants.

The grassland develops from 2,500 feet upwards to 3,000 feet. The dominant plants are Grasses. The conditions are moist, but the surface well drained, and the zone is mainly developed on southern slopes. No woodland is developed at this altitude. Several Highland types characterize this zone. The associations are developed around dry knolls, mossy springs, or along the streams. The Alpine Lady's Mantle is an abundant species.

On the dry ground also occur Highland types, the Viviparous Sheep's Fescue, Mountain Wood Rush, various local Sedges, Alpine Meadow Grass, Alpine Cat's-tail, Alpine Mouse-ear, Pearlwort, Alpine Cinquefoil. Of subalpine types Sheep's Fescue, Bent Grass, Sweet Vernal Grass, Waved-hair Grass, are abundant. Mat Grass, Purple Moorgrass, Common Sedge, are dominant in places. Other associates include a number of common lowland ascending types, as Upright Meadow Crowfoot, Wood Anemone, Rock Pansy, Heath Milkwort, Mouse-ear Chickweed, Procumbent Pearlwort, Pretty St. John's Wort, Mountain Flax, Wood Sorrel, Creeping Clover, Bird's-foot Trefoil, Tormentil, Lady's Mantle, Hogweed, Heath Bedstraw, Devil's-bit Scabious, Daisy, Pearl Everlasting, Milfoil, Dandelion, Autumnal Hawkbit, Whortleberry, Harebell, Eyebright, Cow Wheat, Wild Thyme, Ribwort Plantain, Sorrel, Sheep's Sorrel, Spotted Orchid, Heath Rush, Deer's Grass, Lesser Prickly Sedge, Yellow Sedge, Tussock Grass, Moonwort, etc.

In some parts Whortleberry and Ling are more abundant. In other parts Grasses decrease in abundance, and wet-soil types prevail.

The upper arctic formation may extend over areas where rock masses are absent, and where the surface is even. But in places towards the summits from 2,000 to 3,000 feet or higher, a detritus of loose-rock fragments forms a loose scree, and the vegetation is scanty. Mosses and Lichens are more dominant. Elsewhere steep ravines, affording shelter filled with broken rocks with ledges and fissures, obtain. Here the flora, owing to the different physical conditions, varies from that on the mountain-top detritus. The relative humidity of different habitats varies, and this produces local variation in the plant communities. Highland types characterize the crevice plant associations, or chomophyte formation, as it is called.

The exposed rocks and crags above the detritus furnish a typical rock soil, and the disintegration of exposed rocks gives rise to open associations, in contrast to the closed moorland and grassland associations at a lower altitude. The surface is continually changing, and it is only in fissures and crevices that plants in such stations can gain a foothold. The higher plants have the way prepared for them by the Mosses and Lichens that form a loose humous soil, covering the thin detritus. The plants that find a footing are exposed to wind, insolation, and high temperature, and must be xerophytic in adaptation as a rule, and in all cases are stunted in habit. Also the exposure and slopes influence the chomophyte formation. The amount of moisture varies owing to local conditions. The moisture obtained is atmospheric. Snow may lie in the corries until May, but by July is melted as a rule.

The mountain-top detritus formation consists of two or three different associations. The Moss-Lichen open association is found on surfaces with stones outcropping, and Rhacomitrium Heath association develops where Lichens entirely cover the surface. The former is an open stage, the latter a closed stage. This last may become a moorland association.

Highland types, such as Moss Campion, Sandwort, Saxifrages, occur. The growth-form produces a mat vegetation, comparable to that of the tundras. On the dry areas occur also Azalea, Crowberry, Spiked Wood Rush, Rigid Sedge, Whortleberry, Herbaceous Willow, etc. In the Moss-Lichen open association occur also Upright Meadow Crowfoot, Alpine Rock Cress, Alpine Whitlow Grass, Alpine Campion, Alpine Lady's Mantle, Opposite-leaved Saxifrage, Golden Rod, Alpine Cudweed, Azalea, Viviparous Knot Grass, Herbaceous Willow, Crowberry, Trifid Rush, Mountain Wood Rush, Waved Hair Grass, Mat Grass, etc.

The Rhacomitrium-Heath association contains Alpine Milk Vetch, Tormentil, Dwarf Dogwood, Alpine Chickweed, Heath Bedstraw, Harebell, Cowberry, Red Cowberry, Whortleberry, Bearberry, Ling, Eyebright, Sorrel, Rigid Sedge, etc.

Moss-Lichen associations may also occur where peat has formed at 2,500 to 3,000 feet, where the drainage is bad. It varies, but is made up of Whortleberry-Ling associations below, and Rhacomitrium-Whortleberry associations higher up. A snow-patch vegetation occurs where snow has lain long in hollows, and a silty deposit has in consequence formed, with Herbaceous Willow, Alpine Cudweed, Azalea, Alpine Lady's Mantle, Heath Bedstraw, etc.

In the chomophyte formation four main associations can be recognized: an open community of exposed rock-surfaces, an association of sheltered ledges, an association of shade types, and an association of hydrophilous types. The vegetation is more varied than in the last formation. Some peculiar types are found there. More lowland or subalpine types ascend to this zone, such as Globe Flower, Red Campion, Hogweed, Sheep's Sorrel, Stone Bramble, Moschatel. Dog's Mercury. The greater diversity of this flora depends on the variation in the rock soil, which may be siliceous, calcareous, etc. Some plants grow on shelves, as Lithophytes, whilst others are Chasmophytes, or crevice plants. The former precede the latter in order of colonization. They are open associations. On screes Mosses and Lichens prepare the way for higher plants. The moisture obtained is largely atmospheric, and variation in supply modifies the character of societies formed.

On open ledges, where there is little soil and insolation is intense, the plants are cushion, or mat, plants. Here grow Alpine Rock Cress, Alpine Whitlow Grass, Alpine Mouse-ear, Moss Campion, Alpine Milk Vetch, Mount Avens, Alpine Lady's Mantle, Alpine Cinquefoils, Saxifrages, Roseroot, Alpine Fleabane, Harebell, Wild Thyme, Alpine Bartsia, Trifid Rush, Spiked Wood Rush, Trailing Willow, etc.

On open ledges grow Drooping Saxifrage, Alpine

Saxifrage, Rock Cress, Mountain Sandwort, Alpine Pearlwort.

An association of sheltered ledges is formed on firm, deep, humous soil. The vegetation is sheltered and more luxuriant, and consists of plants on dry ledges, with deep soil, with a southerly aspect, forming an open association.

It includes Blue Rock Speedwell, Small Scotch Gentian, Mountain Scorpion Grass, Alpine Cinquefoil, Rock Pansy, Mountain Flax. A closed association of ledges with deep soil consists of Globe Flower, Wood Crane's-bill, Red Campion, Stone Bramble, Alpine Lady's Mantle, Angelica, Wintergreens, Northern Bedstraw, Alpine Hawkweed, Sorrel, Spotted Orchid, Great Wood Rush, Black Sedge, Alpine Meadow Grass, Alpine Hair Grass.

An association of shade crevice-plants is formed in deep fissures and hollows in the scree, where water trickles down the rock faces, or where the soil is moist. It includes Wood Anemone, Bittercress, Herb Robert, Wood Sorrel, Starry Saxifrage, Alternate-leaved Golden Saxifrage, Opposite-leaved Golden Saxifrage, Moschatel, Dandelion, Alpine Sow Thistle, Alpine Sawwort, Mountain Sorrel, Viviparous Knot Grass, Downy Mountain Willow, Spiked Wood Rush, Black Sedge, etc.

On the bank of alpine streams the association of crevice plants is made up of Moss, Sedge, Rush-Sedge, and Sedge communities. There is a network of little runlets fed by precipitation and drainage. If they traverse peaty areas the water becomes acid in reaction.

The water fed from springs may flow over the terrace formations and cause a result like the dripping face of rocks. Here Mosses predominate, and form a fresh green carpet. Both lowland and

Highland types of flowering plants occur, such a amongst lowland types, Marsh Marigold, Scurv Grass, Bog Stitchwort, Lady's Mantle, Water Blinks Bog Stonecrop, Golden Saxifrage, Butterwort, Bo Asphodel, Diœcious Sedge, Lesser Prickly Sedge; o Highland types, Alpine Meadow Rue, Mountain Mouse ear Chickweed, Starry Saxifrage, Yellow Mountai Saxifrage, Mountain Willow Herb, Alpine Speedwell Viviparous Knot Grass, Mountain Sorrel, Tofieldia, etc

A Sedge community is formed by various alpine Sedges and Rushes, and elsewhere a Sedge community with Butterwort, etc.

The arctic-alpine vegetation is best studied in the Highlands, where it forms a characteristic physiognomy. It may also be studied in Wales on a less extensive scale, and also in the Lake District, and the North of England in Teesdale.

Maritime vegetation owes its inception to the proximity of the sea, and to the fact that the soil is impregnated to a greater or less degree by sodium chloride. The dune formation which occurs along the coasts is primarily due to the proximity of the sea, and the effect of wind accumulating loose banks of sand. This is ecologically a different type, and a desert formation. The salt-marsh, however, and the shingle-beach formations are strictly maritime, or rarely, in the case of the former, as in Cheshire, inland, but in each case dependent upon the salinity of the soil.

There are three main types of maritime vegetation:

1. Salt-marsh formation.
2. Sand-dune formation.
3. Shingle-beach formation.

Allied to these are the strand vegetation of sandy shores, the vegetation of maritime cliffs and rocks, upon which some Lithophytes grow. Where swept by the surf the conditions are similar to the strand vegetation.

All the types of maritime vegetation are characterized by the adaptation of the plants to dry conditions, or rather physiological drought, owing to the concentrated saline solutions of the soil-water. Physical drought also operates through the drying effect of the constant land and sea breezes.

Since the maritime formations are marginal to inland formations, usually grassland, they are frequently invaded by inland types. Cornfields very often adjoin salt-marshes and dunes, and arable soil types may approach the high-water level. The maritime habitats being open formations, plants from the closed inland formations are easily able to obtain a footing. In some cases they manage to persist; in others their existence is purely ephemeral, a large proportion being annuals.

The area occupied by maritime vegetation is also liable to invasion on the seaward side by the sea, which covers it periodically between the tides, and thus causes the soil characters to be permanently saline. But since the invasion of the sea brings also, with the saltwater, deposits of sediment, such areas may, if circumstances favour it, become silted up, and in this way the habitat may quickly change, so that the conditions are not stable. Moreover, the sand-dune formation itself is a mobile formation in its early phase, only becoming permanent as it abuts upon the inland vegetation, being assisted in this rôle by the work of the sand-binding Grasses that actually help to form the sand-dune.

Again, from the landward side, disturbing factors are introduced by the constant silting up in the region of estuaries of tracts at the mouth of rivers.

As the age of the estuary advances the type of sediment varies, being finer as the river reaches its old age, shingly in its infancy.

Rocky habitats, or even sandy shores, are, furthermore, constantly being exposed to the annual erosion of the seacoast by the action of the tides and waves. The amount of this erosion depends upon the form of the coastline, the character of the rock or soil. On the west coast generally the coast is more rocky, and conditions are more permanent; on the east coast the contour of the shoreline is perpetually undergoing modification. Also, some areas are being subjected to an opposite process, where the coast is becoming enlarged by the accretion of large areas of fresh sediment brought down by rivers or cast up by the sea. In some parts there is a regular drift of shingle along the coast, and shingly beaches are being formed. These have a protective action, just as has, elsewhere, the formation of sand-dunes. The latter may be, and is, encouraged by the artificial planting of sand-binding Grasses and Shrubs.

Thus it comes about that the sea margin is an area where new floras are constantly in the making (or the reverse). The vegetation is open, and this phase is the best for the study of the succession of plant formations. In such conditions it may be possible to understand how all vegetation in the past has attained its present form—the history of the changes. This process may be applied with advantage to the study of the inland closed formations, where frequently only the last phase is to be seen, or where rarely at the margin an indication of the earlier stages of succession or retrogression can be studied. An exception may be made in the case of the juxtaposition of aquatic and terrestrial vegetation, where, through the reed-swamp, one phase is constantly being transformed into the other, where invasion is repeatedly going on, of land by water or water by land.

A study of the salt-marsh formation (Fig. 25) shows that, as the tides recur, at high water during the spring tides the area is covered by the sea, if it lies at levels that can be covered. Elsewhere saltwater reaches the salt-marsh only occasionally, as when during storms saltwater is swept over the intervening shingle-bank. This happens on the Norfolk coast, as at Salthouse, when the salt-marshes may be covered by an inundation of saltwater for weeks together. A certain amount of saltwater also drains through the shingle-bank landward and reaches the salt-marsh, so that on the landward side there may frequently intervene a drain or lagoon of saltwater between the shingle and salt-marsh. The concentration of salt in the salt-marsh by repeated accession of saltwater is counteracted by evaporation and rainfall.

Owing to the decreasing percentage of salt in the soil-water landward the salt-marsh formation exhibits a more or less definite zonation. But such zones are not everywhere present. In one area one only may be developed, and so on, depending on the configuration of the surface and other causes.

Four main types of association have been recognized. As a rule the outpost association of the salt-marsh is formed by Saltworts, forming a definite association. Recently many subdivisions of the original Linnæan species have been made. Very extensive tracts of Saltworts occur in estuarine areas, which are made up of denser growth of species as one approaches the next zone. Associated with Saltwort there may occur Sea Manna Grass, itself forming elsewhere an inner zone, Sea Aster, and Sea Orache. Such a fringe as this is external to the better-defined general salt-marsh; and it varies according to locality. Recently on the south and east coasts, its place is taken by an association of Cord Grass.

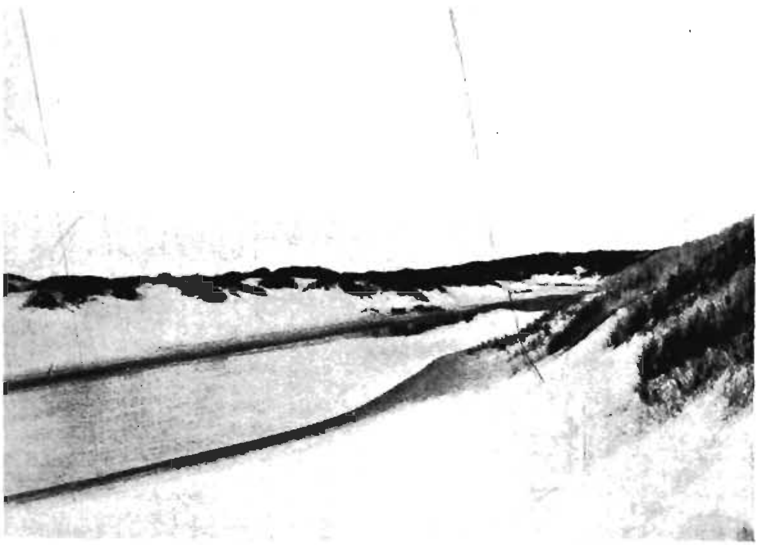
Within this outer zone comes the general salt-marsh at a higher level, covered by tides less regularly. It contains a number of species, some of which may locally become dominant enough to form a society or association individually. Typical of this zone are Sea Spurrey (several species), Sea Aster, Sea Wormwood (this may grow on the landward edge of a shingle-beach community and help to form an embryonic dune, as may also Shrubby Sea Blite and various kinds of Sea Orache, etc.), Sea Lavender (several species), Thrift, Sea Plantain, Sea Oraches, Saltworts, Herbaceous Sea Blite, Sea Arrow Grass (this may form a society), Sea Manna Grass. Where creeks occur Sea Aster and Sea Oraches may also, as at Cley, form large or small communities.

Where the surface of the salt-marsh rises there is a tendency for Grasses to become more dominant, and a short turf is produced by Sea Manna Grass, with other species interspersed, some of which, as Buck's-horn Plantain or Sea Sandworts, may here and there form large or small societies. This area is sometimes covered at high tides, but may only be invaded by seawater at long intervals. Frequently a more varied association is formed by patches or belts of Sea Lavender or Thrift. This zone may, if invaded from the landward side and drained by dykes, become suitable for grazing, and may even be laid to grass. At some places communities of Herbaceous Sea Blite or Sea Manna Grass form small hummocks, which have been developed after Saltworts have thrown up surface banks of sand.

At a level where the tide rarely reaches there is a zone dominated by Sea Rush. To seaward it resembles the second zone. Here grow plants of a

The Author.

FIG. 25.—SALTMARSH INVADED BY THE SEA, NORTH NORFOLK COAST.



The Author.

FIG. 26.—SHINGLE BANK, WITH INCIPIENT VEGETATION, DUNE WITH MARRAM, AND LAGOON WITH SAMPHIRE.

To face p. 132.

different type, such as Sea Heath, on sandy laterals, Lachenal's Dropwort, Sea Milkwort, Sea Plantain, Buck's-horn Plantain, Sea Couch Grass. Each may form a small society. This inner zone is frequently a mixed association, as the soil is less saline and inland types invade it. Many sandy soil Grasses, such as Bents and Fescues, grow intermixed with the maritime species.

On some coasts areas of cliff vary the zonal arrangement above described, and on such rocks, especially on the west coast, grow Sea Lavender, Buck's-horn Plantain, Thrift, Samphire, and more rarely Sea Cabbage, Asparagus, Fennel, Woad (now only at Tewkesbury, on cliffs of the Severn banks, possibly once less inland).

Where the water is brackish there may be at the mouths of estuaries a mixed maritime and inland marsh formation.

Unlike the salt-marsh formation, which is exposed to the sea, the sand-dune formation (Fig. 26) is normally above high tide, and the feature of this vegetation, from the ecological aspect, is that the habitat is made up of blown sand, and, in fact, is a formation of desert plants. The formation of a sand-dune along the coast has the effect of affording a better habitat for the vegetation of the seaward zone of vegetation, which collectively may be termed strand vegetation. Where dunes do not form the vegetation is similar but less permanent. The strand vegetation helps to render dune formation initially possible and at a later stage to stabilize the dune. There are thus moving dunes and fixed dunes. The latter abut upon marginal inland grassland and pass into it. But the dune does not travel landward but seaward, continually advancing its steeper face upon the seafront. Fresh sand accumulates on this face, and the already established

Grasses reclaim it, pushing ever outward their long rooting rhizomes. But a stage may arise when there is no sand supplied to add to the dune face. Here arises then the strand vegetation, which springs up on flat sandy shores. This zone comes next to the high-water level, and is liable to arrest through storms or erosion. Strand vegetation is distinct in character from dune vegetation, but since it is marginal to it, and closely associated with the inception or arrest of dunes, may be studied in connection with it. The flora varies and may depend upon the character of the soil or amount of salt in solution.

Here, as strand plants, grow Sea Rocket, Sea Kale, Sea Purslane, Oraches, Saltwort, Ray's Knot Grass, etc., and Sea Couch Grass, with sometimes, adjacent to incipient dunes, as at Skegness, Fescues, Marram, or Lyme Grass, and Sand Sedge. Other local types are Sea Buckthorn, Tamarisk, Elder, Bittersweet, etc. Mosses may cover the sand amongst the Grasses, and a few Lichens.

Mobile dunes arise from the growth of Sea Couch Grass. Marram is, however, the chief agent in helping to originate a dune, several tracts of coast being designated "the Marrams." An area at Blakeney so called, however, does not to-day support a dune formation, but shingle-beach vegetation here abuts upon salt-marsh. The dunes are now westward of this point, but at an earlier stage dunes may have existed where the Marrams are indicated on the map before the shingle-beach had advanced so far. The researches of Professor F. W. Oliver and his colleagues at this coastal observation station should establish this point, as they are intended to do.

Naturally in an unstable formation the plants that arise on a Marram, or dune established by Lyme Grass, vary with the locality. Plants from the strand vegetation on the one side, and from the land vegetation on the other, invade the initially bare sand-hills. There may be a pasture association of a mixed type, wherein Sand Sedge, Fescues, Creeping Rest Harrow, Stork's-bill, Bird's-foot Trefoil, Sand Cat's-tail, or St. James's Wort, Saltwort, Sea Bindweed, Sea Holly, etc., occur. In places shrubs, or even Ling, occur, and at Skegness a scrub of Sea Buckthorn occurs. In hollows dune marsh forms.

In the mobile dune two generally recognized zones or associations occur.

Sea Couch Grass develops a low dune flanking the higher Marram-formed dunes, as at Skegness.

Sea Couch Grass (of several species) helps to bind the sand like Marram or Lyme Grass, but less successfully. Next to Sea Couch Grass, Sand Sedge is most abundant. This also acts as a sand-binder, but does not tend to heap the sand up, only keeping the level surface from being abraded by wind; but it paves the way for the other types. Here also grow Yellow-horned Poppy, Sea Rocket, Sea Purslane, Sea Holly, Spreading Hedge Parsley, Oraches, Curled Dock, Sea Spurge, etc.

Farther inland Marram forms an association which more actively conserves and helps to stabilize the mobile dune. But where Sea Couch Grass is absent as a zone Marram takes its place. These mobile dunes are called "white dunes," as opposed to "grey dunes" of a more fixed character. The rhizomes may attain a length of 30 feet, and hence a dune may by their agency reach this height or more. When the Marrams are entirely covered, the sand then begins to travel inland, and the dune is liable to become stationary or to be denuded with the cessation of the work of the Marram Grass, and gaps gradually form in the dunes, called "blow-outs." The Marram begins the work of establishing a dune, and its completion is carried out by other types whose colonization is rendered possible by the Marram Grass. All the time sand is blown inland, and the dune thus travels and grows inland. The leeward side of a dune is covered by a growth of other sand-binders, and so long as a continuous supply of sand helps to extend the area of the dune it spreads to leeward by their agency. The dune is fixed when the sand-supply ceases. Later the sea may encroach and the dune become worn away and a flat surface alone remain, which may even be retaken by the sea, or protected by an outer fringe of newly formed shingle.

Amongst other plants that accompany the Marram, or Lyme Grass, that grows on the crest of the dunes, are Sea Purslane, Sea Holly, St. James's Wort, Dandelion, Hawkweed, Long-rooted Cat's-ear, Sea Convolvulus, Sea Spurge, Sea Buckthorn, Sand Sedge, Sand Cat's-tail, Fescue Grasses, Grey Hair Grass, Sea Couch Grass, etc.

To leeward the dune is fixed. Here the vegetation is denser, more varied, forming a carpet. Sometimes a society may be formed by a species that dominates the station locally, such as Sea Buckthorn, Elder, or Dwarf Willow, as in Anglesea, or Brambles, or Sand Sedge. Plants from the neighbouring arable lands to leeward invade this zone, in time causing the formation to become closed, and by degrees an inland type of rough pasture is formed. Marram may, however, persist, though the other maritime species may be ousted by the more vigorous inland types, accustomed to colonize already closed vegetation inland.

Amongst the plants of the grassland on the fixed dunes may be mentioned Whitlow Grass, Heath Violet, Stork's-bill, Creeping Rest Harrow, Bird's-foot Trefoil, Dutch Clover, Red Clover, Hare's-foot

Clover, Bramble, Eglantine, Cinquefoil, Silverweed, Biting Stonecrop, Elder, Lady's Bedstraw, Heath Bedstraw, St. James's Wort, Hawk's-beard, Mouse-ear Hawkweed, Long-rooted Cat's-ear, Autumnal Hawkbit, Carline Thistle, Dandelion, Creeping Thistle, Centaury, Dwarf Forget-me-not, Wild Thyme, Sand Sedge, Fescue Grass, Soft Grass.

There may be a dune marsh in the hollow of the dunes, or lagoons with Glasswort, etc.

Along the south coast, as at Chesil Bank, and on the east coast, where there is a north-and-south or west-and-east drift of shingle, shingle-beaches are thrown up. These, like the sand-dunes, protect the coast, and are encouraged (Fig. 26).

They support a limited flora above high-water level. The beaches may be terraced, and the highest terrace (usually flat) supports a number of plants, which are small communities in themselves. With the shingle sand is blown in from the sea, and settles into the interstices between the pebbles, forming a soil for plant growth.

As the tide may in storm periods wash over the shingle the soil is largely saline. The vegetation is halophilous and xerophytic. The plants that colonize this open formation are mixed. Some inland types occur, as Curled Dock, St. James's Wort, or even Scarlet Pimpernel. Occasionally a community of Shrubby Sea Blite forms a sort of low scrub, and helps to stabilize the shingle, and, as at Blakeney, to induce the formation of laterals on the landward side. Other types are Elder, Viper's Bugloss, Yellow-horned Poppy, Sea Campion, Sea Vetch, Bittersweet (maritime form), Herb Robert (maritime form), Sea Purslane, Sea Wormwood, etc.

As a further illustration of the vegetation of open plant formations, one may study the flora of rocks and walls and of waste places (and allied cultivated or broken soil).

Rocks, as has been shown in discussing the arctic-alpine flora, support a characteristic flora. The plants that grow in such altitudes differ from those of more lowland or subalpine habitats; but these last have the same type of habit, being rosette plants, cushion plants, mat plants. The flora varies according to the character, chemical and physical, of the rock.

On the high ridges of Carboniferous Limestone in Teesdale, and the Pennines in the west of England generally, some of the following may be found, viz: Whitlow Grass, Hutchinsia, Dwarf Forget-me-not, Hairy Rockcress, Bristol Rockcress, Wall Rockcress, Hoary Rockcress, Alpine Pennycress, Rue-leaved Saxifrage, Mouse-ear Hawkweed, Orpine, White Stonecrop, Biting Stonecrop, Large Yellow Stonecrop, Yellow Stonecrop, English Stonecrop, Lesser Meadow Rue (calcareous form), Rockrose, Cheddar Pink, Sandwort, Vernal Sandwort, Wood Crane's-bill, Shining Crane's-bill, Wall Lettuce, Pellitory-of-the-Wall, Sheep's Fescue, and various Ferns.

Akin to the flora of bare rocks is that of walls, which offer the same conditions—dry conditions and poverty of soil. As in the case of rocks, the flora of a wall depends upon the character of the stone forming the wall, or whether the wall is of brick or mud. In some areas stone walls replace hedges, and the mural flora is extensive and varied, though, if little soil has formed, long stretches of wall may be destitute of flowering plants, even though the stones may be covered with Lichens and Mosses. These help to form a soil for higher plants to form a footing. Some plants are general inhabitants of the wall flora, such as Yellow Stonecrop, Rue-leaved Saxifrage, Pearlworts, Meadow Grass, Hairy Bitter Cress. Elsewhere, Ivy-leaved Toadflax, Pellitory-of-the-Wall, Wall Lettuce, Lanceolate Willow Herb, are frequent, with Large Yellow Stonecrop, Thick-leaved Stonecrop, House Leek, Wallflower, Snapdragon, Flat-stalked Poa, Greater Celandine, Whitlow Grass, Wall Barley, Barren Brome Grass, Squirrel-tail Grass.

Some plants from neighbouring soil of fields—Cornfield Weeds, etc.—may occasionally establish themselves also on the wall. One may frequently find any of the following: Shepherd's Purse, Mouse-ear Chickweed, Five-stamened Mouse-ear, Stork's-bill, Lamb's Lettuce, Upright Cudweed, Dwarf Forget-me-not, Field Speedwell, Wall Speedwell, Thyme-leaved Speedwell, Wild Thyme, Sandwort, Black Medik, Mouse-ear Hawkweed, Sheep's Sorrel, Cat's Valerian.

On the walls in hilly regions, plants that elsewhere grow on heaths or moors may be found: Sheep's-bit Scabious, Navelwort, Pepper Cress, Dove's-foot Crane's-bill, Shining Crane's-bill, Stonecrop, Grey Heath, Ling, Hairy Greenweed, as well as many Ferns.

Like that of walls, the flora of waste ground is addicted to open-soil conditions, whether it be that of waste places in the strict sense, or of cultivated fields, stackyards, etc. Here competition is less severe until the flora has become established, whilst, the plants being largely annual, the plants of the first year do not become permanent. Therefore there is an annual rearrangement of the flora as spring comes, the few perennials not making a closed association. In cornfields the wild plants have to adjust themselves to the process of weeding, and are continually competing with the growing crops. Plants that come up in turnipfields, etc., have more open conditions, and the "roots" themselves, though each root occupies a large space, do not exclude the growth of wild plants.

In addition to wild plants that are more or less native, colonists, etc., a large proportion of the waste-ground plants are introduced plants that come here in ballast, in grain, and other ways, and are distributed all over the country with the distribution of the grain, becoming permanently established, though their existence may at first be somewhat precarious.

Amongst the plants that are of frequent occurrence are: Mouse-tail, Small-flowered Buttercup, Hairy Bitter Cress, Thale Cress, Bladder Campion, Mouse-ear Chickweed, Chickweed, Pearlwort, Spurrey, Cut-leaved Geranium, Black Medick, Red Clover, White Clover, Hop Trefoil, Parsley Piert, Knotted Hedge Parsley, Corn Salad, Field Scabious, Scentless May-weed, Groundsel, Spear Thistle, Creeping Thistle, Scarlet Pimpernel, Field Forget-me-not, Small Bind-weed, Dodder, Lesser Toadflax, Cornmint, Field Woundwort, Hempnettle, Ribwort Plantain, Way-bread, Corn Bindweed, Docks, and various Grasses.

Allied to the promiscuous flora of such artificial formations as those of walls and wasteplaces is that of the roadside and hedgerow.

A roadside usually consists of a hedge with trees, and a bank with shade and dry soil, with a ditch below, and a piece of sward fringing the macadam itself.

In the hedge the tall plants that are not shrubs, as Hawthorn, Sloe, Guelder Rose, etc., are climbers, as Clematis, Bryonies, etc. Others that do not climb have their leaves much divided, as many umbelliferous plants, Chervil, etc., or else they have an erect habit and narrow leaves, as Campion. The lower part of the hedge or hedge-bottom, especially on the roadside, where the conditions are open, affords a place for broad-leaved shade plants, as Lords-and-Ladies, Burdock, Hedge Garlic, etc. Under the shade of the hedge grow Wood Violet, Lesser Celandine, Three-nerved Sandwort, etc., and Cowslip, Primrose, Selfheal, Bugle, where light is medium, and a denser vegetation extends to the shrub-line. On the sunny side the plants are rosette plants, as Winter Cress, Hawk's-bit, etc., or on dry shelving banks, trailers, as Cinquefoil, Barren Strawberry, etc.

Below the bank is the ditch, with wet conditions for aquatic or moisture-loving plants, as Watercress, Great Hairy Willow Herb, Sedges, Rushes, Tussock Grass, etc., and where water runs continually Marshwort, Duckweed, Brooklime, Scorpion Grass, etc.

There is a similarity between the flora of the open sward and that of the fields on the far side of the hedge, consisting of Buttercups, Daisies, Dandelions, Speedwells, Cow Wheat, Red Bartsia, Meadow Vetchling, Rushes, Sedges, Grasses, etc.

The trees in the hedge itself are, like the shrubs, artificially planted, and vary according to the choice of the landowner, but may fortuitously or by design resemble the woodland types native to the soil. They include Oak, Ash, Elm, Beech, Willow, Lime, Poplar, Hornbeam, Horse Chestnut, Sycamore, Pine, Larch, and other obviously planted types.

The shrubs include Hawthorn, Sloe, Hazel, Maple, Elder, Privet, Dogwood, Guelder Rose, Buckthorn, etc., as well as the climbing Brambles, Rose, Honeysuckle, Bittersweet, and climbers of all types, such as Ivy, Cleavers, Vetches, etc.

The total flora of the roadside and hedgerow is extensive, the constituents varying with the soil in different areas. Similar to the roadside vegetation is that of hedgerows in fields, where there is also a ditch and hedgebank. In each field, also, there is usually a pond, which is artificial in origin, but which supports a natural aquatic vegetation, largely dispersed by water fowl. In fields, also, one finds manure-heaps, rickyards, and similar artificial habitats for waste-ground types of plants.

Village greens are also waste places where, in the past, as to a limited extent to-day, many uncommon plants, such as Chamomile, Lesser Fleabane, etc., find a congenial habitat.

It has already been noted that such semi-popular terms as wood, heath, moor, marsh, bog, etc., are terms that describe the physiognomy or general appearance of vegetation. Upon the character of these physiognomic types of vegetation depends the character of the scenery which they make up. These physiognomic types, again, are dependent upon the factors that make up the environment, of which soil and the contour of the surface are important factors. The soil in turn is derived from the different geological formations. Likewise, the surface features and orographic variations are, in turn, a result of geological causes. Thus, then, ecology, scenery, and geology have an intimate connection. This fact lends added interest to the natural surroundings in any locality one may like to select. To know the meaning of the vegetation one is accustomed to see in a familiar spot, to understand its relation to past changes in the earth, and to recognise that the very details of scenery each have a definite meaning, is a fact that must increase a hundredfold one's interest in a place.

Geology and scenery (Chapter IV.) is a subject that can be admirably illustrated by the features of any landscape. This has been ably done by Sir Archibald Geikie, to whose works the reader is referred.

The bold features of a landscape (hills and mountains) first owe their origin to upheaval by volcanic action in the past. The resistance of such masses to the agents of denudation, etc., is due to their ancient origin.

This rule holds good in all cases. Striking features are based on harder rock masses, whilst even sloping country is due to the intervention of softer rocks, forming clay soils, etc. Valleys owe their origin to river action, and flat alluvial plains owe their character the same cause. Glacial action produces flat-topped hills or rounded knolls, as do beds of gravel, and sand brought down by flood action.

Lakes may be caused by damming up of valleys by various causes.

River action causes the vegetation of fens and marshes, whilst the same cause produces the characteristic torrents and waterfalls of mountain regions. Denudation, by various causes, produces other features where exposed rocks form crags and fissures. Along the coast the characteristic features are caused by the action of the sea or the wind. In fine, geological causes closely affect both vegetation and scenery, so that ecology cannot be devoid of an artistic setting when studied in its entirety.

From an economic standpoint ecology is closely connected with agriculture. Without a true knowledge of soils no farmer or horticulturist can be assured of a complete measure of success. Ecology is essentially based upon a proper conception of soils—their origin, nature, distribution, and effect upon vegetation. What applies indeed, to wild plants concerns plants under cultivation. The study of the whole environment, which is also a necessity from an ecological standpoint to the botanist, has an important bearing upon agriculture. For farming demands not only a knowledge of soils, but also of the meteorology, climate, and other factors of a district which affect the growing of crops. The limits of cultivation depend upon a certain degree of altitude, and each degree of latitude has also its own special factors that suit different groups of plants, and these apply to cereals and all cultivated plants.

The study of a plant's requirements in a wild state affords adequate data for the proper supply of all those various requirements that make up the needful factors for successful agriculture.

The food of a plant is an important study from a natural standpoint, and upon a proper understanding of it depends the growth of cultivated plants. Only by acquiring such a knowledge can a farmer apply the right sorts of dressings, manures, or food fertilizers in the case of crops.

Since ecology and physiology are really complementary, neither can be adequately studied without a study of the other. Ecology, in a word, supplies the illustrations of the effects in a state of nature of the causes that are studied experimentally in the laboratory from a purely physiological point of view. The various processes of nutrition and growth, or response to stimuli, are experimentally repeated artificially in physiological work, and for particular plants the modes of action of organs carrying out special functions are explained by carrying them out to a conclusion. But each process is studied apart from the environment and separately. There is here no knowledge obtained of the actual character of the environment, nor any demonstration of the interaction of the various factors. Physiology supplies in an abstract manner the meaning of organs, the effect of any particular factor. Ecology supplies in a concrete form the effect of all the factors of the environment, and supplies the material for the connection between cause and effect which physiology demonstrates in the abstract in simple cases. Ecology thus gives a concrete character to the meaning of the physiological causes.

Thus one is dependent upon the other and the two subjects should be studied together, connecting process, cause, and effect.

Ecology may be undertaken as a study from various other standpoints. From a botanical standpoint the chief *motif* should be to investigate the vegetation of the district, to define the plant formations present, and if desired to map their area. In carrying out a full enquiry into the ecology of a district, the physical features must be studied. This means a knowledge of the soils. The slope of the ground should be noted The rainfall of the district must be taken into account, and also the drainage system and river system should be studied. A knowledge of the prevailing winds is essential, especially in connection with hilly areas. Some data should be obtained as to the character of the atmosphere. In some areas smoke affects vegetation. The peculiarities of the flora should be studied and compared with those of other areas.

The adaptation of plant types to the environment is an important study—the nature of the various organs and their connection with the habitat factors.

Man's influence is more or less important in all areas, and requires further study. So also does that of animals, as insects, grazing animals, etc.

As has been seen, plant ecology is a branch of plant geography. The latter deals with floral regions or zones; and ecology is a more detailed analysis of the various types of botanical regions or floras. It investigates environment and causes of distribution on a more minute basis, whereas plant geography deals with major factors, such as climate, altitude, insular, mountain, oceanic, continental, floras, barriers, etc. It endeavours to discover the place of origin of distinct floras, and to determine the relationship between each flora. The facts of distribution on a broad basis help to elucidate the evolution of plant forms, groups, etc.

Ecology deals rather with the life of the individual and the connection between plant variation and the habitat, variations that arise in response to the environment. Morphological variations are more deep-seated, especially those relating to floral structure.

But ecology and plant geography are interdependent, since the main causes of distribution are based in turn upon the causes of an organism's response to environment.

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CHAPTER III

FIELD BOTANY AND SURVEY WORK

It is not too much to say that field botany is one of the most, if not *the* most, valuable branches of botany. Any work that brings one into direct contact with nature must of necessity be more convincing than armchair work. Actual living organisms, whether plants or animals, differ immensely from dead or dry matter. Colour, form, and "nature" disappear when a plant is dried, even by the best method. Only in the field, or when fresh, can the floral mechanism of a flower, for instance, be properly understood. The position, for example, of a flower upon a plant can only be realized in the field. It may be erect, drooping, or horizontal. Glands, hairs, etc., disappear, or lose their prominence when a plant is dry. Pollination, one of the most fascinating features of plant life, can only be studied in the field, and so on.

Moreover, field botany brings one into the habitat of plants. In the field one notes the number of a species, its habit, the soil it requires, its relation to moisture, light, and all the factors of the environment. One sees at once what plants grow together (or form an association), how the one affects the other.

Thus field botany brings one at once to the threshold of plant life, and enables one to study at first hand the conditions that regulate it, the means by which a plant lives, its behaviour, its chance of success, or otherwise, in the struggle for existence.

Furthermore, like all outdoor work, field botany is healthful. And this is a great reason for encouraging it. For the scientific botanist to-day has so much to learn, so much to do, to acquire even a medium knowledge of the subject, which necessarily involves a great amount of indoor study, that the more opportunities he or she has for outdoor work the better.

By the encouragement, indeed, of outdoor botany a far clearer perception of principles can be obtained if, as is maintained, health regulates the working of the mind. One is brought back from abstractions to the concrete, from probabilities to reality, and thereby the meaning of the unseen is clearly revealed. Theory and practice, indeed, must go hand in hand.

So the study of a dozen specimens in the field, or of a single habitat, is worth more than so much time spent merely with books, or in the carrying out of laboratory experiments alone. Each is important, each has its place; and yet the omission of field work from any scheme not only sterilizes enthusiasm and blunts perception, but makes progress far more mechanical.

Like laboratory or experimental work, which is an advance upon other indoor work, field work, being likewise practical, gives one at once an insight into first principles, realities, and actual conditions. Thus, we cannot do better than urge that field botany be given a foremost place in every botanist's curriculum.

By its very variety—the manifold aspects of plant life that can be witnessed and studied in the field—field botany lends itself to diversity of treatment.

If we select the morphological side of botany, which has largely been studied from material collected and supplied for indoor study in the lecture-room, the study, or laboratory, we may illustrate the manner in which field work can be an aid even in this branch of botany. The forms of organs vary, not only because they are inherited, but, being adjusted to the environment, they vary with the latter. So a study of the plant in the field helps the morphologist, by adducing the reason for such forms, apart from their physiological meaning.

Thus the forms of leaves exhibit their special characteristics, not only in relation to the light, the temperature, water-capacity of the soil, etc., but in relation to the whole habit of the plant, and this varies with the environment. The grass habit—where the leaves are erect, as a rule, narrow, long, and flat or rolled up—has been evolved in relation to the habitat, since such a habit is the most readily adapted to the conditions of a pasture or meadow. The same applies to the tree habit, and the shrub habit, and the acquisition of protective thorns, spines, etc., in relation to the habitat, browsing animals, or drought. All these morphological habits, or growth forms and adaptations, apart from their direct physiological significance, can be studied best in the field, where the meaning of any particular type of organ, or variation in it, in relation to environment, can alone be seen. All the meanings of physiological functions of organs, again, can be seen in their right proportion, and demonstrated to have a connection with this or that factor alone in the field. Perhaps the best illustration of this is to be found in the behaviour of the plant or its individual organs. Such processes or activities as sensitiveness, in any form, geotropism, heliotropism, the habits of climbing plants, insectivorous plants, all the various devices used by the plant to secure cross-pollination, the different means whereby a plant disperses its fruit or seed, etc.—all these, be it emphasized, can best be seen in the field, or alone in the field. Only in the field will the hivebee ply its art of wandering from flower to flower, never failing to visit those of the colour it desires to sample most, or, if there be a choice, in a certain order, and so forth.

But, needful as field work is for the proper prosecution of morphological and physiological work, it must be also regarded as essential in all work, even applying to histological work. A study of cells and tissues is barren unless the manner in which the gross structure behaves in nature is studied, by observing the branching of a plant, tree, etc., the parts most liable to strain, and so on.

Systematic botany can only be carried out by excursions in the field, for collection of material for preservation, study, etc. Once field work was largely regarded merely as a means to an end, but latterly field work has become an integral part of taxonomic work. A study of habitats reveals the means whereby distribution and floristic work can be best carried out. It is felt that dried material is less valuable for floristic work than fresh specimens. Series of the same plant are collected, species are cultivated to prove whether they are permanent or not. The true limits of a species are only to be ascertained by careful field work and a study of characters in the field. This means that the systematist is unconsciously, if not methodically, becoming an ecologist. New methods of field study are continually being introduced, either improving old ones or extending them.

Field work is especially necessary in the case of ecology. Indeed, it is a *sine qua non* in this most outdoor of all the branches of botany.

The method by which field botany may be varied according to the object in view may be seen in the few examples I have given hereafter of the variety of treatment of any particular side of survey or other work.

There is, indeed, endless scope for varying the *modus operandi* of any operation that requires to be carried out. Diversity is one of the pleasures of study. The mind revolts against monotony. The imagination is refreshed by wealth of incident or change. If one takes, for example, the study of systematic botany, field work is the first step towards this end, if end it be.

Systematic botany must be commenced, perhaps, in the home, school, or study by a study of the scope of the subject, of the terms used in defining or understanding the characters of plants. Some knowledge of the limits of orders, genera, and species must be acquired as a preliminary to field work. The object in view being perceived, it is necessary to seek in the field the special types one wishes to study, or to go forth prepared to grapple with any difficulties that may arise in the determination of any species that may be found.

Preliminary to other work it is well to dissect several plants in the field, for there alone can it be had in the freshest condition. More careful or permanent dissections can be made at home.

One thing that the systematist requires to do, as a rule, is to collect specimens. For a record of a specimen can only be made by collecting and preserving a specimen. A plant may become extinct in a district, so that unless a dried specimen exist it may be questioned later whether it ever occurred. Moreover, for private and public herbaria specimens must be acquired for study. It is important to know what to collect. Generally, unless there is a reason to think a plant is liable to disappear, or in the case of trees and shrubs, larger specimens than 2 feet 6 inches in height, as a rule, a complete specimen should be collected. Some plants need special treatment as regards what parts are required. Full details cannot be given here, but generally some plants, such as Brambles, must have a panicle and a piece of barren stem collected, and the same applies to Roses, whilst the catkins of trees flowering before leaves are collected in spring, the leaves in autumn, and Grasses should in any case have the roots collected, as some are creeping. Hawkweeds with a rosette of basal leaves, and all rosette plants, should have the rosettes represented. Some plants, as Dropwort, have tubers, and Pignut has an underground "nut," so that these should be collected. Experience shows that large numbers of plants need special treatment, and field work is the only mentor in this direction, as experiment here, as elsewhere, is the final arbiter.

Though the next step towards forming an herbarium —arranging, drying, and pressing—is usually done at home, many botanists like to do this in a field. It has these advantages: plants are then freshest, and all the mess connected with trimming, etc., is made out of doors, saving time in clearing up. Petals, etc., liable to droop or roll up and wither if carried long, can be dried at once in the portable press, and leaves, etc., need less arranging for the same reason. A good selection can also best be made on the spot. Water plants can be floated on to cap-paper in the field. The only disadvantage is that the field examination not being always final, determination cannot be decided at once, and one may dry unnecessary material if one dries in the field. Also, it takes up daylight, which is valuable. None the less good results follow. To get the plants home, proper vascula and other receptacles, labels for Brambles, Willows, etc., should be brought with one.

Mounting is done best by following nature, and in the field one may learn the proper habit of a plant, so that the same may be copied as nearly as possible in setting out the plant in the press.

Written notes should be made in the field as to any characters liable to disappear in the field—as to habit or other factors. Sketches, drawings, photographs, etc., of the plant growing, can be made in the field. These are of great value, as are the dissections previously recommended to be made on the spot.

Field work enables one to learn *at first hand* many facts about plants from a systematic point of view, or details that are generally cited in floras dealing with duration, flowering, etc.

As to duration, some plants are annuals as a rule, but annual Meadow Grass is perennial on the Alps. Some biennials may be perennial, and *vice versa*. Variations in these particulars depend upon environment very largely, and are of considerable interest.

There is a considerable variation in the flowering seasons of plants. This is dependent on the latitude, and records made in Scotland show considerable difference from those made on the South Coast or the Midlands. The seasons likewise exhibit much variation, which affects temperature, and some plants may flower a month later in backward seasons. Field observations on this head are of much value from a phenological point of view.

Though largely connected with ecological work, a study of the frequency or dominance of plants is important from a systematic standpoint, as tending to show the soil on which a plant is native, or not, or the status in general of a species. This is essentially a matter for field observation. Moreover, a series of such observations ranging over a long period helps to elucidate the permanence of a species, whether it exhibits periodicity, or whether the species is on the increase or decrease.

Though, again, strictly a part of ecology, the study of the habitat of plants is also a necessary part of systematic botany. Not only is it necessary to know where a plant grows to find it, but systematic work reveals the different types of habitat a species may have. Frequently the supposed native habitat of a plant is really only an adapted one. Silverweed, so common along the highways on the edge of the macadam, really is more native in wet places by the margin of swamps. Harlequin Weed, also found in dry places, banks, quarries, is probably native in marshes and wet meadows. The difference of habitat of a plant is responsible for variation in the specific characters, and the range and status of a variety or form may be ascertained by a study of the habitat.

As a rule the herbarium specimen, if incomplete at any rate, does not give an idea of the size or height of a species. Field work alone can give one this knowledge at first hand. Height varies with soil, habitat, and other factors, and a knowledge of the limits of height is valuable. On dry soil a plant may be one inch high only, whilst in moister situations it may be one foot.

By the ordinary processes of drying of plants the most unsatisfactory result that one has to contend with is the colour of the flower. Some plants, as Scrophulariaceæ, dry black.* The colour of blue or pink flowers fades very quickly, and white flowers may become dirty yellow. Field work gives one at once the accurate tone of colour, and notes should be always made on this head. The colours of Brambles and Roses, whose petals change or drop, should especi-

* The Fothergill press, with specially prepared wool for drying, dries plants in their natural colours, and the colours can also be retained by a chemical process, either in the dry form or in liquid media.

ally be noted, for they are often aids to identification. Some methods of drying flowers are better than others, and these should always be adopted by preference.

Already the importance of collecting as complete a specimen as possible has been emphasized. It cannot be too often impressed upon the beginner. Once adopted, this habit of collecting becomes obviously the right one. For, allowing for the chance of extermination, and after due care has been taken to avoid this, after all the only method is to collect a *perfect* specimen. If not done at the time it may, indeed, never be possible—in the case of aliens, for instance—to discover another perfect or complete specimen. There is some satisfaction to be obtained from a complete specimen, whereas a scrap is really useless, for some part of the characters necessary for description or identification is wanting.

Another feature of field work which is of real value is the opportunity it affords for ascertaining the habit of a plant. This is never possible in a dried specimen unless the plant be complete, and even so the unavoidable flattening in pressing destroys a great part of the real relation of stem to leaves, and the direction of branching. But in the field the exact habit can be noted, and a memorandum as to this should be written down on the spot.

Field work allows one to note the relation of variation to habitat. Such a character as hairiness may as a rule be associated with dry conditions. Dwarf varieties are also to be connected with the same conditions. In the field it is possible to trace varieties sometimes to the parent type. The relationship of a chain of intermediates may be ascertained in the field by careful search and discrimination.

Hybrids, again, which are often of doubtful origin, may be elucidated by a study of the possible members of the cross. There may be in a single locality a chain of such hybrids, and field work is the only means of ascertaining this. On this account, and for other reasons, the importance of careful and close field work becomes obvious. By confining one's attention to a limited area, a great number of things will reveal themselves that would otherwise be passed by in the frequent hurry of the collector to press on and to find something new or to quickly ransack a district.

Especially in connection with variation in aquatic plants is field work valuable. For the effect of environment in such cases is very important. The gradual change in characters as a plant becomes amphibious, or if terrestrial aquatic, or *vice versa,* can only, or best, be studied in the field. Endless pleasure and knowledge is to be had from careful observations on this head. The character of hairiness, for example, is one which affects most plants, and is connected with the protection of the stomata.

Dwarf forms, again, are liable to occur on certain soils or in certain situations, and the collection of these is important, as such forms may exhibit abnormal characters that may give a clue to relationship.

Hybrids are more frequent in a state of nature than is generally believed. They occur in various groups, and are usually between allied species of the same genus, as in Willow Herbs, Willows; but some bigeneric hybrids occur, as between such Grasses as Fescue and Lolium, or between some Orchids, etc. The elucidation of hybrids can best be undertaken by a study of them in the field, to determine which are the species crossed. There may be a regular chain of such hybrids in a locality where Willows are abundant. It is possible by field study to determine the predominant species. Here again field work is of paramount importance.

The majority of botanists are content to collect a typical specimen of a plant in its mature stage. But there is a great scope for the more comprehensive collection of a species from the seedling stage right up to the fruiting stage. Cotyledons vary considerably, and when they are developing early in the season there is usually less work to do amongst mature forms. Such developmental series preserved as dry material or in spirit may be of much value from an evolutionary point of view. Since the sexes of plants are not always mature at the same time, or both on the same plant, it is advisable to take a little extra trouble and to search diligently for the male and female plants of a diœcious species. Also it should be emphasized that in the case of monœcious plants both sexes are represented by securing the different parts of the same plant upon which each sex is respectively represented. When the anthers ripen before the stigma, or *vice versa*, each mature stage should be collected. Some plants, again, such as the Primrose, are dimorphic, and each type of flower should be collected; others are trimorphic, as Purple Loosestrife; and there also each type ought to be sought for and collected.

Some plants exhibit a sort of mimicry, as the White Deadnettle and the Common Nettle, and a series of such examples collected and placed side by side would be of considerable biological interest.

The foregoing examples are only a few of the points to be emphasized in recommending the value of field work even in systematic work. Such points as the collection of the host plant and parasite in organic connection—*e.g.*, Great Knapweed, and the Broomrape that grows upon it—are only a few of the many instances where deliberation and care may make collecting in the field a hundredfold as valuable as the usual work will be at the outset, unless guided by some such attention to points that need forethought instead of haste.

Naturally, such adjuncts to field work as the carrying of a key to identification, such as Druce's edition of Hayward's "Botanist's Pocket-book," note-book and pencil, map (ordinary and geological), vasculum, scissors, knife, lens, etc., are means that every botanist must employ, dependent upon the exact nature of the object in view. (See Chapter I.)

When we turn to the subject of ecological field work we take a step forward. Ecology must at the outset be based upon a *thorough knowledge of species*. For it is impossible to compare two or more types of associations made up of a number of species unless the identification of the specific units is correct. If this be not so, then identification of the ecological unit is wrong, or at least the comparison is faulty.

Assuming a thorough knowledge of species, it is necessary, further, to have some knowledge of geology, for the use of a geological map must be made to aid one in the determination of the area of the formations. (See Chapter II.) From a knowledge of the rock formations one may determine the nature of the soils, and so of the plant formations which depend on soil factors mainly. A visit to typical sections in each rock formation will enable one to determine the formation by the colour of the rock, the succession, the fossils, and the mode of weathering, as well as the general trend of the formation, and the characteristic features to which it gives rise—*e.g.*, flat, undulating, hilly, or other characters.

An aid to the delineation of the geological formations is rendered by a study of contours. Frequently, or usually, a contour line marks the boundary between one formation and another, or between the phases—*e.g.*, clay or sand—of a particular formation. The contours, also, are thus indices in many cases as to the limits of a plant formation. Again, contours mark very often different degrees of water-capacity, and this is an important ecological factor. Allied to a study of the contours, also, is that of the aspect and the slope, each of which has an important bearing on plant associations. In some areas plants that make up moorland associations are found only on a certain aspect. In the case of the slope, again, the limits between, for instance, Whortleberry or Ling and Matgrass or Purple Moorgrass associations, are indicated by difference of slope, and again of contour.

Connected with all the foregoing factors is that of the water-content of a soil. The formation depends largely upon a definite water-content, and its adaptive characters are moulded thereby. Again, the requirements of a plant or association, so far as water is concerned, should each be determined.

Following the estimation of such master factors, one must determine the character of the plant formation, in the case of a wood, for instance, by the dominant tree, or trees, as well as by the character of the shrub layer and ground flora.

In order to trace the extent of a formation one needs to trace its boundaries, just as those of a geological formation have to be traced, by covering the ground to be surveyed by a preliminary traverse, and then in greater detail. The same applies to those smaller communities within an association, such as an Ashwood, as a society, made up, perhaps, of Dog's Mercury. The permanent delineation of such communities is affected by the delineation of their boundaries upon a map, either on a large or small scale, by the aid of a series of symbols employed to indicate each type.

The present character of the vegetation may be original. But in many cases it is successional to earlier phases. In other words, it is necessary to elucidate the history of the formations. Originally it may have been woodland, which may have developed into moorland, with Cotton Grass, Sphagnum, or *Calluna (Ling) associations, the final stage being* possibly the last.

Apart from the study of the formation or association, it is also necessary to study the plant in relation to its adaptation to its habitat, or the factors that make it up, such as water, dry conditions, light, wind, animals, etc. The variable requirements of each species in respect of each of these factors determine the nature of the habitat that each plant selects.

An important point to determine is whether the formation or association is closed or open—that is, whether the soil on which vegetation is developed is entirely covered with plants, or whether it is partially or entirely uncolonized. It may have been originally untenanted, or due to the retrogression of a formation, with the decay and dying out of a phase, which may pave the way to the next phase. Along the coast the vegetation is open, large areas being unoccupied by any vegetation at all.

When an area is open, as when a tract has had the surface vegetation removed naturally, as in the case of volcanic outbursts and lava flows, or artificially as where furze is burnt, turf is cut, or land is ploughed here, very soon, a new flora springs up, as happens also along the margin of a lake or reservoir, and it is important to note its character at different periods and to determine what phase or element, if any, is permanent.

Similar to invasion of an open formation on soil less covered by vegetation is that of a closed formation by an open one, as when meadow becomes aquatic vegetation, or, *vice versa*, when a closed formation invades an open one, as when the marginal reed-swamp invades aquatic vegetation. One closed formation may invade another, as when scrub occupies pasture, or moorland becomes afforested naturally.

Cognate to this is the study of the various means of dispersal of plants, which may be dispersed naturally or by artificial means. The area of an association will ultimately largely depend upon the means of dispersal. Aliens dispersed by man hardly come into ecological studies, but they illustrate well how an open formation—as waste ground, cornfields, dunes, etc.—may temporarily or permanently be invaded by an alien host.

Artificial associations—such as those of roads and roadsides, hedges, walls, waste ground, canals, reservoirs—may pass through an artificial stage, and become semi-natural in course of time. In the process something may be revealed as to the means by which natural plant formations have in the past effected the same purpose.

A few general remarks upon the importance of observation, note-making, practical work, experimental work, may be given here, though they ought perhaps to have formed the prologue to this subject.

Observation is preliminary to all other work. It must be accurate. Before one attempts to reason either by induction or deduction, one must have facts to work upon, and facts are acquired by aid of perception or observation. There are various modes of observation: by the unaided eye, by lens, by the microscope, spectroscope, etc. Scent, touch, hearing, taste, all come into play, in addition to sight.

Continuous observation carried on on systematic lines leads up to the power of comparison and classification of facts. This gradually leads on to reasoning about facts, and an endeavour to discover the origin or meaning of things.

Observation is a stimulus to enquiry. Perception is renovated by a study of things at first hand, in lieu of a mere supply of facts from reading, though it must be said reading has as important a place in study as observation of actual objects or phenomena.

Further, observation promotes interest. The mind is averse to monotony, and observation gives one an opportunity for learning the variety of nature and its contents.

Above all, observation stimulates the imagination. This develops faculties that may otherwise lie dormant—as invention, intuition, foresight, theory, etc. Fact or truth should come before theory, but many hypotheses have paved the way to ultimate proof or demonstration.

Material for thought is also laid up by means of the power of observation. In fine, observation paves the way for ideas, and without ideas expression cannot be given to the pictures that are conjured up in the mind by the accumulated experience of observation.

But then it will be said that observation must rely on memory for the conservation of ideas. True, and it is here that we must emphasize the continual practice of *translating thought into writing* by the regular making of notes based upon observation and the other mental processes required to make observation of value.

Note-making should, indeed, become a regular habit, if it be only in the form of a diary. Always it is recommended that a pocket-book be carried. Its form, size, etc., will be determined by the object in view.

It may be a journal entry of all the facts observed. It may be simply intended to serve as a diary, without reference to botanical observation alone. But for the present purpose it should be specialized, and, the particular section studied being concentrated upon, descriptive notes under definite heads should be made. These may be accompanied, in the case of ecological work especially, by maps made upon a systematic plan, and other special means of recording information.

The notebook is also necessary for floristic work, not only for recording the exact position of an uncommon plant, but also for describing, in reference to any numbered specimen, characters that may be useful for identification or description, that may disappear.

But above all, the use of the notebook in the field is almost essential for all those facts of biological interest connected with the plant's behaviour which must be recorded at the moment when they are performed, since in this case it is fatal to trust to memory. Such elements of plant life as pollination, for instance, can only be completely known from data recorded in the field. Then, again, there are many notes of general interest that may be put down in the notebook on the spot. These can be later referred to their proper place in the general study of plants when one returns home.

It is impossible to emphasize too strongly the value of sketches and drawings, either of plants themselves, or particular organs, or of types of vegetation, made in the field. Plants may also be carried home and drawn or sketched whilst they are still fresh. The habit of drawing and sketching, once acquired, will be found to be of invaluable assistance.

Notes made in the field may, on return home, be amplified by devoting thought and study to the meaning of brief memoranda which may be unintelligible or disjointed when perhaps hurriedly jotted down on the spur of the moment—though it should be added that deliberation is to be advocated where and when it is possible.

Some memoranda made in the field book may serve as future lines of enquiry, hints for development of some scheme or research to be added to by subsequent observation. The field notes may alone be a bare record of facts. But they may become a chain of evidence in some line of investigation, carefully analyzed, arranged, collected, and thought out. One series of observation may be found to bear upon others. They are especially valuable when they form a description of some phenomenon or process of plant life.

The notes made in the field may then be rewritten and extended on separate sheets for arrangement on the card system. All cognate facts relating to some particular subject or object may in this manner, if desired, be collected together under that head, or in any other manner. There will thus be two sets of notes: a journal series, and a classified subject series. Special lines of enquiry may be continued by the use of special notebooks for consecutive memoranda upon some definite subject or object, species of plant, or type of plant formation, process, etc.

Of equal, if not greater, importance is the practical field work. For, valuable as theoretical or observational work is by itself, practical work gives a greater insight into the real nature of plants, and the principles which regulate plant life and work.

One may devote oneself to practical work for systematic purposes or for ecological work. For systematic studies, already some reference has been made to other means of investigation apart from the making of notes. Thus, practical work depends upon intelligent collection, which must be done with a definite object, and varied according to that end. One may, indeed, be either an expert collector or an amateur or careless collector, and of the two the former is the more desirable. A practical means of learning the characters of natural orders, genera, and species is to regularly make dissections of the flowers, which may be temporary or permanent. Again, the execution of drawings of plants or their parts, or of a plant in relation to some factor of the environment, is in itself practical work which gives knowledge and experience only thus to be gained. Much the same applies to the habit of sketching or painting plants, their parts, etc. Colour in particular is best recorded by aid of water-colour sketches. Photographs are valuable, as recording habit and habitat. Photography may also be applied to the record of a plant specimen whilst still fresh, or for an enlargement of the same; or, again, for making an enlarged picture of a dissection or small structure that requires a magnified view.

Much help in systematic botany is rendered by the growing of plants under observation in the garden especially forms that are doubtful species or varieties. This also is a practical method of obtaining a knowledge of the relationship and origin of species. Hybrids, also, are best studied in this manner. The permanence of species, too, can be ascertained by this method. It also gives some idea as to the requirements of species, in this case affording data of physiological or ecological value.

Much valuable practical work may be undertaken from a systematic point of view by carrying out experiments in cross-pollination in order to determine what species are fertile *inter se*, and to try and reproduce, artificially, the work of plants in a state of nature, or to unravel the origin of hybrids, and variations from a type; and, indeed, for a great variety of purposes.

Practical work from an ecological standpoint may be of a very varied character. Indeed, a large part of ecological botany is strictly practical, or experimental. Observation alone is necessary for the perception of the characters of the vegetation of a district, but to be complete it must be followed up by practical work.

In the first place, a prime object is to determine the nature of the plant formation, the associations and societies it comprises. This entails much practical work, beyond mere observation. The soil characters must be estimated by chemical, or physical, or mechanical analysis. Points of the compass must be ascertained, also the dip, aspect, slope, etc. It is required to know the character, depth, etc., of the water in the case of aquatic formations, and in the case of terrestrial formations the water content, light intensity, and temperature, etc.

There is also the essentially practical work of mapping, on whatever basis. This requires the use of theodolite, levelling apparatus, contouring, etc.

A large amount of practical work is entailed in the securing of accurate meteorological data, such as the recording of barometer, thermometer, minimum, maxi mum, and ordinary readings, dew-point, wind force, sun intensity, and of rainfall, etc.

All these data are necessary, apart from the practical work connected with special or normal factors of the environment, the estimation of any particular plant's requirements on the one hand, or the actual factors the environment presents and the response of the species found there on the other. Here physiological and ecological work come into direct contact. Many other special features of ecological work demand practical study, and it is only necessary here to give a small selection of the more important lines of enquiry. Each working ecologist has his, or her, own system of work, and it is quite unnecessary to detail the scope of the ordinary routine entailed before each operation can be commenced.

Apart from general practical work, which is of itself experimental, though following known lines, and seldom, except when so directed, giving variable (and so experimental) results, there is also what may be called experimental work, since it is carried out with the express object of affording answers to questions that, as yet, have been unanswered.

In this respect, one may consider a large part of the work as physiological. Such are experiments concerned with the requirement of selected species with regard to any of the following factors (amongst others), as soil, water, air, etc. Plants may be grown in different types of soil in order to determine exactly what soil is most suitable, and the same applies to air, water, etc. Here one commences with the species and ends with the habitat factors, thus combining physiological and ecological work. One may also estimate light, temperature, and other requirements.*

Commencing from an ecological standpoint, one may select a definite station, as has been done at Blakeny, Holme, and elsewhere, and study the conditions in a prescribed area, making a yearly record of the results obtained. The work may be carried on at intervals as opportunity presents itself, or continuously for a definite period.

Such work is especially valuable, from the experimental standpoint, in determining the development, or

* Plants may be grown in the open under different conditions, or in pots, taking perhaps half a dozen pots each provided with different soil, etc.

history, of a formation, by studying the progress in a limited area of plant growth in open formations, or by making such open conditions and watching the growth and mode of invasion of plants purposely established there, or allowed to colonize the ground naturally.

Correlated with such an ecological survey are, of course, the physiological results that simultaneously accrue.

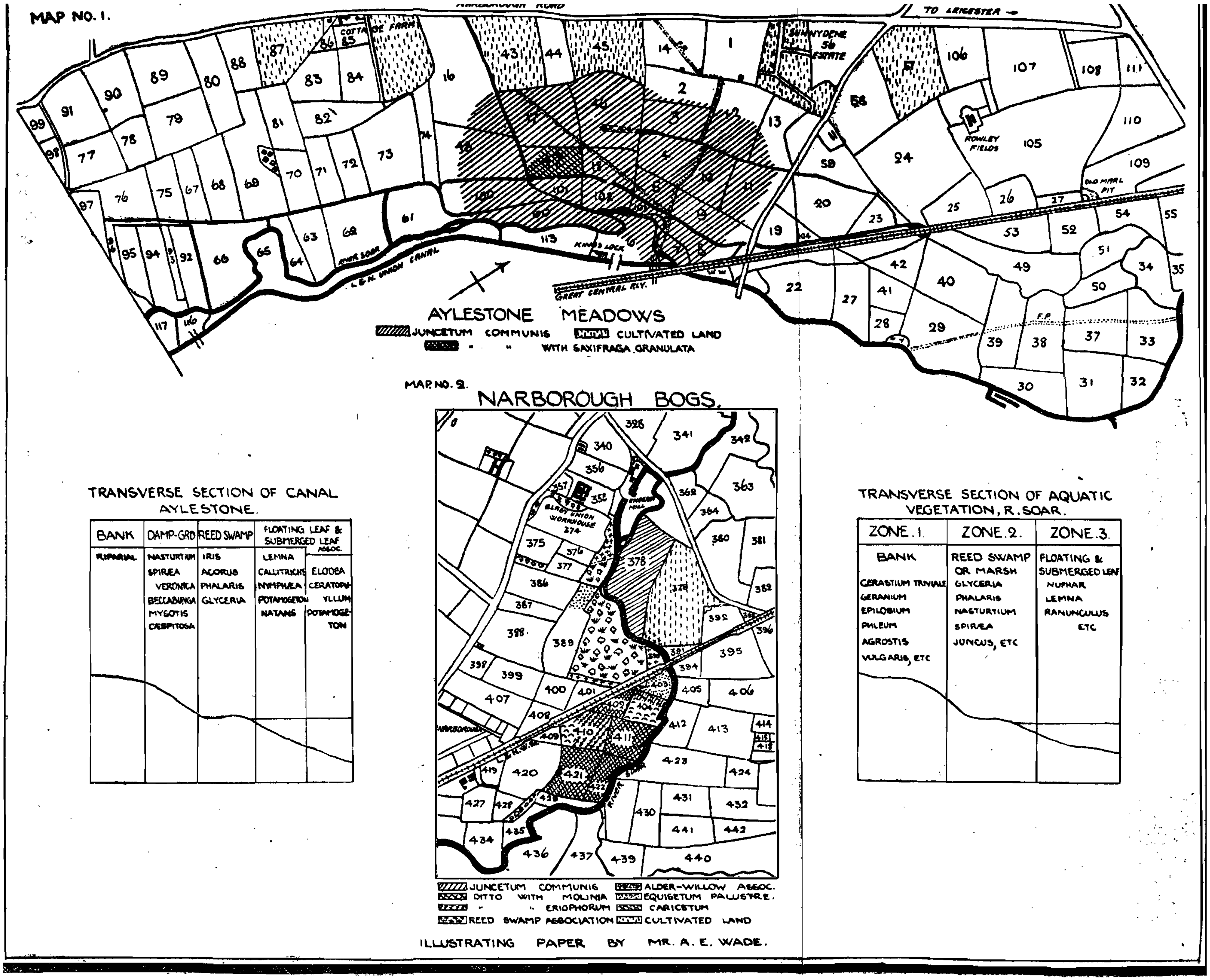
In such work a systematic meteorological record is kept. This continuous record affords means of comparison, and any unusual phenomena may be found to react specially upon the vegetation. In doing experimental work it is necessary to make systematic soil samples whereby it is possible to correlate the relation between the environment and the plant.

As in ordinary practical work, it is possible to carry out a variety of experiments by pot and water culture, in addition to making soil samples.

Systematic work is experimental when it is concerned with the growing of hybrids to determine relationship, etc.

A method of carrying out preliminary survey work which is suitable for beginners is what may be termed "Field to field work,"* or the use of the ordnance survey maps. This is systematic survey work in that it is based on the utilization of the areas in each six-inch map for reference (Map, Fig. 27). The areas are numbered, and the numbers are quoted in examining each area in the list or more detailed observations made upon that area. A large proportion of the areas in each sheet consists of fields, pasture, or meadow; but woods, coast areas, lakes, rivers are also represented, and these are numbered in the same way.

* The word "field" is relative, and for reference only. The work includes all other areas—such as woods, heaths, etc.—given on the ordinary ordnance map.



G. 27.—SURVEY METHODS BY THE "FIELD-TO-FIELD PLAN." MAP ILLUSTRATING RESULTS OBTAINED BY PUPIL OF THE AUTHOR'S. ALSO ILLUSTRATES TRANSECTS (*see Fig.* 32). To face p. 16[illegible]

This preliminary work is subsidiary to mapping, but mapping must be done on some such plan, and the six-inch map can be taken as a basis for maps on a larger scale, made on squared or other paper, to the desired scale.

It is necessary in survey work initially to fix the exact position of the station of an important plant, or the locality of a number of species, or the position of a plant formation or association. Since fields vary little locally, except where soil varies, this map survey enables one readily to refer each field to its type; and the employment of boundaries, and the method of working provisionally by them, in this way fixes relatively the position of the assemblage of plants and the relative position of the associations it represents.

Further, the ordnance map method is a means of reference. The numbering of each area affords a means of reference to the plant notes made in each area, and the fixation by the map of the flora recorded in each list. This, again, is a point of importance. It at once gives the mere list, or the fuller notes, a greater value. And no method for the increase of value of work ought to be omitted or rejected as tiresome or unnecessary.

As stated, *each* area is numbered. Suppose the map is XXXI. S.W. Middlesex, the fixing of the locality of a plant upon that map ensures the indication of it within a mile or so. When the actual area on the map where it occurs is numbered, and this number, —say 80—follows the map number—*e. g.*, XXXI. S.W. 80—it gives one within a hundred yards or so the exact position of the site. If a map of the area is made, the actual position within a few inches or feet may be ascertained. In the case of trees, these are inserted upon the twenty-five inches to the mile map already, but the species is not indicated.

The method of numbering, being artificial, may be systematic—*i.e.*, one may number each area at the outset from left to right across the sheet in rows, or each area may be numbered as examined. The boundary areas on each ordnance map by itself are, of course, not all complete, and the portion on one map may be numbered and cited by the number of the sheet, whilst the adjoining portion on the next map may be cited by the number of the sheet and the artificial number; and in such cases both numbers should be cited together, coupled by =, with a letter N., S., W., E., in brackets against each to show the point of the compass for citation purposes.

This numbering of areas on the map, and of the notes made upon them in the notebook by the same numeral, affords a direct means of cross-reference. It serves to give the geographical position at once. Naturally when all the lists or notes on all the areas in a map have been collected, these may be placed together as the pieces of a puzzle and pieced together. One then obtains the necessary plant lists to form a botanical map of the area—supposing this has not been done independently—and it is necessary in reading the meaning of these data to dispense with the artificial boundaries of the areas—which are hedges, etc., and of human origin—and to delineate the real, or natural, boundaries. If all the areas are fields, and the soil and other conditions are the same, the whole area, unless it varies from any reason, may be mapped by aid of colour, symbols, hatching, or other methods.

Though this method is intended to be introductory to more detailed survey work, any area that demands special study may be charted by drawing a map to a larger scale of the area, using paper ruled in squares of definite size, each square on this representing so many feet, and by indicating the species by a symbol or other means. This gives an accurate idea of the actual vegetation of such a tract. If only isolated plants need mapping, they may be put in, or a letter of the alphabet may be used to denote the type of plant formation, such as, A for that of clays and loams, and a Roman numeral for the type of association—*e.g.*, I. for damp oakwood association, II. for scrub association, III. for neutral grassland, and so on. In vegetation maps, colours are used and letters of the alphabet are employed on the same colours.

The ordnance maps are on a definite scale, the ones recommended being six inches to the mile ($\frac{1}{10560}$). The map can be readily enlarged to a greater scale if desired, by using any scale required and representing the map, or any special area or areas, by so much more. The area may be measured by the map scale, and this multiplied, say, ten times, when the scale will be $\frac{1}{1056}$, or five feet to the mile. If the area is one inch square, the map used will then be ten inches. The actual length of the area being known from the scale, if the paper used is graduated into squares it is easy to measure the length of each square; and as the area is laid out in such squares the vegetation in each square is readily delineated. One may adopt the reverse plan and work from the scale, and reduce the enlarged plan to the six-inch scale for laying down of features on the six-inch ordnance map, which is the most convenient method.

A further feature of the map method of survey is that it gives one at once an accurate sense of direction, and enables one to preserve the proportion of things.

By means of the map, the points of the compass can also readily be ascertained.

Information as to altitude is also obtainable from the ordnance maps. The contour lines are given, and these help one to put in the boundaries of the formations dependent on soil. The geological one-inch, or better, six-inch, maps used in conjunction further help one in the same manner.

Upon the six-inch ordnance maps, also, a good deal of topographical information is given, which may be of much value. Some place names give a suggestion of the former existence of valuable plant indicators, such as Ling's Hill, which denotes the existence formerly, or at present, of Ling. The larger-scale tithe or parish maps and some old estate maps give even names of fields, etc., and the existence of woods, etc., since destroyed.

This method is invaluable to beginners. It arouses the interest. A close study of a field enables one to know exactly the type of flora, and gives one an intimate knowledge of a district; and it is naturally a more scientific and systematic procedure than ordinary botanical work, which is often desultory and aimless. Moreover, it ensures careful work. It is systematic and thorough, leaving no opportunities for omission of important facts; and, being preliminary to survey work on more detailed lines, ensures gradual progress.

Where detailed survey work is rendered unnecessary, from the absence of well-defined or natural plant formations, this preliminary survey work is quite sufficient. Woods, etc., being examined on the lines suggested, their type can be subsequently determined by this method without more detailed mapping if desired.

If it is desired to do special ecological survey work with a view to the construction of a botanical survey map, or vegetation map, the methods employed in the foregoing case need to be more detailed and thorough, as a rule, though in some areas only the few really natural plant formations need be so treated, and for a small-scale map even these could be so treated. But if enlarged scale maps of a large area or of special tracts are needed, the area must be mapped out and surveyed yard by yard, and the vegetation mapped accordingly.

For this purpose it is necessary to adopt some definite line from which to start, and gradually extend the area examined. This is called the base-line. Its length will vary according to the extent of the area to be examined. Care should be taken in the selection of its position. It would be wise in the case of maritime vegetation to start from high or low water level landward, and not *vice versa*. In examining hilly country, which is often unsuitable for this type of survey, the direction of the hill should be taken into account, as zonation usually follows the contour. Where an isolated tract is to be carefully examined, it is advisable to select as far as possible level country, unless it be especially required to study land which varies in altitude. An advantage of choosing level country is that it enables one to sight an object readily, to take levels, etc.

Following the choice of the ground to be examined (parenthetically, if a whole region is to be surveyed in this way, there can be no choice of the area, but only of the fixing of the base-lines), it is necessary to make initially a careful study of the physical and geological structure of the area, as this has an important bearing on the ecology. For this purpose it is necessary to make use of the geological map, and, if this is on a small scale, to put in the boundary lines on a map of the same scale as the map to be constructed to compare these with the plant formation boundaries.

For the same purpose it is necessary to make a thorough study of the altitudes, by aid of ordnance maps, and if additional ones or contours are needed, to determine these by levelling with the theodolite, range-finder, plane table, or other method. In the case of great variation in altitude the aneroid may be used. Contour lines may often coincide with geological structure or ecological boundaries, and hence they are important. At each hundred feet they are given on the ordnance map.

When these details have been ascertained it is necessary to study the ecological features, which for mapping purposes include the charting of the plants. To make such a chart accurate it is necessary, working from the chosen base-line, to survey the ground systematically. This is done by dividing the base-line up and plotting upon these divisions rectangles, which are in turn divided up so that small squares are formed which lend themselves to accurate charting upon squared paper having a definite relation to the squares of vegetation (Fig. 28). The scale chosen will vary according to the purpose.

Having plotted the main square and marked it out on the ground by tapes, measuring each side, stakes are driven in which serve for obtaining sights, and for numbering for reference. The numbers may be written in large figures and letters that can be readily seen at a distance. The main posts being driven in, bearing flags if desired, each side is divided up, and from the sides of the squares parallels are run to the opposite sides, each divided up as the sides, and stakes driven in at intervals. If the system of squares and divisions is made on the decimal system, it allows, if the scale be on a decimal system, of the ready reduction of distances to the chart used for mapping.

When the boundaries and posts are fixed, it is then possible to take a square at a time and to examine all the plants and to put down on the squared paper the exact position of each plant. When the area is done, the arrangement of any communities, their outline, may be put in by using symbols for each one, and the areas themselves may bear a reference letter or number. The individual plants may be put in graphically—*e.g.*, trees by an approximate sign appropriate to the form of the habit, as on ordnance maps, or by symbols; the initial letters of the Latin names being used—*e.g.*, for *Quercus pedunculata*, Q. P. There are various ways of charting, and in some cases the com-

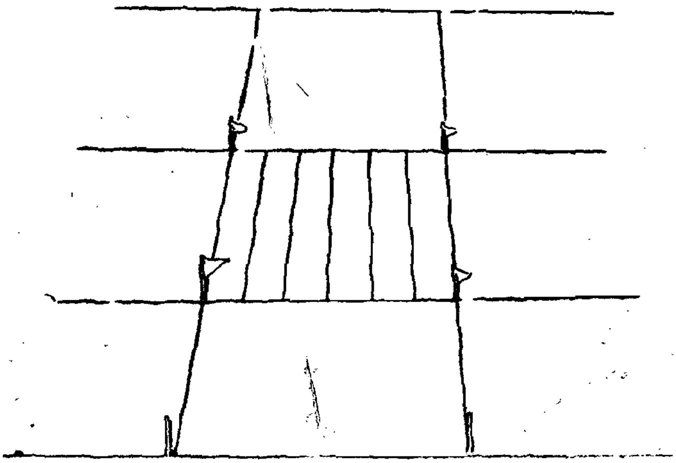


FIG. 28.—DIAGRAM TO SHOW PLAN OF SURVEYING BY THE SQUARE METHOD, WITH SQUARE ALSO DIVIDED INTO "GRIDS."

plete areas of formations, or associations, or societies, may be indicated by suitable hatching or by colours. This last method is the most graphic.

When the field chart on squared paper is completed it may be transferred to a definite final map on the required scale. It is either reduced or enlarged. The form of the final features—physical, physiographical and ecological—and the method of representing them may vary; but the first two may be shown, as in geological maps, by hatching or colours.

Unless there is a definite desire to carry out a survey on such detailed lines, the above method need not be adopted throughout, but only for certain areas where the vegetation is complex and demands it. The method is equally, or more specially, suited to experiment and permanent ecological work independent of mapping, and will then deal with the determination of the soil-water, light, temperature, and other factors, the regular keeping of meteorological data, the study of plant succession and invasion, and the study of the adjustment of the plant to the environmental factors and the adaptation of the plant to those factors, the study of the genesis and history of the formation, and so on.

The survey methods above outlined may be on the square method, as above; or any square may be studied in greater detail on the gridiron method, each square being divided into five parallelograms by running four parallels from the base-line to the opposite side (Fig. 29). Each parallel may be divided up as before. This last is only for the most careful and detailed work.

Mapping, indeed, may be done without detailed charting. The boundaries of the formations, associations, etc., may be put in from the 6-inch ordnance maps, by aid of the contours and geological maps. A perfect knowledge of species, of the different ecological formations and associations, is an essential preliminary to this type of survey, however, which should not be attempted until such knowledge has been acquired.

Preliminary work for mapping may be done by the "field to field" method as already outlined. It trains in habits of accuracy and in accustoming one to the use of maps. But it is necessary to distinguish between using the 6-inch maps to put in the broad outlines of ecological divisions for charting each type on a map, on a reduced scale, and the examination of each field, etc., in each six-inch map—that is to say, making a thorough and systematic analysis of each area or the whole of the ground covered by the map. If one takes a map of an area in a cultivated region, where fields actually predominate, a brief survey of the whole area by

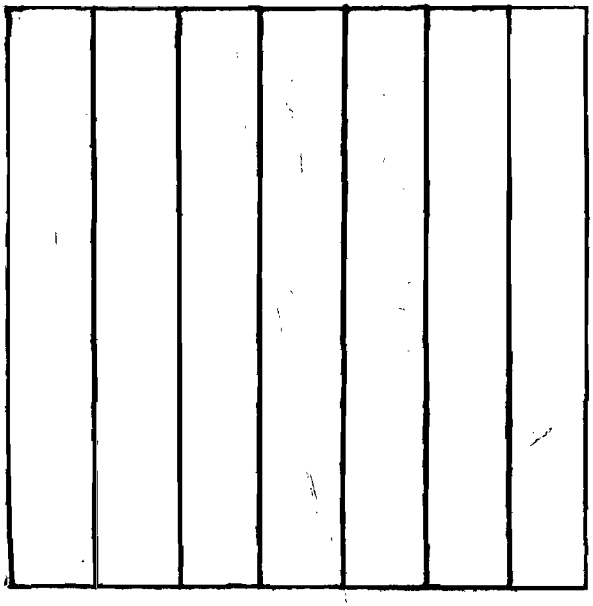


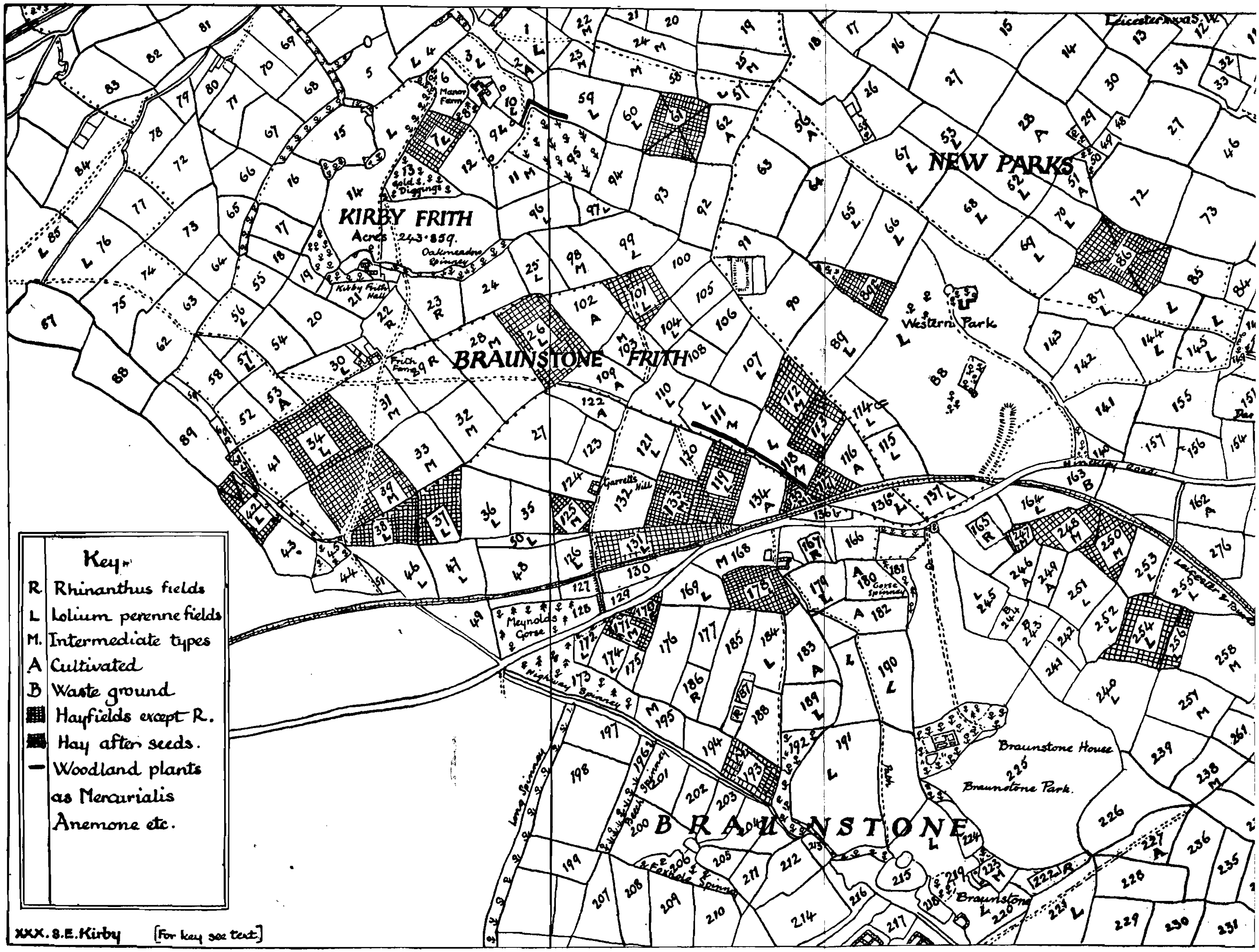
FIG. 29.—DIAGRAM TO SHOW PLAN OF SURVEYING BY THE GRIDIRON METHOD: SQUARE DIVIDED UP INTO "GRIDS."

walking diagonally across the area in one or more directions, and a rapid examination of a few typical fields, would suffice for all practical purposes to determine more or less accurately the type of plant formation—*e.g.*, neutral grassland, with possibly an Oakwood here and there—and from such a survey the botanical map could be made by colouring the area of woodland in one colour, and the rest by another colour. But if a subdivision of the types of pasture or meadow included in the neutral grassland, and varying locally, is required, then the more careful field-to-field method is necessary. This would reveal, for instance, any vestige of the natural vegetation which might be so small as to be negligible when represented on a small-scale map. Such surveys are eminently desirable, but they are the work of years, and require the organization of a large band of workers living on the spot to carry them out to perfection and completion (Map, Fig. 30). It is necessary, for instance, to visit each area several times in each year, and as there are often 150 areas on a single map this may mean 600 visits. In a small county where there are perhaps 100 tracts, each represented by a map of this type, to be examined, it therefore means 600,000 visits. A single observer, with limited time, cannot, allowing for accidents of weather, etc., expect to do such work unless a large part of a lifetime be devoted to it. It is therefore not without reason that this method, simple as it is, is recommended to all who wish to study plants from an outdoor point of view.

Anyone, everyone, can attempt it. Every one who does will benefit thereby. The more numerous observers working on such lines are, the sooner will a detailed analysis of British plant formations be completed.

Perhaps the most obvious reason for emphasizing the value, importance, and need for this detailed work is the fact that it affords a preliminary, if not final, soil survey of the country; and this is of the greatest importance to agriculture, and is of economic value. Any botanist who attempts it is therefore not only rendering a service to his country, but is becoming a soil expert, and learning the principles of agriculture from the most important aspect.

As a rule the employment of the square or gridiron,


KIRBY FRITH
Acres 243·859
NEW PARKS
BRAUNSTONE FRITH
Western Park
Braunstone House
Braunstone Park
BRAUNSTONE
Key
R Rhinanthus fields
L Lolium perenne fields
M. Intermediate types
A Cultivated
B Waste ground
Hayfields except R.
Hay after seeds.
— Woodland plants as Mercurialis Anemone etc.
XXX. S.E. Kirby [For key see text]

or other similar method, is necessary if one wishes to study the development of a formation; although in some cases this may be determined independently without survey work—*i.e.*, charting accurately definitely measured areas—since, as it is necessary to study the relationship of adjacent related associations, which have replaced each other, the whole character of each

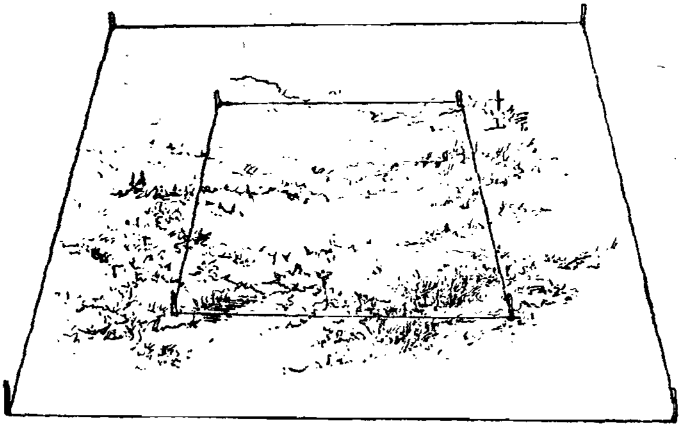
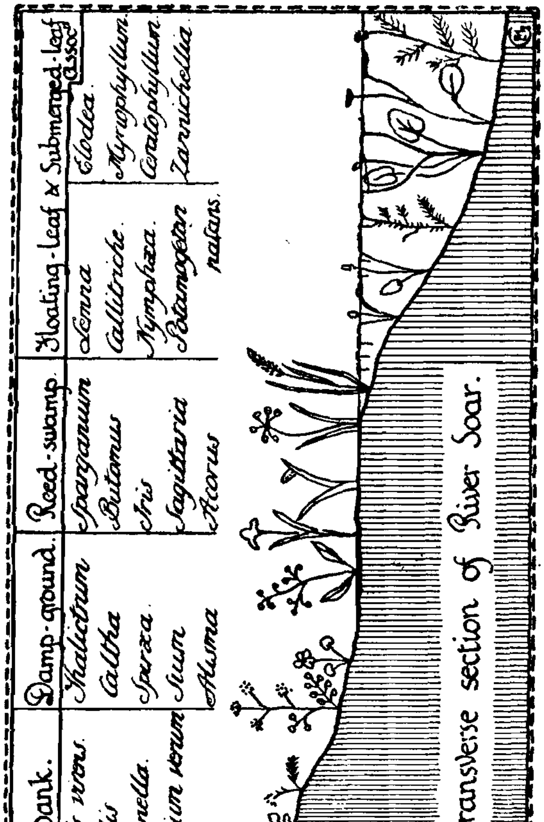


FIG. 31.—SURVEYING VEGETATION BY THE QUADRAT METHOD: DIAGRAMMATIC SKETCH.

and the conditions of the dominants under varying conditions, and their relation to other dominants, when growing in association, is required to be known, amongst other data.

Survey work, as understood above, is also necessary if a detailed description of a definite plant formation in a definite area is required—*i.e.*, if the whole conditions are to be determined and to be explained, and not merely the reference of the vegetation to its type is required. The more so is this necessary when the environmental factors are to be ascertained and the response of the species to the stimuli of the environment needs to be elucidated.

If a particular area requires to be studied on the square system, one takes what Clements has called a quadrat, or square, marked out on the ground to be



G. Mercer.

FIG. 32.—TRANSECT ACROSS A PORTION OF AQUATIC VEGETATION: GRAPHIC REPRESENTATION.

examined, say a metre square, and examines one at a time thus without using a base-line, since here a definite small area is chosen (Fig. 31). The quadrat system can be extended indefinitely, and the sides may be as large as one likes, say 100 metres, and may then be equivalent to the square method.

Another useful method, or the making of what is termed by Clements a *transect*, consists in making a section across a piece of ground, and marking the plants that are observed on the line traversed (Fig 32). It corresponds to a geological section in geology, as a geological outcrop corresponds to the area of an ecological plant formation. Such a method, when carried out in different directions chosen on the basis of the geological outcrops, may enable one to put in the preliminary lines of a plant formation.

Plant formations are arranged primarily on two plans. They either show an alternation, as when one formation is separated from the same type by a different type, due to soil variation as a rule, or where the formations or associations form a zonation or banding, where the succession from one to another is clear. Zonation is often obscured by alternation, which is the commoner of the two.

If the survey work is designed especially to make physiological observations, or to carry out experiments of a physiological nature, it should be remembered that this is part of ecological work, or rather that the two branches of botany are complementary. Therefore the setting up of an ecological station affords the necessary scope and opportunities for physiological work, dealing with the processes or effects of factors on species. Special physiological apparatus will be required for this (*vide* any physiological textbook).

There are numerous operations that have a physiological bearing, which may produce results either physiological or ecological in character, according as the work or experiment deals with a single species or with a community, or from the purely physiological standpoint or the ecological.

One of the most preliminary observations will be the collecting of meteorological data, involving the keeping of records, the construction of tables and graphs, acquired by the use of instruments, including the barometer, thermometer, hygrometer, rain gauge, anemometer, heliometer, and other instruments. The observation will enable one to ascertain conditions at any period of the year, as regards atmospheric pressure, temperature, dew-point, rainfall, wind, sun.

A series of soil analyses—chemical, physical, or mechanical—made by means of simple chemical tests, reactions, weighing, elutriation, sieves, etc., will give details relating to the soil. The water-content is estimated by drying the soil and weighing with chemical balance before and after drying.

Experiments may be made to show the adjustment of the plant to light, temperature, wind, and also as to the adaptation of the plant to these under the special conditions of the habitat. An estimate of the slope or aspect, etc., will be made by compass, clinometer, aneroid, or other means.

A general study of the atmosphere will be made to show the light conditions, cloud, fog, mist, etc.; the purity of the atmosphere, whether smoke or other gases are present; and also as to the pressure of the atmosphere, and the humidity.

Similar studies are necessary as to the water of the habitat in the case of aquatic plants. It is necessary to determine the character of the water from the standpoint of rate of current: whether it be stagnant, stationary, slow, or quickly flowing. Also the amount and character of the mineral salts in solution must be known, whether it be poor or rich in mineral salts, whether giving an acid or alkaline reaction. It is important to determine the depth of the water where necessary, as in deep lakes, by sounding.

A study of the successional stages of a flora, or association, which shows how it has passed from one type to another, explains the variable conditions which give rise to such changes, largely due to water-content; and this has a bearing on the physiology of the habitat.

Similarly the study of the invasional factors in an environment gives an insight, from the physiological standpoint, into the conditions that enable a plant to obtain a foothold in a new habitat, and its chance of succeeding. For this purpose an area subject to invasion, such as aquatic vegetation, or shingle-beach, should be selected, and a definite area marked out and studied for a long period.

There is a correlation between the foregoing work and the general environmental characters. Each factor has a connection with the plant's welfare, and conditions for its success. The whole of the factors have an accumulative effect upon the plant, and this needs comparing with the effect of each factor separately. The extra stimulus of one factor may affect the rest.

For the purpose of physiological work in the field, quite simple apparatus may be made and used in place of expensive and delicate instruments which may be damaged in the field or subjected to atmospheric effects. Some jars, wire, string, wood, a saw, knife, some nails and pins, together with a few glass tubes, spirit lamp, filter-paper, flowerpots, some cardboard for making shades, black paper, photographic printing paper, etc., will go a long way. Indispensable instruments that must be taken should be as few as need be, unless the station is permanent.

A general study of the physiographical conditions should be made, which will be useful from a physiological as well as an ecological standpoint. If the region is level all variations on a small scale should be taken into account. If mountainous, the effect of variation on a large scale should be studied. Proximity to the sea, prevailing winds, etc., will, like other factors too numerous to mention, each have an influence on the vegetation, and the means by which it adjusts itself and adapts itself to the conditions.

The study of conditions of a limited tract is involved in the establishment of a station for the study of either physiological or ecological conditions.

Such a study has, largely from the ecological standpoint, to do with the history of a formation, considered apart from its constituents or type. Such work is only to be carried out by carefully observing the changes that take place in the association over a long period, and for this reason alone the choice of a small tract is the only possible one, for it would be difficult to undertake more, owing to the labour and time involved, unless the number of workers is large.

Only gradually can the history of a formation be unfolded, for the earlier stages only persist when and where the earlier conditions persist. Such remains may occur on the margins of an association, or in other spots where conditions vary from the normal.

In studying the history of a formation, how it has come to be, it is necessary to take into account the principles which govern the establishment of a formation or its contained association. Primarily the forming of a community or family, as the members or individuals derived from one parent are termed, depends upon the formation of an abundance of fruit and seeds which are dispersed by various means either near or at a distance from the parent. This is termed aggregation. The study of the factors of dispersal is therefore an important one. According as the plant possesses adequate or inadequate means of dispersal, depending on its adaptations to this end, and the suitability of the surroundings for these to effect this object, so will it either succeed or not in the struggle for existence. For a wood, for instance, is a barrier to such dispersal; so are mountains, embankments, open water (in the case of land plants), etc. The migration of plants, as this process is called, depends on these and other factors. Migration may be brought about by definite means or by accidental means, and according to many authorities the latter has had a great influence on plant distribution.

The success of the two first processes depends upon the element of competition which exists between individuals of the same species, and between different plants. The difference in habit of plants is an adaptation to this end, and also influences the success of plants having other habits. The tree habit overshadows all else, and in the open the grass habit succeeds. When a plant has obtained a footing, and its seed has germinated, it proceeds by ecesis to establish itself. This may or may not be successful, and various factors regulate this—as the suitability of the soil and other factors. But assuming ecesis is successful, the next principle or process comes into play—*i.e.*, invasion—as in open formations, such as maritime formations, dunes, strand vegetation, etc., or where the reed-swamp invades aquatic vegetation, or scrub extends over pasture. As a result of the invasion of one formation by another we have as a natural sequence another process, or the succession of associations in one habitat, whereby one is replaced by a new stage. The converse state, or retrogression—return to a former state—as where pasture becomes scrub, and scrub woodland, may obtain.

The arrangement of formations is nowhere uniform, as conditions are never uniform over a large area. And formations are thus everywhere diversified. But this diversity, though obscured, is regulated by two principles, whereby formations alternate, etc., the more common arrangement, or where they exhibit zonation. Alternation is more general in closed formations, zonation in open formations, as in the case of aquatic vegetation, moorland formations, or maritime vegetation. In the study of a limited tract, apart from the study of the above processes in the genesis of vegetation and its history, we may study the correlative adjustment of the plant to the factors. Thus the adjustment of a plant to water involves a study of the processes of absorption, transport, transpiration. Adjustment to light deals with photosynthesis, translocation, and storage of food material, phototropism, nyctitropism. So also adjustment to temperature deals with the various processes, amongst which are digestion, chemosynthesis, respiration, fermentation, germination, growth and nutrition generally, reproduction and propagation, pollination, and fructification. Adjustment to gravity, contact, and shock, is another means of studying the life processes of the plant, dealing with geotropism, climbing plants, etc.

A further study of a limited tract may deal with the adaptations exhibited by plants as a result of their adjustment in the foregoing manner to the various factors of the environment, according to which plants, in relation to water, may be Xerophytes, Mesophytes, Hydrophytes, Amphibious, and these last include floating, submerged, and bog plants.

In relation to light, plants also exhibit special adaptations, and may be divided into sun plants and shade plants.

Work in the field has a direct connection with laboratory work. It serves to explain the latter, as in turn the latter explains the former. It gives concrete examples of the result of unseen physiological processes which are studied in the laboratory.

General results can be, moreover, obtained in the field by water and pot cultures, and these may be applied, not to types alone, which are the main sources of laboratory study, but to all the plants of the habitat. Such general results may be tested by more delicate tests in the laboratory.

Laboratory work is concerned largely with quantitative results or effects. It deals with measurements, graphic representation, reactions (chemical, etc.), analyses. But it may also be qualitative and describe the nature as well as the extent of any particular factor. It is also regulated by controls, which check results, and help to prove them more clearly. Laboratory work deals largely with elemental processes, or the bases of principles, and helps to demonstrate them. Field work provides material for the testing of those general principles, and by the study of variable results it helps to show the limits of action.

This is due often to the employment of different species, or different plants, under varying conditions (often it may be unknown).

Furthermore, laboratory work is largely theoretical and experimental, except when dealing with known causes and effects, and it starts from hypotheses, in order to work from the unknown to the known. It also determines the meaning of results by aid of tests. Hence this work is more suited to the study than the field.

Field work must, from the nature of the surroundings and available appliances, deal more largely with material, or specimens in a word. The application of the study of the meaning of the material in the field to the principles explained, elaborated, and tested in the laboratory, is more especially the scope of field work. The two in every sense, field and laboratory work, are complementary.

There is one especially valuable feature of field work. It demonstrates on a broad basis the experiments in the laboratory.

In laboratory work, more or less, it is the parts of a plant, or its different organs, in the case of physiology (which is here especially referred to in connection with such work), that are especially utilized for demonstration, analysis, and study.

In the main the object is to establish the nature of the functions of each organ, and their relation to the known main causes or factors generally, irrespective of different phases of each cause—*e.g.*, water, light, temperature, etc. In the adaptation of organs to their adjustment to such factors variety is shown—as in the types of climbing organs, adapted to climbing, which are of various types and different structure.

Further experiments in the laboratory from the physiological standpoint deal, to a great extent, with processes governing growth, nutrition, movement, behaviour, and with their meaning, history, and correlation with other processes.

As a rule, physiological work in the laboratory may be said mainly to deal with definite, usually common, plants, and the illustration of the working of each process in such cases.

In the case of field work there is an assumption of the course and action of the processes, and by utilizing a wealth of material it enlarges the data obtained in studying the few well-known types, and the illustration of processes or responses to stimuli.

Field work affords the illustration under nature of the connection between stimulus and response, at once, and the visible effect or nature of adaptations evoked by the factors of the habitat.

Field work also provides, by the infinite material it affords, scope for the study in nature of all the processes concerned in plant nutrition, growth, and behaviour at one and the same time. This gives a synthetic idea of the life processes of plants, just as an analytic conception is obtained by their study in the laboratory.

There is, moreover, an opportunity for the study of the complete behaviour of a plant throughout its lifetime. Such a study gives one a continuity of action, a succession of changes, bringing into proportion the whole activity of the plant. It is a study in development. Such connected studies give a far better idea of the life and behaviour of a plant than merely isolated studies of perhaps three or four processes which do not give a complete history of the plant's mode of existence.

Taking an annual plant, one may study first of all the seed, which is the first stage of the new plant's activity or the culmination of the parent plant's. But little or no change can be observed in the seed during its resting period in autumn and winter. It is only when certain factors — sun, air, light, water — are supplied in the proper proportion at the initial season of activity in spring that the process of germination commences, and not until this stage is reached can one in general observe any active changes in the plant, any movement, any growth, any adjustment to the character of the environment. As germination proceeds, the seedling exhibits considerable change in form and structure, and all these manifestations of life are of the greatest interest. Following the early stage comes the formation of the first true leaves. These vary much in form, and show some relation to the requirements of the habitat, and are also arranged on the stem, which keeps pace with their development in relation to light and water-supply. Buds exhibit much variation also, the arrangement of leaves within them being diverse. Trees exhibit well the characters of leaf-buds. The evolution of the stem, its adaptation to its surroundings, whether erect, prostrate, climbing, twining, etc., forms another stage in the history of plant life. Its mode of elongation is varied, and so is its structure, all of which can be correlated with the demands of the habitat. The form, mode of unfolding, and arrangement of the leaves is a subject for an infinite amount of study. Flower-buds exhibit a certain arrangement which is connected with the arrangement of the parts of the flower. Flowers and the order of their development, the structure, relation to insects, or other agencies concerned in pollination, afford likewise a wealth of material for observation. So also do the various forms of fruits and seeds, their adaptation to dispersal, and effective germination.

It is not too much to say that the study of development of a tithe of the British flowering plants is sufficient to occupy one's attention for a lifetime. Especially interesting are the processes of pollination and dispersal, which are intimately connected with the evolution of the flower and the distribution of plants.

These last two processes, pollination and dispersal, may be studied from a variety of standpoints. In regard to pollination there are the relations of floral structure to insects, wind, water, etc., all of which are adaptations influencing the evolution of the flower, which, from an originally open flower, has become a tubular structure.

Pollination is of two types: cross-pollination and self-pollination. The former is the more beneficial of the two, and there are therefore devices to ensure that it is secured.

Cross-pollination may be secured by contrivances to avoid self-pollination, such as the diœcious or monœcious condition, or the ripening of anthers before the stigma, or *vice versa*, and by other means. The floral mechanism is itself directed to favour this cross-pollination, the scent and colour of flowers in themselves being a means of effecting the assistance of insects, as are also the provision of pollen and honey. The manner in which the mouth-parts of insects are adapted to the securing of the honey, the contrivances whereby pollen is deposited on the insect in such a position that it comes into contact with the stigma, and the various insects that visit each flower should also be noted. These are only a few examples of the interest that surrounds pollination.

Dispersal of fruits and seeds is of especial interest from the ecological standpoint because it is initially by its means that plant formations and associations are formed.

Dispersal has a connection with the processes of aggregation, whereby plant individuals come together. This is the result of reproduction. By migration the arrangement becomes diverse. It is achieved by the dissemination of spores, seeds, fruit, offshoots, or the plant itself. The fruits or seeds are adapted to dispersal by being saclike, winged, provided with silky hairs, with parachute structure, or are chaffy, plumed, awned, spiny, hooked, sticky, fleshy, etc. The agents of dispersal are water, wind, animals, man, gravity, glaciers, growth, propulsion—in the last case the fruits or seeds may be hygroscopic, turgescent, dry, or indehiscent fruits.

By competition the effect of aggregation is influenced by other plants, and this causes a struggle for existence. If the plant is able to establish itself by ecesis, it helps by degrees to form the association or formation.

All these processes may be traced back to reproduction and dispersal, and the general sequence of changes each plant undergoes, the history of its success or failure, is elucidated by a study of this subject. It affords endless scope for observation.

Both of these processes—pollination and dispersal—are essentially adapted to field observation, and can only be studied adequately in the field.

What may be regarded especially as biological study is concerned with the relation between plants and animals. Pollination and dispersal are largely associated with animal agency, and are part of this study. But there are other relationships between animals and plants. There is, to begin with, an antagonistic relationship. Animals are often harmful to plants, whether wild or cultivated.

Caterpillars ravage wild plants, other insects bore into trees, herbivorous animals browse leaves and tender parts of trees, shrubs, etc., and plants therefore have developed defences to protect themselves. Some plants are poisonous—as Hemlock—and exhibit a warning sign. But plants poisonous to man are not always poisonous to animals.

There are many seed- and fruit-eating birds. These may help on the one hand to lessen the number of plants (especially in the case of annuals), on the other hand they may disperse them. Naturally plants form the staple food of many animals, so that there is a mutual relationship also between the two kingdoms. Browsing animals may not harm plants, but encourage vegetative propagation, and so cause plants indirectly to become rhizomatous—*e.g.*, Grasses. Insects, by living on plants for food, eating leaves, may reduce the carbon production and impoverish plants. Trees devastated year after year by caterpillars may in the end succumb.

Some plants that are tender exhibit a protective adaptation—the White Deadnettle resembling the Nettle, and escaping thereby.

Beneficial relationships between plants and animals are illustrated by pollination and dispersal, animals serving as the agents in a large number of cases. Also plants use up carbon dioxide and give off oxygen, thereby purifying the atmosphere, save at night. Animals give off carbon dioxide and use up oxygen, so that the plant and the animal are dependent on each other. A similar relationship exists between the soil and the plant, so that all three kingdoms—the mineral, vegetable, and animal—are complementary.

Some plants are pests by preying on others, as Fungi and all parasites and Saprophytes. But, again, some plants, such as host plants, are beneficial to other plants. Moreover plants by decay form humus in which other plants may grow.

Mycelia of Fungi serve to take the place of root-hairs in other cases. Plant bacteria also benefit plants, though some are harmful types.

The whole subject of the relationship between plants and animals is one which will repay careful study. It is intimately connected with economics. The uses of plants is a branch of it, and man's relationship to the plant world is in itself a field for extensive research.

There is, moreover, a special connection between ecology and the interaction between plants and animals. It is by the aid of animals, as well as plants, that humus formation is rendered possible; and the formation of humus is essential to the welfare of large numbers of plants—as woodland plants. Without the agency of insects the carnivorous or insectivorous plants could not obtain their nitrogen, the soil, though containing nitrates, not being able to give it up to the plants.

Aeration by earthworms renders soils that otherwise are badly aerated to be properly aerated. Some animal bacteria have a beneficial effect upon plants.

Especially connected with ecology is the assistance rendered by animals in the dispersal of fruits and seeds, an indispensable preliminary to the formation of definite plant communities. Not only do birds effect this, but also mollusca, squirrels, mice, ants, and other animals.

Birds on migration accidentally carry bits of water plants, fruits, or seeds on their feet, and so disperse many plants in this manner.

This is another subject which is primarily a matter for study in the field.

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CHAPTER IV

BOTANY AND SCENERY

THERE is a close connection between vegetation and scenery, and hence the botanist cannot ignore their interdependence, or be unmoved by the beauty of scenery as a whole, any more than he can despise the beauty of a flower.

We may regard the earth, with its solid crust, or lithosphere, and its inner softer core as surrounded by the hydrosphere or oceans, lakes, etc., and the atmosphere, as one whole. Each of these three spheres helps to make up in the bulk the external features of the globe. Scenery thus is formed by the blending of the various forms assumed by the earth, sea, and sky. When we study the earth more minutely we find that it again is made up of a variety of physical features which may be grouped under the following main heads: mountains, valleys, lakes, volcanoes, plains, plateaux, deserts, and glaciers. These, as will be seen, have been formed in various ways as a result of geological changes. To such terrestrial physical aspects, which are parts of the continents or islands, may be added the oceans, seas, rivers, etc., which make up the rest of the surface.

Upon both land and water* surfaces there is, moreover, a further covering formed by vegetation. This gives a special character to the surface, or a physiognomy. The principal types of physiognomy, so far as

* Mainly freshwater, and, in marine areas, characterized by Algæ.

land and freshwater plants are concerned, based on vegetation, considered from a popular point of view, are meadow, or pasture, woodland, heath, common, moor, bog, marsh, fen, swamp, salt-marsh, dune, shingle-beach. These terms apply especially to the British Isles.

A landscape owes its character primarily to the former sets of geological or physical feature, and in the next place to the generic types of vegetation, if we may so call them, as woodland, etc. Owing to the diversity of factors—geological, etc.—the physiognomy wears varied aspects. Long ago, no doubt, uniformity of conditions prevailed, since in the British Isles virgin forest was practically general. To-day, owing to various causes, such as human intervention and natural changes, British scenery is most diversified.

A typical area shows stretches of woodland, green in spring and summer; yellow, brown, ochreous, even red, in autumn; and in winter (save where evergreens grow*) black, or various shades of a dull hue. Between may stretch an expanse of green meadows or golden cornfields, each set off by lines of hedgerow and trees as squares on a chessboard, or divided, as in the north, by long lines of stone walls of a dull amber brown colour. In lowland districts little else will vary the landscape, save where the lake gleams in the sun in some shallow amongst the moist water meadows, or in the glade of the wood, in which last case the contrast is the greater or more pleasing.

Where barren wastes occur expanses of heaths give a varied aspect in spring and early summer, often golden with rough clumps of Gorse in spring or autumn, or where Ling grows purple with Heather in autumn.

Physical features lend the greatest aid to scenery,

* The British Isles is in the belt of deciduous forest-trees.

and this affects the scenery very strikingly in the diversity of vegetation. Hills are the region of the moors, where bleak expanses extend for miles and miles, sometimes made white as snow by the Cotton Grasses, or green with an early growth of Whortleberry, Ling, Sedges, and Grasses, and in autumn purple with Heaths and Ling, varied with other flowers of manifold hue. There also in upland regions hills alternate with valleys, each clothed with characteristic vegetation, with trees at lower altitudes—the graceful Birch and gnarled Oak (Fig. 33).

Where wet slopes occur bogs develop, and in lowland areas, close by the meandering river or stream, the sameness of meadow or pasture is varied by patches of marsh or fen.

Along the coast the margin is fringed with alternations of salt-marsh, dune, and shingle-beach, or rocks with different types of vegetation in each.

Such are the physiognomic phases of vegetation briefly described. The physical features of a region each bear a particular aspect of vegetation, which may be summarized.

Thanks to lofty mountains we are able in a single tropical area to see in a bird's-eye view all the zones of vegetation which extend from the equator to the poles. First there is at the base a zone of trees, with dense forest—Oaks in temperate zones, Palms in the tropics. Above, a zone of scrub with shrubs, then a belt of grassland, studded with some gay flowers, whilst higher still Lichens reign supreme, and the summit is adorned with perpetual snow.

Typical of mountains is the arctic flora, and outside the arctic regions alpine plants. The plants here have a cushion habit. A carpet of bright blooms makes the alpine flora as resplendent with colour as a flower garden.

Lakes are fringed with tall reeds and other graceful grass-like plants, whilst their surface is covered with chaste Lilies and other flowers, and a host of under-water plants (Fig. 34). Lakes tend to get filled up by the silt that accumulates, and the lake vegetation helps to accelerate this. Some pools in which Sphagnum grows are gradually filled with peat, marsh, and bog vegetation developing first at the margin and gradually filling up the clear area. Upland pools especially tend to disappear in this way. Around the mouths of rivers deltas form, and as the ground is lowland, and silt is frequently accumulating, much the same filling up happens as in the case of lakes, only a channel is left clear somewhere, and the delta lengthens. Reeds, tall Grasses, marsh plants in general, Willows, etc., fringe the river itself, and form a sort of jungle in some parts of the world.

In the regions of estuaries sometimes sea silt forms, and side by side a form of peat, as in East Anglia, not formed by true Bog Moss, but by other Mosses, and by Sedges, Rushes, Willows, etc. Fens form and have a characteristic appearance. Broads are enclosed aquatic areas which get filled up again. Here, graceful reed-beds, clumps of Bulrush, vary the vegetation of the broad, and a scrub or semi-woodland of Bog Myrtle, Willows, Alders, etc.

By the coast salt-marsh develops, with bright green patches of Glasswort, and other types on higher ground.

Marr writes of the fens: "The beauty of fenland is the result of the atmospheric conditions and the nature of the vegetation. The glorious sunrises and sunsets, and the magnificence of the cloud effects, have frequently been described. The peculiar vegetation of the fenland has nearly disappeared, though the flora which once occupied the meres still brightens the

G. B. Dixon

FIG. 33.—ROUNDED HILLS OF THE SOUTH-WEST OF ENGLAND.

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FIG. 34.—VIEW OF LAKE AND ISLANDS IN THE ENGLISH LAKE DISTRICT.

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ponds and dikes which are scattered through the cultivated tracts, and one piece of undrained fen, Wicken Fen, yet survives to show the nature of the former uncultivated plain.

"There one can still roam through the Sedges and Rushes, and observe the fronds of the Marsh Fern (*Lastræa thelypteris*) and the blossoms of a fenland plant. The great pit at Roslyn, near Ely, filled with water at the bottom, gives some notion of the former appearance of the fenland meres.

"Anyone looking over the open spaces between the reeds from a boat, when the banks are out of sight and the water is covered in one place with the leaves and flowers of the Yellow and White Water Lilies, in another with the pale yellow flowers of the Bladderwort, and yet again with the beautiful yellow blossoms of the Limnanthemum, can well imagine that he is afloat on one of the meres of the pristine fenland; and the knowledge that the flat places of the earth may be filled with beauty is here brought home to one in a striking manner."

That this fenland area has been at a higher level is shown by the prevalence of submerged forests along the coastline.

Plains in all parts of the world have their characteristic features. The limited areas in the British Isles are almost everywhere under cultivation, and are mainly devoted to meadow and pasture, or cornfields, with scattered woodland, and here and there heath or marsh, and in valleys aquatic vegetation.

But where the plains, as on the continents, are large and for the most part not cultivated, the natural vegetation gives them a special character, and the plains of one region differ very strikingly from those of another from this cause.

The rolling expanses of prairie in North America are mainly rough grassland, and have been largely reclaimed for stock in some areas. River plains in South America, called llanos, are also grassy expanses bordering the large rivers, and in the wet season are green, but in the dry season bare and sear. In the same region pampas border the Parana, La Plata, etc., and are likewise grassland, with tall Thistles, Cardoons, etc. There are some boggy tracts here and there. But in the drought season all is dried up.

A sort of jungle in Asia is formed in the plains of the Himalaya region of much the same nature. Tundras in Russia have much the appearance of deserts like the pampas. The polders of Eastern Europe are river plains, and here also occur sandy heaths, and some woodland tracts.

Plains in the temperate regions, and where a high rainfall exists in the subtropical zone, support a luxuriant form of vegetation.

When we reach the arctic regions we are met with a uniform dwarf vegetation made up of small Willows, Birches, Alders, and Grasses, with farther north Mosses and Lichens, and some gay alpine flowers—as the Gentians and Saxifrages—at intervals.

In true deserts vegetation is generally conspicuous by its absence. There are long periods of dry conditions, and plants suffer in the same way as arctic and alpine plants from inability to absorb moisture, which is lacking in the one case, and unavailable in the other. The Cactus plants, Aloes, Yuccas, Giant Spurges are characteristic types. The shrubs are spinose. In the desert we find the curious Wind Witches, and Manna, a species of Lichen.

We have no active glaciers in the British Isles, only dead ones, relics of the Ice Age; but we have remains of the flora and fauna of that Age, preceding the present one, in the alpine floras on our high mountains, and in the lingering here of such animals as the mountain hare and other animals.

In active glacial regions to-day there is a characteristic flora. The moraines are often covered with dense forests, and with a scrub of Alder, Spruce, Ferns. Forests grow on the ice itself. An Alga settling on the ice hastens the melting process, and colour is lent by the Red Snow, another Alga. From amongst the ice rise up islets, or rocks, or peaks, and these, sunk as if buried by wind-blown sand, bear an alpine flora, including Monk's Rhubarb, Opposite-leaved Saxifrage, Alpine Saxifrage, Alpine Whitlow Grass, Moss Campion, Spiderwort, found near Snowdon, etc. These alpine florulas occur on most of our loftier hills, and resemble on a small scale the more extensive floras of the Pyrenees or Alps, from which they may be derived.

Such, in brief, is an outline of the characteristics or the physiographical features of a country with their main or striking botanical characters.

There is an intimate connection, as has been seen, between geology and the vegetation of the earth. Apart from the connection between plant distribution and the soil (its composition, porosity, etc.) there is a relation between the major geological characters and vegetation.

Firstly, the division of plants into land plants and water plants depends on the relationship between land and sea, and, so far as freshwater plants go, upon the occurrence and work of rivers, streams, brooks, etc., the occurrence of lakes and other pools; all of which are present-day agents in sculpturing the surface, or in accumulating deposits, such as silt, peat, etc. Another agent, in this case invisible—*i.e.*, elevation or depression—which may be sudden, as in volcanic activity or earthquakes, or gradual, as where a sea-bed is raised to the surface and becomes dry land, is very influential in determining the relative relations of land and sea (Figs. 35-36).

This last agent also, along with rivers, which carve valleys and wear down the general surface, causes the distinction between highland and lowland plants. As mountains usually, on one side at least, are moister than plains, so certain plants grow there and not in the lowlands, which when moist are fed by telluric water, not atmospheric or hygroscopic moisture. Uplifting of a region into high hills causes a marked change in altitude. Many of these uplifts are of very ancient date, and so distinctly geological causes. Plants vary according to altitude, and we get a zonal arrangement, as from equator to poles.

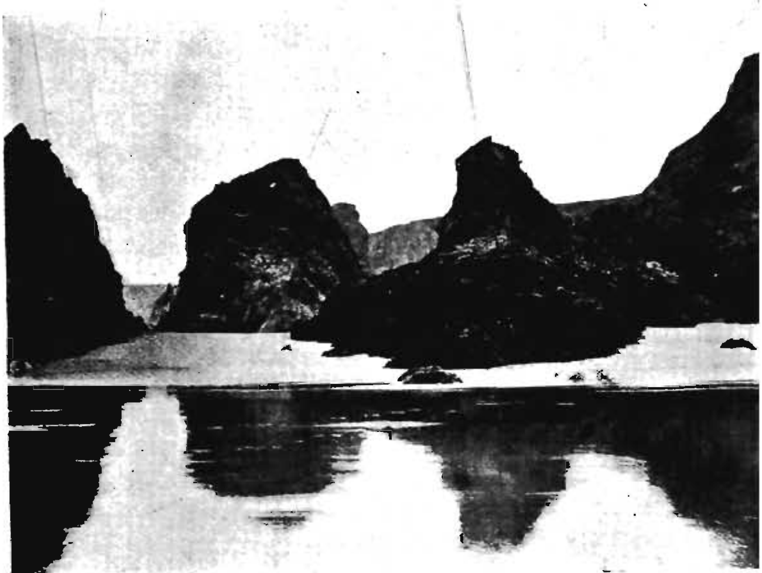
So in an area diversified by geological agencies we find the vegetation equally varied. Hills are divided by valleys, so highland and lowland plants are juxtaposed, and on the hills a zonal arrangement obtains. Nowhere over any wide area is vegetation similar. Plains may vary in the character of their vegetation. Such a plain as East Anglia, caused by the blocking of the Wash by sea silt on one side, peat on the other, has a distinctly varied flora. The inequalities of the surface and river drainage cause a difference in the soil moisture, and thus we get plants of dry soil, even those adapted to drought in a plain, and also Hygrophytes, or those requiring a medium supply of moisture —as marsh plants—and those that live in water, where water lies to some depth.

Altitude, again, determines the limit of trees. Water-content of the soil, due to soft and hard or permeable and impermeable strata, influences the type of woodland.

The occurrence of lakes, deserts, glaciers is also a determining factor. Lacustrine plants are of a special

G. B. Dixon.

FIG. 35.—THE SEA AND ITS WORK, IN CORNWALL.



G. B. Dixon

FIG. 36.—A CORNISH ROCK SHORE.

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type, so are desert plants, adapted to drought, and glaciers, again, have an alpine flora. The present types of physiographical features are a legacy of the past; so geology causes their present existence and distribution, and thus the nature of the vegetation.

The surface has been broadly formed by accumulation, denudation, and sculpturing. These are the main geological agencies. By their means we have diverse rocks of different ages distributed all over the surface. By their means these rocks lie below the soil or at the surface, which is more or less level, as in the Midlands, south-eastern counties, more or less elevated in the north and west. The arrangement of the rivers and valleys is due to pre-glacial causes in many cases, later changes in others. The Ice Age brought us the alpines from arctic regions, and the steppe flora of East Anglia. In other ways it caused changes by the mode of its accumulations, and the character of them, part clay, part sand, often calcareous, and by carving out river valleys. Present causes are altering the surface—as on the seacoast by erosion, forming of shingle and dune, and salt-marsh. Rivers are forming alluvial plains and exposing rocks below the surface, altering levels; and waterfalls are wearing back rocks (Fig. 37). Springs with tufa, etc., are forming deposits. Lakes are being filled or formed, with marsh floras on their margin. Peat is being formed in many ways. Other purely physical agents—as frost, snow, ice, rain, atmosphere, wind, cold, heat, etc.—are causing the various effects that each especially achieves, and continuing at the present day their work in the past on a different surface and over a different area. Climate changes as do the seasons, so plant communities become extremely complicated as regards composition and distribution.

These major causes, which are physical and physiographical, and at the same time geological, with certain secular causes, have paved the way for the present character of the soils, the climate, and the altitude of the country.

On account of the diversity of the rocks formed by accumulation by sea, rivers, lakes, wind, glaciers, volcanoes, organic and chemical agencies, the soils of any area are extremely varied. This is so because upheaval and depression have revealed to us the edges on a broad or narrow margin of the different rocks. Hence, too, in a region of alternate soft and hard rocks we have a series of hills and valleys with the varying water-content of the soils respectively producing dry and wet conditions. All these and many other factors have a marked effect on scenery, as have the master factors just dealt with.

By reason of the diverse arrangement of the rocks, and the fact that different rocks produce different soils, and, further, of the relation of vegetation to this diversity, the country is so modified that the vegetation assumes a patchwork arrangement, and monotony of scenery is seldom encountered. Clay and loam soils have their special flora, so have sands and siliceous soils.

The flora of limestone, chalk, oolite, marls, differs again from any of these. And all the foregoing differ from marsh vegetation or fen vegetation. Aquatic vegetation, based on the existence of water deep enough to cause plants to be submerged, or partly so, bears no resemblance to any of the foregoing.

Peat deposits, again, make the flora essentially different from any other type.

Altitude plays its part in differentiating the alpine vegetation from lowland types, and the correlated occurrence of peat at high altitudes produces a special type of vegetation. Coastal vegetation depending on the occurrence of sea salts in the soil or water inhibits

FIG. 37.— A WATERFALL AND ITS WORK: TORC CASCADE, KILLARNEY.

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the rest of the vegetation from growing on the sea-coast, and thus it has a special character of its own.

Generally altitude, as remarked, marks off the alpine plants from all others, and as one ascends a hill the vegetation changes the higher one goes. Some plants ascend to higher, others descend to lower, altitudes. So scenery on hills varies between the summit and the base.

Climate determines the distribution of plants, and so affects scenery. The plants of North Scotland differ from those in the south of England. The western plants differ from the eastern, largely owing to the hilly nature of the west, the flatness of the east (and Midlands), so the scenery is dissimilar as each extreme of the compass point is reached.

There are some peculiar plants in the south-west, south-east, and south of Ireland, and the south-west and south-east of England, that help to cause a diversity in the flora. These, however they reached these shores, owe their present continuation to the warmer latitudes, in which they grow, compared with the rest of the country. On the west and south coasts Fuchsias flourish out of doors and grow to the size of tall bushes. They are unknown in this state on the east coast.

Climate has, moreover, a marked effect upon scenery when we consider the earth as a whole. It is the physical features in a limited area that influence scenery in the first instance, in determining geological structure, whilst soil, etc., again regulate the character of the vegetation. The same physical features obtain everywhere, but there is a definite distribution of each type—*e.g.*, deserts in the subtropical areas, glaciers in arctic regions—as a rule. Plains, plateaux, valleys, lakes, mountains, volcanoes, are generally distributed, however. Valleys and hills often alternate. Volcanoes tend to lie along the sea margin, and so do mountains to a great extent; whilst plains and plateaux are generally inland, and so are lakes.

According to temperature, the earth may be divided into zones, with a central tropical zone on each side of the equator, the hottest region, followed to the north and south by a subtropical zone, then a north or south temperate zone, and finally an arctic or antarctic zone. Each climatic zone has a different type of vegetation. The distribution of land and sea influences somewhat the boundaries of each zone, as temperature is more uniform over oceans and seas than land. Altitude also has a similar effect. High hills or regions are colder than lowlands in any latitude. Mountainous regions are wetter than lowlands, and this influences vegetation.

In the region of the greatest heat—the tropics—the rainfall is very heavy, owing to increased evaporation, hence vegetation is luxuriant, growth being rapid. Dense jungle and vast regions of forest characterize this zone.

Wallace describes this region in Brazil thus: "The beauty of the Palm-trees can scarcely be too highly drawn; they are peculiarly characteristic of the tropics, and their varied and elegant forms, their beautiful foliage, their fruits . . . give them a never-failing interest to the naturalist, and to all who are familiar with descriptions of the countries where they most abound.

"The rest of the vegetation was hardly what I expected. We found many beautiful flowers and climbing plants, but there are also many places which are just as weedy in their appearance as in our own bleak climate." In the estuaries and lagoons along the coasts, mangrove swamps with prop-roots, giving some idea of the vegetation of that past age of luxuriant vegetation—the Carboniferous—when coal was formed, is also typical of the hot regions. Epiphytes and large and curious Orchids, Pitcher Plants, Venus's Fly Trap, and other insectivorous plants, are found here in various regions. This is the region of Savannahs. Beach jungle is typical.

There is a much smaller rainfall in the subtropical area, and it is largely occupied by deserts, and lofty plateaux where tall Cacti and other leafless types grow, with Aloes, Yuccas, etc. Prickly Pear is a very common associate of such conditions.

It is the region of maquis, a sort of copse of Myrtle, Heaths, Strawberry-tree, etc. Some of the vegetation consists of prairies, steppes, where Grasses are the dominant feature—*e.g.*, Pampas, etc. Not all the vegetation is so xerophytic, though most of the types are subjected to drought.

In the temperate zones we come to the regions of forests, evergreen and deciduous, up to the northern limit of trees. Many trees are conifers. In the forests many plants are early flowering and bulbous. In addition to forests there is a scrub of Shrubs found in the woodland, or Heaths may occur on dry soil, with the characteristic Heath plants—Ling, Heaths, Whortleberry, Furze—all more or less xerophytic. Elsewhere grassland forms large areas, with Grasses and many gorgeous flowers. This is the zone of prairies and northern steppes. On uplands wet meadows and moorland, with bogs, are found. The coast has its characteristic vegetation, on dune, shingle, and salt-marsh, all largely xerophytic, dwarf, and usually erect, with some shrubby types.

In the arctic zone trees find their limit, where it unites with the temperate zone. This is the region of tundras—snow-covered areas with stunted vegetation. Similar vegetation occurs on the tops of high hills, which is termed alpine. Many brilliant flowers are to be found—Gentians, Saxifrages, Stonecrops, etc.

The vegetation has a mat or cushion habit. In the highest latitudes only Mosses and Lichens—*e.g.*, Reindeer Moss—develop. Lastly, there is nothing but perpetual snow, and only an Alga (Red Snow) may be found, save where a few rocks jut out, and bear Lichens or Mosses.

One feature of scenery is its grandeur, its magnificence, when on a large scale, and apart from its inherent beauty and charm. Nothing appeals to the imagination more surely than the picturesque. Hence scenery has a potent effect upon the imagination, and it is thus an important agent in the moulding of the human mind along the lines of the ideal. Everything that moves the senses, the higher senses, has an effect, again, upon the inner feelings which are able to respond to the highest promptings of the being. Scenery and noble thoughts are thus correlative. Mountains convey to the human mind a sense of loftiness, of greatness. Such sentiments reacting on the mind give rise to elevating thoughts. All the poets have appraised the value of hills in the inspiration of noble sentiments. Such uplifting ideas springing from the elemental bases of scenery when they have been assimilated by the mind may be the origin of endless themes for the author, the artist, and all that class of men to whom imagination is a prime cause of action or thought.

Apart from its power over the imagination, scenery has a stimulating effect upon the sense of the æsthetic. Being in itself empirically beautiful, scenery evokes in man all the powers of recognizing, of appreciating, of creating beauty in another form; or in the case of the painter the desire to imitate it, or to express it, for no painter actually imitates nature, since he has always to obtain mechanically an effect which, analyzed, is no part of a picture, whereas the effect conveys to the mind the artist's idea of what he sees mentally, which he attempts to express for himself or *pour les autres.*

In natural scenery the æsthetic does not depend alone upon the composition of the picture, as upon the number or species of trees in woodland scenery, but rather upon the general tone, colour, and the main growth-form or habit of the trees. An entirely different effect is created by a few rugged Pines from that of a dense Pinewood, where detail is eliminated. So, too, an Oakwood awakens a different type of sentiment to that created by a Pinewood. But comparison does not rest upon the specific character of the trees, but rather on the general effect, of colour, of outline or form, and of mode of occurrence.

Much the same applies to the other types of physiognomy which make up scenery. The beauty of a Heath lies not in the Ling or Heath, but in its massed colour effect, which might for that matter be produced by any other plant. Indeed, at a distance of a mile or more, whence the effect is visible, it would be impossible, without glasses, to determine the nature of the plant.

A lake owes its beauty to the effect of light and other factors upon the surface, and to the general arrangement of the plants on the latter.

It is, indeed, the broad bases of scenery that attract, and therefore painters and authors are seldom naturalists, much less botanists, though this may be less true to-day than in early Victorian days.

Viewed from the botanical standpoint, what gives to scenery its character? Firstly, one notes that there are certain types of habit that are very characteristic, and stamp the physiognomy of a district. Woodland is dominated by trees. The tree habit is recognizable at a distance. It is the giant of the plant world. Every tree has something in common, and yet each tree differs in its habit again; and so one can recognize a distant Elm, and distinguish it from the Wych Elm, and so on. The tree habit has succeeded, hence the prevalence of forest in many regions. Scrub is at once recognized because it is made up of plants having the shrub habit, which, like the tree habit, is a successful one, and ensures the plants' effective struggle with other less formidable growth types.

Where there is no woodland or scrub, vegetation is dominated by herbaceous plants, or "herbs," as they were called. Amongst these a large part of the surface is covered with grassland. The grass habit in the open is, indeed, the dominant one. One can recognize grassland at once from the habit of the plants. Some Grasses give quite a character to the scenery—*e.g.*, the pampas, or bamboo-swamps—and Reeds in the reed-swamp.

Marshes and fens have often a very characteristic appearance, caused by the growth-forms that predominate. Often the plants have the sedge habit, which is due to the occurrence of Sedges, Cotton Grasses, or Spike Rushes. Others have the rush habit, and one may note a long way off the occurrence of Rushes over a wide area amongst Grasses, forming a rush society.

Heaths on a heath also have the heath habit, and this gives to the whole heath a characteristic appearance. In this way the bird's-eye view of a piece of scenery one gets from a distance may owe its origin, apart from its general characters, to the character of the plants that make up any particular type of physiognomy. Sometimes such tracts are uniform, when the blending of the whole affords a characteristic effect, from colour, etc. Certain Grasses, for instance, such as Mat Grass, give a grey and tufted, rough aspect. In early spring Bent Grasses or Purple

Moorgrass give a bright green effect. Later in the year the effect is warmer, a bright red or purple. Similarly the colour of the leaves of trees in spring has its particular tint, according to the species. In autumn the tints assumed by different trees is peculiar for different species, and here also scenery depends upon the nature of the species.

Where the effect is varied again, not uniform, the diversity depends upon the nature of the specific units. Thus we find, as in other matters, diversity in unity and unity in diversity.

What, now, are the bases of scenery from the geological standpoint? We have discussed the main character of the physical features, which are an expression of the result of certain geological agencies at work in each age.

It is of interest briefly to consider how the present surface, like the past, has received its special character, or, rather, how the crust in general has been formed and featured.

The earth, sea, and sky each have their various features: size, form, surface, colour, and movement. These details may be studied in any work on physiography or physical geography.

The earth is made up of a series of rocks which, if all piled up in one column, would reach a thickness of some thirty miles. But they have not all, or any of them, been formed all over the world: as land and sea have from the early history of the earth occupied different areas, so some rocks have formed in one place others in other places; and the arrangement is like a patchwork quilt, with some areas covered by contiguous squares in one region.

Rocks are of various origins. Some are igneous, produced as molten masses and since brought to the surface, where they have cooled and consolidated.

Others are derivative and formed by the destruction of other rocks or the work of animals, or due to chemical action. Still others owe their character to changes brought about by pressure, heat, or alteration of the constituents, and these are metamorphic rocks.

All rocks differ in durability, in composition; some are soluble, others insoluble, and owing to mechanical differences they differ in texture. Likewise they differ in structure. All these bring about the differences in physical features, and in this manner affect scenery. Soft strata are the lines of valleys. Hard strata form ridges, hills, and, when uplifted, mountains and peaks.

In their structure rocks differ owing to the nature of the divisional planes. These planes may be those of stratification or lamination, and are then formed after the rocks have been deposited. Joint planes and fault planes, often at right angles to the first, are formed after the rocks are deposited. Cleavage planes and planes of foliation are produced by metamorphic agency.

Stratification is usually horizontal (Fig. 38). Strata are the lines of deposition, and may be recognized by their parallel character, each line indicating a change of sediment or conclusion of some phase. The strata as seen in a section often dip at an angle owing to subsequent movement. Where strata show at the surface they exhibit their outcrop. Some strata are thrown into folds—as anticlines, or saddles; synclines, or troughs; monoclines, or hogbacks. Joint planes have their master joints, which may have parallel systems.

There are also strike joints, dip joints, and fault planes. Cleavage planes are at right angles to other planes, and are vertical or highly inclined in slates which have this characteristic structure. Foliation planes occur in schists and slates.

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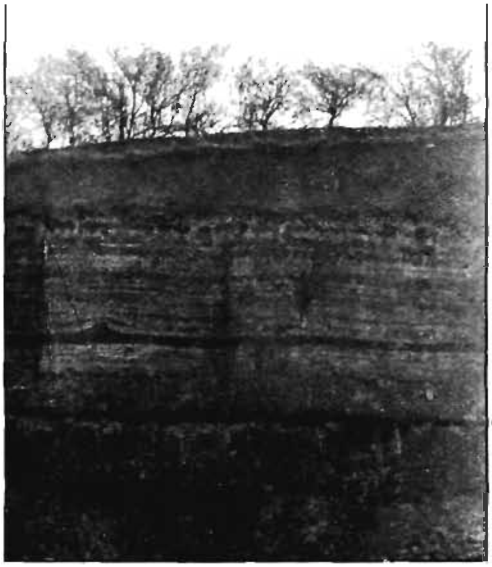

The Author.

FIG. 38.—SECTION OF STRATA SHOWING HORIZONTAL LAYERS, AND ACCUMULATION BY AQUEOUS AGENCY.

C. R. Mapp.

FIG. 39.—WORK OF RIVERS. STREAM SILTING UP, WITH LATERAL SHINGLE BANK.

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The production of the dominant forms of earth structure are due to three principles in the main: accumulation; elevation, or depression; and sculpture.

Accumulation affects sky, water, and the earth. In the sky the flat cloud is so produced. In the case of water a flat surface obtains by the same principle, and water finds its own level. By accumulation the earth is covered with horizontal strata. Thus accumulation produces planes in each of the spheres.

By elevation, or depression, we have such structures as the dome, basin, ridge, and trough. Earth waves occur, and there is a differential movement of different layers, with alternating ridges and hollows, as the ridge and furrow in a field. Such factors modify the effects of accumulation, causing horizontal arrangements. The two are antagonistic, and from this antagonism results variety and scenery.

Sculpture, too, is another disturbing or rearranging factor. It produces additional diversity. It may be compared in its effect on land to the influence of sea waves on the ocean. It operates by a process of graving. Sculpturing takes on a particular form according to the structure of the rock, the nature of the agent, and the character of the climate.

Denudation is a great sculpturing force. It does its work by the agency of changes in temperature, the wind, rain, frost, rivers, sea waves, by erosion, by the action of various organic bodies, and by gravitation, etc.

In this manner the general tendency is for the land to be reduced, and for the ocean to become filled up. It is the battle between the continents and the seas.

Such, in brief, is the course by means of which scenery is produced as a result of geological agencies, which are ever at work to-day, as in the past, in changing the character of the lithosphere, the hydrosphere, and the atmosphere—or land, water, sky.

Marr, whose "Scientific Study of Scenery" may be recommended to all students of scenery, sums up admirably the work of various agencies in modifying the earth's surface. He writes: "As the results of accumulation here and denudation there, of difference of climate in different places, of difference of rock-structure, of variations in the nature and the amount of the materials which are accumulated, and, lastly, of the operation of earth-movements, we are presented with those diversified features of our earth's surface which it is our present object to study in detail. Here we meet with mountain chains, there with rivers meandering through their valleys; on one place is the desert floor, in another the fenland flat. Anon we stand by the sparkling mountain tarn; again we wander along the salty borders of the inland sea. At one portion of the river-course we find the stream foaming amid boulders, whirled boldly over the precipice, at another winding sluggishly through oozy swamps. At one time we may be standing above the seething cauldron of the volcanic vent, at another watching the apparently motionless sweep of the glacier. The eye may be gladdened by the vivid carpet of alpine flowers or saddened by the monotonous line of the desert scrub. We may gaze at the vivid colouring of the striped rocks of the American gorge, or the white glint of the chalk cliffs of Albion, at the turbid waters of the Yellow Sea, or the azure hue of the alpine tarn. Over all is the ever-changing sky, with the clouds hurrying past, driven by the tempest, or wreathing languidly around the mountain peak. Happy is the man who takes heed of these things, and pleasurable are the emotions which are excited by enquiry into the causes which have produced them! And lives there one who, communing thus with Nature, and admitted to some of her secrets, is not led to ponder with reverence upon the First Great Cause?"

Much of the modern aspect of scenery is due to man himself. Human activity is responsible for the general appearance of countries under a high state of cultivation. Initially, man, as soon as the first stages of agriculture were reached, commenced to form clearings. In time large areas were felled to prepare the ground for the formation of plots of land for corn. Tree felling was more extensive in later periods also, for construction of dwellings in Saxon and later times. Many districts still retain half-timbered dwellings. Before coal was used, wood was the chief fuel. Later, in Alfred's time first of all, and up till Nelson's time, wood was used for shipbuilding. To-day wood is used for various purposes, but much is imported from abroad from Norway, Russia, Canada. The need for straight trees has modified much of our woodland, and the Larch and Pine (the latter native in some areas) have replaced much of our native woodland.

Following tree-felling—which in itself has transformed the original scenery, by the splitting up of continuous virgin forest into isolated woods,* almost absent in some areas—there was a natural necessity for the drainage of such felled tracts. The drainage was originally effected by means of ridge and furrow, which can be seen in all parts of the Midlands, and characterizes especially clay land. In sandy areas it may, where apparently absent, have been obliterated by natural denudation, rain, wind, etc. On a large scale the amount of drainage, carried out less than two hundred years ago by a Government scheme, is seen

* Many ancient forests have disappeared, as Charnwood, Sherwood, Arden, Hainault, etc. There are only fifteen or so left that are Crown lands or controlled by the Government.

in East Anglia, where the Fenland, once universal, is now restricted to one or two areas.

Next to the felling of trees and drainage comes cultivation, which, up to 1,000 feet, is general in all but rocky or hilly areas, where the soil is amenable to tillage. Some areas have been converted into pasture or meadow and have not been under the plough. Ridge and furrow indicate ancient cornland. To-day in the lowlands on the sides of valleys, in plains, and up to 1,000 feet on hills, corn and other arable land is to be met with in every country. Even in Scotland oats have been cultivated on high lands.

Again, enclosure has within the last two hundred years become general, and hence the country has been divided up into small areas bounded by hedges, with planted trees and ditches, or in some hilly areas by stone walls, in the fens by drains or dykes. This patchwork arrangement has a great effect on scenery.

In some areas, especially in hilly regions, or in lowland bogs in Scotland and Ireland more especially, peat is cut on an extensive scale. The natural bog plants disappear, and Rushes, or other pasture plants replace them. Occasionally cornland takes the place of the peat bogs (see *ante*, Chapter II.).

In some parts of England areas are devoted to the culture of hops, as in Kent, or to fruit-growing, as in the Vale of Evesham, Hereford, Devonshire, and elsewhere. This gives a characteristic appearance to the country.

In all parts of the British Isles there are numberless villages, towns, and cities which give a special character to the scenery, though artificial scenery would be bereft of much of its picturesqueness without them, just as in a painting as a rule the introduction of the human figure is deemed necessary even in pure landscapes.

The introduction of the steam engine brought in railways, but this cannot be said to add to the picturesqueness of scenery; and, indeed, one has heard of much strenuous resistance to the laying down of lines through property in itself beautiful. In one case a sort of battle (the Battle of Saxby) is said to have taken place. Viaducts and aqueducts are less obtrusive, but wherever they occur mar the effect of natural contours by their rigid lines and curves.

On roads and railway lines, telegraph wires (sometimes laid across country) not only disfigure the countryside, but in times of bird migration are sources of danger to migrants.

Unlike some other artificial structures, windmills, either in flat country or perched on a hill, have, especially when dilapidated, a decidedly picturesque appearance. The same cannot be said of hayricks and cornstacks, though the old-fashioned round types with conical thatch are an improvement upon the modern rectangular ones, which stand near barns in the fields or around the farmstead. Alone they are obtrusive, but surrounding old tile-covered farm buildings or houses they, too, may be of scenic interest.

Quarries in a hillside, though not in themselves beautiful, may, when disused, cause the new vegetation that springs up on their face to possess additional charm. Brick pits also when disused may give rise to pools and be surrounded with a scrub, which causes the ground to assume a more natural appearance.

Tumuli and mounds of other types, the eminences on which old castles once stood or still stand, often planted with trees, are objects that have a certain picturesqueness.

Such are a few of the effects of man's interference with Nature, in some cases adding to its beauty, in others diminishing it even to ugliness.

But man in such cases has hardly attempted to treat the earth as scenery or to study his effect upon it. There are other cases, in a few instances where utility is the chief aim, where he has deliberately endeavoured to improve nature or to alter it to his liking. Such artificial scenery can generally be distinguished from the work of nature. The vicinity of old country houses is generally surrounded with parkland, where the trees are planted in such a manner that, though they have no geometrical arrangement, in most cases they are placed at certain points to gain an effect or to secure by enclosure the home area from observation. In some cases, lines of trees or avenues are deliberately set at definite intervals, the individuals in each row being regularly (or irregularly) placed. This may be compared with hedgerow trees, also planted as a rule.

In definite instances gardens and parks are arranged on the lines of landscapes and an attempt is made to reproduce nature. Here the effect may be charming, though still artificial. Trees, water, and other elements may be blended into an harmonious whole, which makes for the picturesque.

In other cases plantations of trees have been made for various purposes, sometimes for ornament, the woods often being mixed and containing conifers, and so easily distinguishable from natural woods. In many countries where fox-hunting is carried on coverts and spinneys or copses are formed for the purposes of sport, to hold a certain number of foxes.

In most countries coverts are also formed for shooting, and here the pheasant holds sway—less often in Birchwoods the woodcock. As the charm of nature lies, equally with plant life, in the wealth of animal life, this is an advantage to the lover of nature. In Scotland large deer forests have been formed for a similar purpose, and these certainly may be regarded as picturesque.

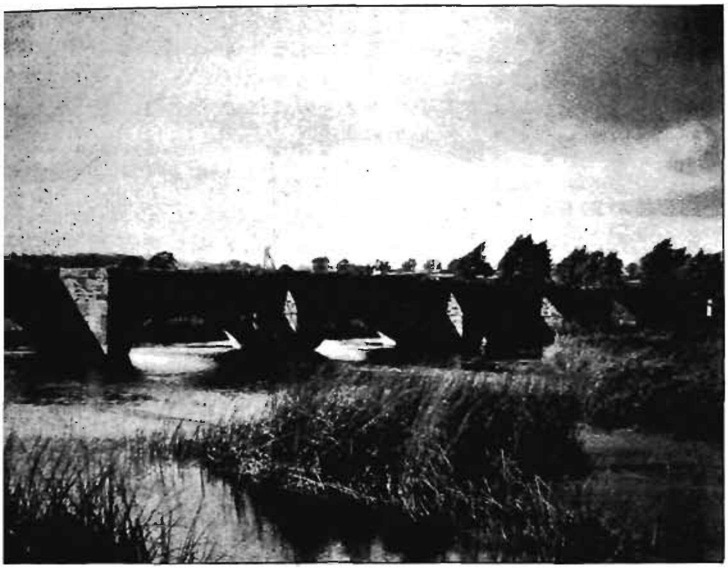
As with woodland, so with water: man has produced artificial scenery for ornament. Each big house usually has its lake with lilies, flags, and water fowl. For other reasons—utility—canals or waterways have been made across the country like railways. These usually soon develop a natural and charming type of aquatic vegetation like natural rivers. Reservoirs for water-supply also soon take on the appearances of natural lakes. Akin to the last are sewage farms. These frequently harbour many rare and curious aliens. Watercress-beds, osier-beds, reed-beds, especially the two last, may have quite a natural appearance, and always have a beauty of their own. The first may resemble the sewage-bed.

Ponds, ditches, and water-tanks in fields are really artificial, and formed for useful purposes, but often harbour the natural vegetation of pools formed by nature itself. Old flax pools, now disused, may, like marl-pits, be found in many parts of the country, and these may be the resort of many interesting plants. Moats, like artificial earthworks, kitchen-middens, again, are relics of the past that call up legend and romance, and besides may be the lingering grounds for such plants as Belladonna and the like.

On heaths, formerly treated as commons, or on dunes by the coast, a new type of scenery—artificial, it is true—has sprung up, in the formation of golf links on such areas. Often they are also the special habitat of rare plants. They may be so laid out that they are picturesque, in spite of artificial bunkers, teeing grounds, etc., and rain shelters, and the inevitable golf-house, with its garage and lunch or tea room.

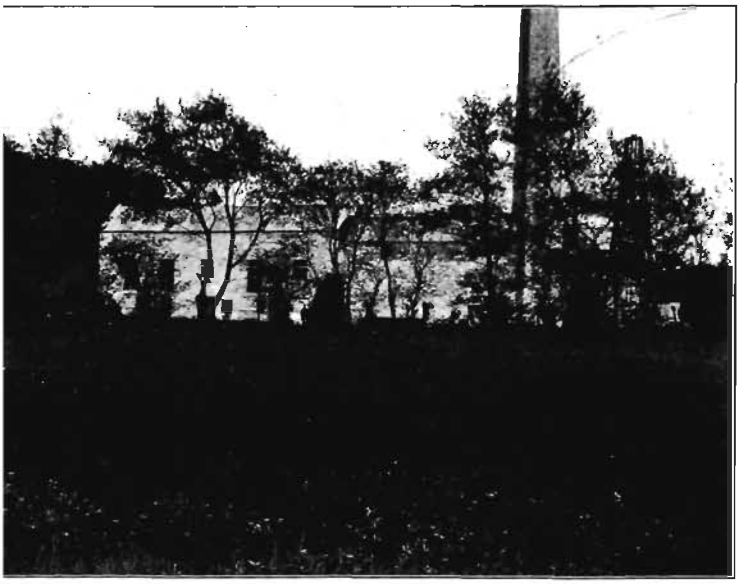
Probably only the townsman can appreciate the setting down of such man-made habitations amid beautiful natural scenery, but as comparison requires contrast natural beauty may not be so much marred by the occasional blurring of beauty spots by white-washed pavilions—or red-brick structures jettisoned amid the wilds of nature—as utility has its office, and solitude may be even monotonous till broken by associations with the living world (Figs. 40 to 41).

Here, at risk of dwelling too long on this side of the question, I would quote at length the apt remarks of Marr on the contrast between the natural and artificial. He says: "Allusion has just been made to the influence of man in modifying the scenery of the earth's surface. Perhaps too marked a contrast has been drawn between the work of man and of other animals, in affecting the appearance of the outer surface of the globe, as indicated by the use of the expression 'natural' scenery, and by talk of 'artificial' changes made therein; some writers, indeed, speak of the work of man as though it generally tended to mar the aspect of a country. When speaking enthusiastically to a Scotch boatman of the beautiful hill scenery of the north end of the Isle of Arran, I was at first somewhat surprised at his remark that I should see the flatter south end, with its cornfields; I was not prepared for the influence of contrast with the normal surroundings in determining a man's ideas of what is beautiful. Anyone who had journeyed long in a desert region would no doubt be more profoundly affected by the sight of the cultivated fields of our own country, with the rustic cottages nestling here and there among their orchards, than by the finest 'natural' scenery in the world. Nevertheless, one would regret the obliteration of all 'natural' scenery, even if it were replaced by an harmonious substitute, due to the labours of man. Much more does one regret the mutilation of a district, rich in natural beauty, by works



E. H. Grant.

FIG. 40.—OLD STONE BRIDGE AND AQUATIC VEGETATION, PICTURESQUE THOUGH ARTIFICIAL.



Meta Boyd.

FIG. 41.—MARSH, SPOILT BY THE ERECTION OF A FACTORY, IN IRELAND.

To face p. 220.

which produce a feeling of discord—works which are often wrought, not for the general advantage of man, but for the sake of benefiting the pockets of greedy speculators to the extent of a few pounds. And yet, this mutilation of some of the fairest scenes of our own country has proceeded, and is proceeding, unnoticed, save for the words of regret of a few lovers of Nature, whose protests are, alas! unheeded by the great mass of our countrymen. America has its National Park set aside for ever, as a thing of beauty, owing to the far-sighted intelligence of its legislators. We, too, have our exquisite jewels of natural beauty—jewels so exquisite that they are prized, not only by hosts of our own countrymen, but by others, who come from afar to gaze at them. Devon and Cornwall, Wales, the Highlands of Scotland, and, perhaps, above all, the Lake District of Cumberland and Westmorland, are glorious possessions of the English people, where the jaded dweller in towns may find an exceeding great peace. Do we appreciate these as we should? Alas! the very stones cry out against us. The two lakes of Llanberis, things of beauty at a time within the recollection of the present generation, are now receptacles of slate rubbish, extracted from the adjoining hills, which are marked by scars that cannot be effaced till long ages have rolled by. One of the most beautiful upland hollows of Wales, which nestles under the glorious precipice of Snowdon, has been sadly despoiled for the sake of a few pounds of copper ore; the curved bays of Thirlmere—effect of wave-lapping along the beach for many a long day—are replaced by angular indentions of the banks of a reservoir, made to supply the thirsty folk of a large town. This conversion of lakes into reservoirs is justifiable on the score of necessity; but who can look without indignation on the unsightly heaps of slate refuse which have sullied the beauty of that fair valley which was the chosen home of Wordsworth?"

It is true that much vandalism, both in regard to wild plants and to scenery, has taken place in the past, but in the latter case there now exists a National Trust for preservation of monuments of natural beauty; and, in the former case, some real progress has been made towards the education of the public as to the need for the protection of wild plants, especially rare ones, and of tracts of natural vegetation in danger of transformation, and, it is hoped, in the near future, to put this movement on a firm and public basis.

We may further consider scenery and the seasons, with special reference to the aspect of vegetation during the different phases of the year.

Each season has its characteristics, and thus, whilst there are numerous different types of physiognomy, each of these, again, wears a different aspect in winter, spring, summer, and autumn. Indeed, each habitat has its special quota of flowers for each month, if we cared to run over the Calendar of Flora. But it is enough here to merely scan the face of Nature during the four seasons in a broad manner.

Winter, with its biting frosts and cold breezes, is essentially a period of lack of colour, as a rule. The whole earth is, sooner or later, clothed in a mantle of pure white. Even the water may be frozen hard and assume a glassy appearance.

In the bright forest, bespangled trees, shrubs, and even the grass, glitter in the sun, as with myriads of diamonds. Icicles hang from many rock faces. The trees are bearded with hoar frost. All but evergreens have shed their leaves. Plant life, save for trees and shrubs, appears to be absent from its usual stations.

Spring succeeds the dull, wintry waste, and with it all assumes a tone of freshness from the new green verdure, the opening buds of trees, and flowers. There is a feeling of renewed activity, and it is the spirit of spring which heartens one, so that it is endeared to most, above all other seasons. Before spring is gone the summer birds have come, and most have built their nests. The May is in bud, Cuckoo Flower, and Marsh Marigold, and Sloe, and many another early flower, adorn the earth.

Summer comes on with her fulness and glory, her wealth of flowers and thick curtain of greenery. The earth is transformed: no longer can one see in wooded country so far as in winter. The hedges are blind and bright with blossoms of the Rose, redolent of the sweet scent of the Woodbine, and the meadows smell of new-mown hay.

Autumn comes boldly on. It is a season of fruition. All the flowers have gone to seed or fruit. The fruit-trees bow with their weight. The corn is golden. The nuts are filling. Already autumn tints are beginning to appear as soon as summer is over. Bronze, carmine, gold and red, as well as yellow, ochre, and green vivify the whole earth over. Now the meadows and pastures look sear. But still many gay flowers are to be seen, and the variety of hues and colours with the wealth of form and structure is a right royal feast for any artist or lover of scenery.

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CHAPTER V

PHENOLOGY AND NATURE DIARIES

MUCH of the interest in nature that appeals most strongly to the keen observer lies in the succession of events in the plant and animal worlds. The times of flowering and other phases, or the study of the first appearance each season of the plants of each month, is termed phenology. It is the making of a calendar of flowers, in short. But it is really more than that, for it discloses in the vagaries of the activities of plants the waywardness of the seasons, and the seasons vary with the atmosphere, the temperature, and many other factors which are in themselves of a physical nature. The same features are to be observed in the case of animal life. Migration and other phenomena are retarded or accelerated as the season is backward or in advance.

Thus, phenology, apart from its interest to the naturalist in the record of plants in flower, and the meaning of their first appearance, determined by the keeping of a series of yearly records with first and last dates of flowering, is also of value from an agricultural point of view. There are certain phenomena that may be predicted by the occurrence of a particular one, since particular phases of weather produce precise effects on the members of the plant and animal worlds.

In a word, there are simultaneous responses to unusual stimuli on the part of widely different types of plants. A late spring affects the early flowering of wild flowers. The same cause affects crops. Fruit trees, etc., are also influenced by the eccentricities of the weather. Many old proverbs, in some of which great truth is contained, bear witness to these abnormal occurrences.

So far as plants are concerned one of the greatest factors determining the flowering period is temperature. We know in general that temperature varies, since each of the seasons we recognize—spring, summer, autumn, winter—has its particular characteristics. Spring may be cold, but is generally warmer than winter, for each day the sun's rays are becoming more powerful. Wind and rain and cloud may, however, modify the effect of the sun's heat adversely. Even frost may intervene, or snow, and hailstorms are by no means uncommon. Summer, when the sun is much more powerful, is generally the warmest period, and hence most of the wild plants flower in summer. By its means the fruits and seeds are ripened, and the autumn brings us to the ripening corn. Many flowers do not bloom till then, and we may thus distinguish autumn flowers. Winter, following this final stage in the plant's activities, fruition, is a season of inactivity, of quiescence. During this last season plants are in the resting stage. The bulbous plants that have long ago flowered — in spring—have already large reserves stored up to enable the flowers to blossom in early spring, before the trees have put on their leaves.

There are thus flowers of winter—the Snowdrop, Aconite, Spurge Laurel, Mezereon. Spring brings us to the time when the Coltsfoot, the Violet, the Hazel, the Daffodil, and, later, trees in general, the Cuckoo-Flower, Sloe, etc., are in bloom.

In summer so many flowers are in bloom that it is unnecessary to particularize. With May we find the

Hawthorn blossoming; in June the Dog Rose adorns the hedgerows.

In autumn the Grass of Parnassus, Autumn Gentian, Purple Crocus, Meadow Saffron, with many others, are especially prominent.

The Ivy is the only flower that blooms during the winter.

There is a special reason for the difference in the period of the germination, opening of the first buds, the opening of the flower, the ripening of the fruit amongst different plants. It is because a definite amount of heat, or the accumulation of a definite number of degrees of temperature is required, from the first appearance of plant activities until the performance of any of the above functions, which cannot be observed until such a stage is reached. This point is known as the thermal constant. The thermal constant for each progressive function is higher than the previous one; and the thermal constants of different plants are not the same. Hence the diversity of plants in flower in each of the twelve months of the year.

As explained by Kerner, all motion can be transformed into heat, and measured in terms of the latter from the mechanical theory of heat. Thus it is possible to determine the heat requirements of plants as a constant numerical quantity—in other words, to find the thermal constant. This determined, it is possible to "estimate beforehand, from the heat conditions prevailing in any particular place, whether this or that plant species would thrive, whether it could produce ripe fruits, and whether or not its cultivation would be advantageous and worthy of encouragement."

As to germination, seeds can develop at very low temperatures. Thus, White Mustard, Wheat, Rye, the Wild Violet, can do so at a temperature near freezing-point, or between zero and 1° C.; Flax, Poppy, Beetroot, between 1° and 5°; Sainfoin, the Sunflower, between 5° and 11°; Tobacco between 11° and 16°; Melons above 16°. The length of time that a seed requires to be exposed to such temperatures varies. Thus, Gold-of-Pleasure and Poppy seeds can germinate at 4° or 6° C. in four and ten days respectively, whilst between the same temperatures Beetroot takes twenty-two days. Thus there is a considerable difference. These differences in length of duration when multiplied by the temperature give the thermal constant, and so the thermal constant of Gold-of-Pleasure is 18·4, that of the Poppy 46·0, of Beetroot 101·2. The temperature is that of the soil in the shade. When the thermal constants of foliage-production, flower-opening, and seed-ripening are to be determined, it is necessary to add together the daily maxima of sun temperature from the first of January until each stage is reached.

Thermal constants for the opening of foliage-leaves of the Gooseberry, Hazel, and Beech are 478°, 1061°, 1439°.

For the opening of the flowers the following examples will suffice to show the range:

Hazel, 226°.	Elder, 2313°.
Snowdrop, 311°.	Foxglove, 2640°.
Cowslip, 968°.	Ling, 4164°.
Apple, 1423°.	Meadow Saffron, 5024°.
Hawthorn, 1649°.	Ivy, 5910°.
Horse Chestnut, 1708°.	

For the ripening of fruit, the following are examples:

Apple, 4730° (*i.e.*, before Asters are in flower).	Horse Chestnut, 6034°.
Elder, 4913°.	Oak, 6236°.

Leaf fall also has a definite connection with temperature, as the following thermal constants show:

Elder, 6644°.	Oak, 6979°.
Horse Chestnut, 6863°.	Apple, 6999°.
Hazel, 6884°.	

Phenological phenomena are intimately connected with climate. As Hopkinson remarks: "Combined with meteorological observations, those we are considering (phenological) may afford valuable assistance in investigations on climate; for these periodical phenomena, both of plants and animals, are all more or less regulated by the laws of climate and the varying influences of the seasons."

A few general considerations as to the principles regulating phenological phenomena may be advanced. It is useful to remember that there are three seasons of activity: that of growth in spring, maturation in summer and autumn, that of rest in winter. The seasons are regulated by other than purely natural causes. There are artificial factors that come into play in the case of cultivated plants, crops, etc. Cultivation has the effect of hastening or curtailing the earlier seasons. Cultivated plants of the same species flower and fruit earlier than the wild types. Acclimatization is the cause of the irregularity of their flowering in many plants. Bulbous plants, largely natives of warm climates, flower early because it is the period of the wet season of their place of origin. Acclimatized trees flower early, since that is the time when the temperature of their native country is warmest.

A high temperature and drought both have the effect of shortening the growing season. In either case there may be an abnormal second leafing and flowering.

As to the order of the seasons, this is largely regulated by the relative length of day and night. This is seen in the extremes met with at the poles, on alpine mountains, and the tropics. Growth, of course, takes place in the dark, when energy is liberated, and maturation in the light, under the effect of warmth and light (light rays being turned into heat rays as required). The arctic plants are dwarf because of the cold, short nights and long days. In the tropics growth is continuous and foliage is luxuriant, whereas in arctic climates flowers exhibit profuseness instead.

In a good season the yield of crops is double that in a bad season, and hence climate, or its component factors, must be taken into account.

Some data upon the influence of climate on farm and garden by Mawley help to bring out the relative effects of the different factors of climate in causing phenological phenomena. This is clear if we realize that only 5 per cent. of the food of a crop comes from the soil (the nitrogen and ash constituents), the rest, directly or indirectly, from the atmosphere; and as this is affected, so are the vital functions of the plant's mechanism.

The British climate is insular, and not governed appreciably by latitude. It differs from that of the mainland, which is continental. On the west there is the influence of the Atlantic and Gulf Stream, on the east of the Continent, and cold and dry winds in place of moist and warm ones. Thus the British Isles have, as a whole, a mild and equable climate, so that the country contains more native plants for its size than other countries. The mean minimum temperature in January (below 31° to 42°), and the mean maximum in July (58° in Shetlands to 72° in Hants and Surrey) show what differences can exist. Cornwall in January is 10° warmer than the Midlands, and the latter region in July is 10° warmer than North Scotland.

Rainfall is heavier in Ireland than in England, and still heavier in Scotland. Rainfall decreases eastwards.

The atmosphere is, generally, more humid than on the mainland, owing to greater rainfall and cloudy atmosphere. This is of advantage to plant growth.

Generally speaking, the climate is moist, mild, and equable. There are, it is true, frequent changes, but a sort of uniformity is produced by the general moistness of the atmosphere, the cloudy atmosphere, and the effect of the ocean in the west and the Continent on the east. The mean minimum temperature in January varies from below 31° F. in the Midlands in winter to 42° in the south, and the mean maximum temperature in July varies from 58° in the Shetlands to 72° in Hants, so that there is a considerable variation.

Temperature, frost, rainfall, drought, snow, sunshine, and wind have a great influence on the seasons of plant growth.

Temperature receives its warmth, not only from the sun's rays directly, but also from the heat of the ground. It is effective on the roots both above and below the soil.

There is an optimum temperature, at which every plant grows best, and the optima of different species vary. There must be a certain amount of warmth maintained for a definite period for each plant to mature. The best conditions for plant growth appear to be a gradual rise in temperature during the first seven months of the year, and as gradual a decrease during the last five months. Most of the crops are annual, whilst garden produce is mainly of a perennial character, and wild plants are mainly perennial.

Each of these types demands different conditions. Not only is the soil heated, but also the subsoil. A clay soil, at one foot depth, is colder than the surrounding atmosphere; sand, at the same depth, is warmer; and chalky soil is nearly of the same temperature as air. But a depth of four feet below the surface the temperature is colder than the atmosphere from April to August, but warmer during the succeeding months; and Buchan says that "light soils are subject to a greater degree of frost near the surface than strong, clay soils, but that frosts do not penetrate so far down into light soils as into strong, clay soils, the explanation being that light, loose soils are worse conductors of heat than strong, clayey, compact soils."

Next to temperature, rainfall is one of the most important factors in promoting plant growth. Too little is detrimental, as is an excess, and a medium supply is most beneficial. Different soils, however, vary in their capacity for holding and retaining moisture, hence the effect on plants is variable. But every plant requires a certain amount of moisture to carry on effectively absorption, transpiration, etc. Much depends on the nature of the root system, the depth of roots in relation to different soils. As a rule, deeply rooted plants suffer less in seasons of drought—*e.g.*, trees. But in the latter case, an after-effect may be disastrous, even to them. Percolation is permanent in winter; in summer only a fourth is permanent, and three-fourths is lost, owing to evaporation. Densely matted, lush vegetation, as grassland, absorbs most moisture in summer. Protection against drought may be had by the application of nitrate of soda, which promotes growth in length of roots. Nitrates are conserved in dry seasons, lost in wet seasons. Mawley writes: "It is during the late spring and early summer, when most plants are growing more rapidly than at any other period of the year, and evaporation is greatest, that the want of sufficient rain is most keenly felt. On the other hand, continued wet during the same period is also undesirable, principally because a long continuance of rainy weather at this season invariably means, in these islands, also a long continuance of unseasonably cold, humid, and sunless weather."

Apart from the quantity of rain that falls, some influence is, no doubt, brought about by the duration of rainfall. Rain may be partial, intermittent, cold, or warm; and it may be heavy, torrential, or sudden; or fine, and prolonged. All these differences have an effect upon plant life.

Drought may be absolute or partial. That is to say, it may be severe and prolonged, or slight and interrupted by intermittent, slight rainfall. Some plants can resist drought better than others, this being a question of the depth of the root system and the soil characters. Slight rainfall, cooling and moistening the atmosphere, may adversely affect plants during drought, causing the soil to cake, and promoting evaporation. So grassland is affected more than arable, where the soil is broken up. The best precautions against drought appear to be to regularly water, mulch, or hoe the soil, so that percolation may be regular and uniform. This reduces dryness in the garden. Fruit trees suffer least in a drought, as the root system is deep. Lawns suffer much where there is a mixture of weeds that are adapted to drought able to get the mastery over the grass itself.

So far as snow is concerned, a deep fall in winter is really beneficial. It maintains the soil at a warm and uniform temperature. It protects the vegetation on the surface from frost. If it lies heavily on boughs or branches of herbaceous plants it may, however, cause injury to those parts that may snap from sheer weight. A slight covering of snow, however, protects plants against frost or cold wind.

A third most necessary factor of plant growth (in addition to heat and moisture) is sunshine or light. Heat, water, and soil can each be supplied artificially, whilst sunlight cannot, and artificial light is ineffective or detrimental. Every crop is more dependent upon sunshine at some period than any other. Mawley sums up the importance of sunshine in the following words: "For instance, corn at the time of ripening, the grass crops in the spring, the roots in the autumn, the fruit crops when approaching maturity, and so on."

"In the spring months it is sunshine rather than rain that is mostly wanted: sunshine to warm the ground, for, without this, rain is of little service, either for the germination of seeds or the growth of plants. Again, it has been found at Rothamsted that, while certain seasons may favour the mixed herbage of grasslands, in so far as luxuriance of growth is concerned, it is in others—no doubt, during the more sunny ones—that this herbage becomes properly matured. So that in the latter case, although the yield may not be so great, the quality is very superior. Corn crops are likewise similarly influenced, some seasons favouring growth while others favour more particularly the perfecting of the grain and its maturation. In gardens the difference in the character of the shoots made during a wet and cloudy spring and early summer is very distinct from that in a period of almost continuous sunshine. Abundant sunshine in the autumn is also of the greatest value to a large class of hard-wooded plants and trees, and especially to fruit trees, for without this there will be little prospect of the growths of the current year becoming satisfactorily matured before the winter sets in."

Sunshine and the amount of water vapour given off under transpiration are closely connected, and as the latter is a vital function it is easy to see how important sunshine is.

Wind is *the vehicle of climate*, and is of such importance that it has been said to make the weather.

In the British Isles we have two main currents. The first is a moist prevailing wind coming from the south-west from the Atlantic, vapour-laden, which is cool in summer, warm in winter. The other comes from the north-east or east, from the Continent, and is dry and cold, often harsh. It causes the hottest summers and coldest winter temperature. The north-east winds greatly retard vegetation. For this reason south-west sites are chosen where possible. In the late summer winds may do harm by laying the corn, and by causing damage to trees and garden or wild plants by bruising, etc.

What applies to crops and garden plants applies equally or more to wild plants. Cultivated plants are under control and can be protected; wild plants are not, and suffer all the hardships vagaries of the weather bring about.

Temperature when below the normal retards plants, so in a cold spring flowers are late. In some years as many as thirty-three days (or more) constitute the number of days in arrear of the mean date of flowering when the season is very cold. Prolonged rain, little sun, and cloud have a similar effect. On the other hand, a warm spring, with moderate rain, produces an acceleration of flowering or other activities, and plants may be a week or two, or more, in advance.

Frost also retards plants, and if late frost occurs it will damage all prospect of fruits in the case of wild fruit trees. It may kill off tender annuals.

Drought may accelerate flowering, produce second leafing and blossoming, and in the next year may give rise to increased fruit crops, or the reverse.

Snow acts as a protection against frost, but retards spring flowers if it falls late, except the bulbous forms. Sunshine is essential to wild plants, and acts like temperature and rainfall on their activities, accelerating them when other conditions are favourable; whilst fog, mist, and cloud, coupled with cold and rain, retard flowering, etc. Cold winds, especially east or north winds, have the same effect as frost or low temperature on growth, and also produce injury from their harshness and damage from their force.

In all these ways vegetation is retarded or accelerated by the behaviour of any of these factors below or above the normal. The following is an illustration of the effect of a cold, dull season upon flowering.

In a report on the phenological phenomena observed in Hertfordshire during the year 1891, Mawley summarizes the effect of the cold season thus:

"THE WINTER OF 1890-91.

"The weather continued very mild until the last week in November, when a severe frost all at once set in. This memorable frost did not break up until the third week in January. Consequently throughout these eight weeks all vegetable growths remained entirely at a standstill. On the farms scarcely a sound turnip or swede was anywhere to be found. In the gardens many half-hardy shrubs, as well as all the winter vegetables, were severely injured. It also proved a very trying time for birds, many of which succumbed to the cold and the want of suitable food. The remainder of the winter proved, on the whole, rather mild, while the duration of bright sunshine was much in excess of the average. The first plant on the list, the Hazel, was from six to twenty-two days late in coming into flower." He adds: "As showing the lateness of the early spring flowers, the observer at Hitchin states that on February 28 'vegetation in the woods was very backward—no Primroses, no Violets, no Celandine.'" The foregoing is an example of the effect of cold on the early winter and spring flowers. Similarly, other abnormal causes have as important an effect on flowering.

In order to show what differences there are between the seasons, and how abnormal phenological data may be, a few illustrations may be drawn of early and late flowering plants derived from records made in various parts of the country.

As an instance of early flowering, on New Year's Day the following garden flowers were noticed at Birmingham in flower:

Christmas Rose.
Erica carnea.
Winter Heliotrope.
Primrose.
Polyanthus.
Hepatica.
Gloire de Dijon Rose, in bud.
Clematis Jackmanni, shoots six inches long.

The same year, in Shropshire, the following plants were in bloom on the dates named, viz:

Primrose, January 29.
Barren Strawberry, February 9.
White Violet, February 14.
Dog's Mercury, February 14.
Lesser Celandine, February 15.
Dandelion, February 18.
Coltsfoot, February 25.

Again, on March 4 Rhododendrons were noticed in bloom, and Rhubarb well up. In Bedfordshire Coltsfoot was noted in bloom on January 29 the same year. Near Peterborough, on January 7, Gorse, and on December 27 of the previous year, the Violet and Primrose were in flower.

In Bedford on January 1, Winter Heliotrope and Furze were in bloom. The following notes, made on March 12, near Burton-on-Trent, show the earliness of the season, viz: Lords-and-Ladies coming up, Dairy Maid's Dock, Musk Thistle in leaf, Bluebell sprouting, Wood Sorrel in bud, Hawthorn in bud, Honeysuckle in leaf, Hazel (male and female flowers), Lesser Celandine in flower; and on March 19 Wood Anemone sprouting, Dog's Mercury nearly in flower.

The Rev. T. A. Preston noted at Marlborough:

Rough Chervil, February 1.	Hazel (female), February 5.
Snowdrop, February 3.	Dog's Mercury, February 10.
Lesser Celandine, February 3.	Lamb's Lettuce, February 19.
Spurge Laurel, February 5.	Butter Bur, February 24.
Hairy Bitter Cress, February 5.	Coltsfoot, February 26.

In Bedfordshire the following notes refer to flowers seen rather later, thus:

Lesser Celandine, March 6.	Barren Strawberry, March 26.
Vernal Whitlow Grass, March 8.	Butter Bur, March 29.
Marsh Marigold, March 15.	Ground Ivy, March 30.
Hairy Bitter Cress, March 15.	Wild Strawberry, April 2.
Wood Anemone, March 18.	

Some other later plants, seen in Shropshire and Derbyshire, are given below:

Cuckoo Flower, April 30.	Bugle, May 7.
Goldilocks, April 30.	White Deadnettle, May 7.
Red Campion, May 3, May 6.	Rough Chervil, May 10.
Hedge Garlic, May 6.	Upright Meadow Crowfoot, May 10.
Bush Vetch, May 6.	Archangel, May 10.
Crosswort, May 6.	Bluebell, May 12.
Wild Strawberry, May 6.	Woodruff, May 15.
Early Purple Orchid, May 7.	

In Lincolnshire the following dates have been recorded for the plants named:

Spurge Laurel, March 6.	Wood Anemone, March 30.
Lesser Celandine, March 7.	Ground Ivy, April 7.
Coltsfoot, March 7.	White Deadnettle, April 8.
Elm, March 9.	Cowslip, April 8.
Violet, March 17.	Larch, April 11.
Dandelion, March 28.	

These may be contrasted with the following, noted the same year at Nottingham:

Cowslip, April 3.
Violet, April 3.
Plum, April 3.
Marsh Marigold, April 12.
Cherry, April 12.
White Deadnettle, April 17.
Purple Deadnettle, April 17.
Ground Ivy, April 17.
Blackthorn, April 17.
Hedge Mustard, April 17.
Speedwell, April 17.

At Burton-on-Trent an observer notes:

Hazel, March 1.
Daisy, March 5.
Crocus, March 5.
Marsh Marigold, March 6.
Larch (male flowers) March 6.
Dog's Mercury, March 7.
Coltsfoot, March 7.
Elm, March 8.
Larch (female), March 8.
Chickweed, March 8.
Shepherd's Purse, March 8.
Moschatel, March 18.
Sweet Violet, March 18.
Lesser Celandine, March 18.
Purple Deadnettle, March 20.
Barren Strawberry, March 21.

Compare these with notes made the same year at Dorset, on the South Coast, viz:

Sweet Violet, March 1.
Primrose, March 3.
Wood Anemone, March 7.
Purple Deadnettle, March 15.
Wood Violet, March 17.
Germander, March 19.
Speedwell, March 19.
Moschatel, March 19.
Dog's Mercury (male flowers), March 19.
Chickweed, March 19.
Coltsfoot, March 19.
Daisy, March 19.
Marsh Marigold, March 20.
Ivy-leaved Speedwell, March 20.
Red Campion, March 20.
Dandelion, March 20.
Field Forget-me-not, March 20.
Sun Spurge, March 20.
White Deadnettle, March 21.
Spring Snowflake, March 25.

In Northants and district, records include:

Lords-and-Ladies, February 17.
Greater Celandine in leaf, February 17.
Daisy in flower, February 17.
Elm, March 8.
Lesser Celandine, March 8.
Sweet Violet, March 9.
Ground Ivy, March 19.
Wallflower, April 2.
Coltsfoot, April 2.
White and Purple Deadnettles, April 2.
Ground Ivy, April 2.
Marsh Marigold, April 9.
Cuckoo Flower, April 9.
Daffodil, April 9.
Hedge Mustard, April 12.
Scentless Mayweed, April 12.
Hairy Bitter Cress, April 12.
Horsetail, April 12.

In the Repton district, farther north, an observer records:

Snowdrop, February 17.
Sweet Violet, March 5.
Coltsfoot, March 5.
Ground Ivy, March 5.
Marsh Marigold, March 5.
Daisy, March 5.
Lesser Celandine, March 17.
Dog's Mercury in bud, March 17.
Vernal Whitlow Grass, March 25.
Wood Anemone, March 25.
Primrose, March 25.
Rue-leaved Saxifrage, April 5.
White Deadnettle, April 5.
Hairy Bitter Cress, April 12.
Cuckoo Flower, nearly out, April 12.

In Bedfordshire the following notes include some other species:

Dog Violet, March 8.
Moschatel, March 20.
Hairy Bitter Cress, March 23.
Pasque Flower, March 27.
Cowslip, March 27.
Early Sedge, March 27.
Cuckoo Flower, April 7.
Goldilocks, April 7.
Bulbous Crowfoot, April 10.
Archangel, April 10.
Herb Paris, April 17.
Cotton Grass, April 18.
Field Wood Rush, April 18.
Field Forget-me-not, April 18.
Sloe, April 18.
Horsetail, April 19.

In Staffordshire we may remark:

Daffodil, March 21.
Lilac in leaf, March 21.
Barren Strawberry, March 21.
Hazel, leafing, March 21.
Lesser Celandine, March 21.
Dog's Mercury, March 21.
Gooseberry in leaf, March 23.
Coltsfoot, March 24.
Hairy Bitter Cress, March 26.
Grey Speedwell, March 26.
Gooseberry in flower, March 28.
Moschatel, March 28.
Goat Sallow, March 29.
Horse Chestnut, March 30.
Larch in leaf, March 30.
Wood Sorrel in flower, March 31.

In Bucks one may note the following:

Daisy, February 21.
Dog's Mercury, February 22.
Hazel, February 22.
Primrose, February 26.
Snowdrop, February 26.
Sweet Violet, February 26.

A Kentish observer notes:

Stinking Hellebore, February 21.
Hazel, February 21.
Coltsfoot, February 21.
Lesser Celandine, February 28.
Chickweed, February 28.

On leap year day in Leicestershire, the following were in flower:

Sweet Violet, in bud.
Dog's Mercury, in bud.
Lesser Celandine, in bud.
Snowdrop.
Daisy.
Coltsfoot.
Speedwell.
Hazel.
Primrose.
Alternate-leaved Golden Saxifrage, March 14.

A Nottingham observer records:

Sweet Violet, March 7.
Lesser Celandine, March 7.
Goat Willow (female), March 13.
Coltsfoot, March 20.

A Shropshire botanist records:

Hazel, February 25.
Barren Strawberry, February 26.
Dog's Mercury, February 26.
Dandelion, March 3.
Lesser Celandine, March 8.
Coltsfoot, March 8.
Wood Anemone, March 13.
Willow, March 15.
Moschatel, March 21.
Wood Sorrel, March 24.
Green Hellebore, March 24.

In Bedfordshire most dates are earlier:

Green Hellebore, February 11.
Hazel, February 22.
Dog's Mercury (female), February 29.
Coltsfoot, March 3.
Purple Deadnettle, March 10.
Sweet Violet, March 10.
Moschatel, March 13.
Wood Anemone, March 13.
Lesser Celandine, Marsh Marigold and Butter Bur were in flower on March 13.

An Oscott observer notes:

Snowdrop, February 22.
Daisy, February 22.
Chickweed, February 22.
Mezereon, February 28.
Coltsfoot, February 29.
Hellebore, February 29.
Elder-tree in leaf, March 3.
Crocus, March 6.
Hawthorn in leaf, March 7.
Groundsel, March 10.
Polyanthus, March 10.
Yew, March 11.
Lenormand's Water Crowfoot, March 12.
Annual Knawel, March 13.
Mouse-ear Chickweed, March 13.
Horse Chestnut in leaf, March 17.
Field Wood Rush, March 21.
Dog Violet, March 21.
Jonquil, March 21.

In Worcestershire average dates are:

Primrose, March 9.	Dog's Mercury, March 9.
Sweet Violet, March 9.	Speedwell, March 9.

At Henley-on-Thames:

Upright Meadow Crowfoot was seen in flower on February 1.

At Castle Ashby the following are dates for flowering of many spring flowers:

Groundsel, January 1.	Winter Aconite, February 21.
Primrose, January 1.	Yew, February 29.
Sweet Violet, January 1.	Coltsfoot, March 1.
Heart's Ease, January 1.	Crocus, March 4.
Field Speedwell, January 6.	Red Deadnettle, 4.
Chickweed, January 7.	Wych Elm, March 4.
Shepherd's Purse, January 7.	*Alder, March 5.*
Whitlow Grass, January 8.	Celandine, March 5.
Winter Aconite, February 13.	Sweet Violet, March 8.
Daisy, February 13.	Elm, March 8.
Snowdrop, February 17.	Dog's Mercury, March 9.
Hazel, February 17.	Primrose, March 12.
Polyanthus, February 19.	Sallow, March 12.
Hazel, February 20.	Dog's Mercury (female), March 15.
Spurge Laurel, February 21.	Lungwort, March 15.

The foregoing illustrations include most of the common spring flowers, and are interesting as showing the difference at different places in the first date of flowering. They show that warmer conditions induce earlier flowering. As we go north plants flower much later.

Many flowers, equally affected by the season, bloom late instead of early. In the first week in January as many as forty flowers have been found, under such circumstances, in bloom. These include, amongst others:

Marsh Marigold.	Hedge Garlic.
Vernal Whitlow Grass.	Sweet Violet.
Hairy Bitter Cress.	Gorse.
Winter Cress.	Hairy Vetch.

Water Avens.
Rough Chervil.
Musk Thistle.
Ox-eye Daisy.
Dwarf Forget-me-not.
Wood Sage.
Primrose (early).
Little Nettle.
Field Wood Rush, etc.

There are many plants that continue to flower all the year round, more or less, and some of the foregoing are to be included in this category. On some occasions that early flowerer, Dog's Mercury, has been found in flower as late as December 28, in Bedfordshire. In the Peterborough district, an observer noticed:

Lesser Periwinkle, December 10.
Sweet Violet, December 27.
Furze and Avens, January 7.
Ivy-leaved Toadflax, January 7.

On the South Coast plants remain in flower much longer than elsewhere, and there and in the Scilly Isles one may experience the mildness of the Riviera. At Falmouth, late in December and on January 1, 100 plants were observed, amongst others:

Fumitory.
Pepper Cress.
White Mustard.
Dyer's Weed.
Dog Violet.
Bladder Campion.
Red Campion.
Herb Robert.
Furze.
Avens.
Hogweed.
Wild Carrot.
Hawkbit.
Long-rooted Cat's-ear.
Nipplewort.
St. James's Wort.
Corn Marigold.
Milfoil.
Sheep's-bit Scabious.
Field Speedwell.
Wood Betony.
Primrose.
Scarlet Pimpernel.
Thrift, etc.

In the North Midlands an observer noted in bloom:

Harebell, October 14 and 29.
Field Scabious, October 15.
Mouse-ear Hawkweed, October 15.
Herb Robert, October 18 and December 10.
Selfheal, October 18.
Centaury, October 18.
Marjoram, October 18.
Meadow Crane's-bill, October 19.
Milfoil, October 25.
Lesser Spearwort, November 1.
Foxglove, November 5.
Cowslip, December 8.

On New Year's Day, in Bedfordshire, one might see in flower such plants as:

Dog's Mercury.
Daisy.
Dandelion.
Mouse-ear Chickweed.
Creeping Buttercup.
Winter Heliotrope.
Groundsel.
Shepherd's Purse.
Gorse.

In the Burton-on-Trent district, so late (or early) in the year as January or February—

Rape,
Thyme-leaved Sandwort,
Parsley Piert,
Scentless Mayweed,
Wall Speedwell,
Shepherd's Needle

were noticed in flower, with others that are perennially in bloom, and some few early flowers.

In Staffordshire the following were observed in flower in September:

Meadowsweet, September 21.
Great Hairy Willow Herb, September 21.
Meadow Crane's-bill, September 21.
Selfheal, September 30.
Herb Robert, September 30.
Harebell, September 30.
Campion, September 30.
Woundwort, September 30.

Another record, at Falmouth, on November 23, includes the following (and others) then in flower:

Swine's Cress.
Red Campion.
Cinquefoil.
Fennel.
Alexanders.
Devil's-bit Scabious.
Sow Thistle.
Hawksbeard.
Spear Thistle.
Knapweed.
Purple Heather.
Creeping Toadflax.
Spotted Deadnettle.
Ribwort Plantain.
Pellitory-of-the-Wall.

In Bedfordshire, the latest flowering dates include:

Wall Lettuce, August 24.
Dropwort, August 28.
Basil Thyme, August 28.
Venus' Looking-Glass, September 29.
Grass-of-Parnassus, September 29.
Lady's Fingers, September 29.
Rest Harrow, September 29.
Bush Vetch, October 3.

Great Bindweed, October 3.
Clustered Bellflower, October 10.
Grassy Stitchwort, October 10.
Fluellin, October 10.
Narrow-leaved Toadflax, October 10.
Autumn Gentian, October 10.
Rockrose, October 10.
Burnet Saxifrage, October 10.
Wild Mignonette, October 10.
Water Betony, October 10.
Lesser Scabious, October 17.
Base Rocket, October 17.
Herb Robert, October 17.

The foregoing illustrations show that in different parts of the country there is a decided difference in the cessation of flowering of different species. They also show that this largely depends on the character of the season.

The reader may find much of interest in the noting of the seasons of flowering of the plants of his or her district. Not only can one study the earliest flowering, and the latest dates of each plant, but also, and this is of more phenological value, we may determine the normal date of the first flowering, and how much a season varies in this respect; how much earlier or how much later than the usual date of first flowering a particular date is, and also what is the mean date, which can be discovered by keeping a series of records consecutively for a number of years. The same applies to the latest season of flowering. We may thus study, not only the extremes, but also the variations from the normal of the extremes, and also the average dates.

All this indicates how intimately connected phenology is with meteorology. It has indeed been sufficiently indicated by a discussion of the principles regulating phenological phenomena, or the natural causes affecting flowering. The variation in the character of these causes, such as temperature, frost, rain, drought, snow, sunshine, wind, etc., can only be studied properly by aid of meteorological instruments. Hence phenology and meteorology are essentially connected. Phenology is regarded strictly as a part of meteorology, and a subsidiary guide to the elucidation of weather characteristics. It may be subsidiary, but as the phenomena it records are the result of the effects of weather causes, it is more than subsidiary: it is also complementary. The weather changes are causes, which have other than phenological effects—*e.g.*, the damage done by a storm. But whilst meteorological data are abstract (the records of instruments), phenological data are concrete, being actual illustrations of the results of weather change or action. This being plain, since the elements are not identical with meteorological charts, any more than phenological tables are identical with flowering seasons, it is obvious that meteorology and phenology are related, whether as to the tables constructed, or the causes and effects the tables represent, graphically or otherwise.

It is really necessary for the phenologist, therefore, to make himself conversant with the meaning and use of meteorological instruments, in order to explain phenological phenomena. It is not proposed here to go into details on this head. Reference should be made to the admirable and concise guides and booklets published by the Meteorological Office and the Society.

Briefly, however, we may note the importance of certain instruments. There is frequently in large towns, or, in some cases, in country districts, controlled by a public body or by private individuals, a meteorological station, and the local information is often published in the local paper. The Meteorological Office also publishes daily, weekly, and monthly weather charts, and there are also yearly summaries, and records covering a series of years, of statistics relating to rain, etc., for comparison.

For estimating the pressure of the atmosphere, which is a guide to wet or fine weather, and of rain or dry weather, the barometer is utilized. For the measurement of temperature, the thermometer is used. The lowest minimum temperature is recorded by a minimum and the highest by a maximum thermometer. From these one can obtain the mean temperature, and the accumulated temperature above 42° F. is obtained from such data. This factor is important as deciding the activity of plants, germination, leaf and flower opening, and fruit formation and ripening. Dew-point, another important factor, is measured by a wet and dry bulb thermometer, or hygrometer. This gives an indication of the chances of wet or dry weather. Rainfall is measured by means of a rain gauge. The fall in inches, or parts of an inch, per diem is recorded, and thus the rainfall of a week or month or year.

Wind can be measured, according to a system, the Beaufort scale, either by an anemometer, or by noticing the reading of a wind vane on a church or other building, and by determining its force by the same scale. By actual observation, cloud, fog, mist are also recorded, on the same scale, by actual eye records.

Sunshine may be recorded by the same kind of method as the last, or by a sunshine recorder. Frost and drought, both extreme phases, are effects or causes which can be measured, in the first case, by the thermometer, or by the rain gauge in the second. Other less general phenomena can be measured by special instruments, or by ocular observation. The main thing is to choose a proper site for observations, to record regularly, and at the proper times. The accumulation of such data is of the greatest value, not only from the phenological, the meteorological, or a general point of view, but in relation to agriculture, and this connection makes it imperative that such observations should be conducted efficiently, on a national basis, and universally. There is need for a large number of stations, and of more public support, in money and interest, of both pure meteorological surveys, and of phenological surveys. Connected with the latter, there are less than 200 observers for the whole of the British Isles, or only about one for each county. Surely, more students of this interesting subject, which has its economic value, can be found.

Enough has already been said to show the value of keeping a daily record of observations made. Such a record is of the nature of a diary, of course, and many people have a prejudice against making a diary. But, really, though the task may be irksome, a diary, when complete, is a most useful record, whatever it records.

Take, for instance, the classic instance of Gilbert White, whose "Natural History of Selborne" is a concrete instance of the value of making notes.

It affords an illustration of how, from a daily records, a series of data may be collected or accumulated, and serve for descriptive memoranda of different species rearranged under subjects from the chronological observations of the diary.

The calendars of White and Markwick, for the first ten days of January, run as follows:

	White.	Markwick.
Redbreast (*Sylvia rubecula*) sings ...	Jan. 1-12	Jan. 3-31, and again Oct. 6
Larks (*Alauda arvensis*) congregate	Jan. 1-18	Oct. 16, Feb. 9
Nuthatch (*Sitta Europæa*) heard ...	Jan. 1-14	Mar. 3, Apr. 10
Winter Aconite (*Helleborus hiemalis*) fl.	Jan. 1, Feb. 18	Feb. 28, Apr. 17
Shell-less snail or slug (*Limax*) ap.	Jan. 2	Jan. 16, May 31
Grey Wagtail (*Motacilla boarula*) ap.	Jan. 2-11	Jan. 24, Mar. 26
White Wagtail (*Motacilla alba*) ap.	Jan. 2-11	Dec. 12, Feb. 23

fl = flowering ; ap = first appearance.

A large number of these data, when arranged under the heads of the plant or animal to which they refer, may, in time, help to form a life-history of the species.

Linnæus, earlier, in 1755, made a "Calendar of Flora," and, as edited by Stillingfleet, the first part is as follows:

I. MONTH.

" Reviving nature seems again to breathe,
As loosened from the cold embrace of death."

January 5. Rosemary (*H. Rosmarinus officinalis*), f.
" 11. Honeysuckle (*Lonicera periclymenum*), l.
" 23. Archangel, Red (*Lamium purpureum*), F.
Hazelnut-tree (*Corylus avellana*), f.
Honeysuckle (*Lonicera periclymenum*), L.
Laurustinus (*H. Viburnum tinus*), F.
Holly (*Ilex aquifolium*), f.

A calendar of Flora made by Theophrastus at Athens, latitude 37° 25′, runs:

February 1. Violet, early bulbous (*Leucojum vernum*), F
Wallflower (*Cheiranthus cheiri*), F.
Cornel-tree (*Cornus mas*), L.
Dogberry (*Cornus sanguinea*), L.
" 14. Bay-tree (*Laurus nobilis*), L.
Alder (*Betula alnus*), L.
Abele (*Populus alba*), L.
Elm (*Ulmus campestris*), L.
Sallow (*Salix*), L.
Poplar, Black (*Populus nigra*), L.
Plane-tree (*Platanus orientalis*), L.

f = flowering ; l = leaves beginning to open.
F = flowers full blown ; L = leaves quite out.

Thus, at all times there has been an interest in the events of nature. Theophrastus was born 390 B.C., and from his day onward (or even before) there have been continual efforts to try to understand and describe natural phenomena.

Of recent nature diarists, the work of Westell is perhaps the most illuminating. No fact of the slightest interest is omitted from his Calendar of Nature. Everything has its place. In the "Book of Nature" he has given us a classified summary of the events of each month. All the phenomena of bird life appear under "Birds," the first three items reading: "Blackbird sings in mild weather. Brambling appears about middle of month. Chaffinch starts to 'pink' towards end of month." Other headings are: "Insects," "Plants," which include—"American Witch Hazel still in flower. Arborescent Witch Hazel flowers. Bulbs in gardens push through," "Miscellaneous." It will be seen that each item is alphabetically arranged. The whole calendar is thus an Abecedarius of Nature.

As a sign of the times—viz., that nature study is becoming more popular, more general—it may be remarked that some daily newspapers, during the spring and summer, allow their staff to publish daily nature diaries—*e.g.*, the *Daily Mail*, which prides itself on being to the front in all things. Thus Mr. (now Sir) W. Beach Thomas, on February 10, wrote: "February 10. Frosts in February are normal, but not within memory —and country memories are quite sound for three-score years or so—has a February frost found so many delicate things on which to wreak its vengeance.

"Many people are wondering whether we shall have any fruit at all this year. In the south the Strawberry bloom is out, and those who did not take the stark and proper method of snipping off the bloom, find to-day every flower blackened to the core," etc.

Speaking of "Nature Detectives," the same popular daily paper says: "These detectives have also solved the secret of how to keep their parents young. Many country residents now offer little rewards for news about natural history—for the discovery of a wood ant's nest, or geometric moles' nests, or the whereabouts of the first migrant birds, or queen wasps. Many parents are working laboriously to keep up with the learning of their children, who are turned into instructors. One very remarkable book has been written by a parent, who was taught the first elements by his son.

"Some of the County Councils—one of which is Oxfordshire—are issuing little natural history note-books and diaries. Half the elementary and private school teachers encourage the subject, and the public schools begin to have most flourishing natural history societies. We shall very soon become a nation of naturalists, and the ideal of that great French artist, Rodin, will be realized, that all education should begin with 'the harvest of the eye.'

"Apart from any remote benefit of this sort, one result will be natural protection, all through the country, of the insects and birds and animals which are useful to the gardener and farmer."

As with the daily record, so with the yearly record—it is necessary to make observations regularly, so that the record may be complete, and not show any hiatus or blank. The main value of a series of records lies in its continuity and recurrence over a number of different seasons. It thus approximates to a complete record, and recurrence gives also a measure of variation.

The yearly record is, of course, made up of the daily records, followed out for twelve months. Partial records are not of such value. To be most valuable a yearly (and so the daily) record should deal with one district. If spread out over a number of localities or districts, the record must be carried on for a number of years in order that any one district may have a representative record, and for this purpose each locality must be visited at each season of the year.

Records from several localities or districts have, of course, an additional value, if fairly complete, in giving the range of distribution, and from such records maps may be drawn up. At the same time observations in a limited area also may be mapped. Indeed, the use of maps, whether for a small or a large area, is to be advocated always where it is possible to use them, not in botanical matters only, but in all natural history work.

Daily records, if considered separately, are isolated memoranda, and may be then considered as purely geographical data. Yearly records, composed of a series of daily records, are seasonal, and, being consecutive, are also biological, giving a record of the various activities, or as much of the whole life-history as possible of a plant or animal.

Just as a series of daily records goes to make a yearly record, and is thereby the more valuable, so a series of yearly records is more valuable than one year's or two years' data.

The observations in no two consecutive years will be exactly alike, and the longer the series, the more variation will there be, so that a summary of, say, ten years' records will go a long way towards establishing a permanent series of life-histories of the plants or animals observed.

Reverting to the subject of maps, it is impossible to overestimate their value. However valuable a diary may be, unless it is supplemented by a map it can never convey so graphic an idea of the natural history features of an area. This method has, happily, already been introduced into schools, where the pupils are taught to compile a map of the district, the neighbourhood of the school, based upon observations made in the field, and recorded, or not, as the case may be, in their nature diaries. To make a mark on a map by a sign or abbreviation, letter or number, corresponding to a mental or written observation, has the effect of impressing it more surely upon the mind or memory. Apart from this, such a pictorial summary, as it were, of the data observed exhibits them in entirety, and the effect of juxtaposition and completeness is especially instructive.

Maps may either be provided, and consist of printed ordnance or other maps, or they may better be constructed by the observer himself or herself. The latter alternative has the effect of further impressing the nature of local surroundings and phenomena on the mind. The mere plotting of lines or fixing of points to scale, or otherwise, gives the child, or the adult, an invaluable insight into how to define position, how to preserve proportion, apart from the actual acquisition of knowledge of the details of the locality, possibly previously entirely unknown to them. The delineation of data on a map locates the data.

As has been remarked already, the use of nature diaries in schools has become very general. It is, indeed, a logical beginning for the cultivation of habits of observation, and in the practice and art of making memoranda.

Many kinds of nature diary are in use. Some publishers print forms for the insertion of notes in tabular or columnar form, or otherwise, under definite heads, with space for remarks.

To be ideal, such a form should be wide in scope, but not too minutely classified for beginners.

So far as the writer is aware, the nearest approach to perfection is shown by a form suggested by Mr. Westell, the well-known writer on natural history from a juvenile and popular standpoint, who is also a skilled observer and trained ornithologist. The headings he suggests are given below:

Date.
Barometer (reading).
Thermometer (reading).
Seaweed (effect on).
Wild flowers (observed).
Rainfall.
Direction and velocity of wind.
Locality, soil, etc.
Ornithology (birds observed or heard).
Farm and crops (current activities).
Farmyard (current activities).
Garden (current activities).
Entomology (insects seen).
General notes and observations.

If the diary is primarily botanical the tabular information may be thus divided :—

Plants seen.
Date, locality, habitat, frequency.
Seeds germinating.
First leaf.
Buds unfolding.
Catkins or flowers open.
Fruit.
Life-history.
Pollination, insect pests, fungal pests.
Local folk names.
Dispersal.

Surroundings.
Number of field on map or other data to fix position.
Mode of occurrence ; relation to other plants.
Soil.
Details of habitat.
Plant formation or association.
Water-content (or rate of current ; type of water).
Slope, temperature.
Aspect, rainfall, light intensity.
Surface features.

There is, as will already have been remarked, an especial value in the practice of making and keeping a nature diary for school purposes. It is a natural introduction to natural history work. It provides a ready means of carrying out a course of nature study. It is the ledger book of the nature student. Subject studies (as opposed to object records) come later, but are based, as has been shown, on a daily record made in the nature diary, or independently. The keeping of a diary is a beginning. The statement of brief notes in a diary paves the way for more detailed study of some one object. There is an innate shyness in the majority of children towards committal of observation to writing. It requires application and practice. But, just as composition is not mastered until the alphabet, spelling, short sentence formation, have been learnt, so description, brief or elaborate, follows, not precedes, the making of entries in a diary.

Not only does the keeping of a diary train them in expression of thoughts in writing, and induce the habit of observation, causing, by emulation or desire, the acquirement of vigilance and the multiplication of observation, and so practice and following perfection, but—and this is a most valuable feature—it also promotes and fosters interest. Once interest is aroused, then desire to progress soon follows (it is ever *mactute est virlute*); and so an initial difficulty is already overcome—namely, shyness, lack of desire to progress, or other hindrances to learning. These are only some of the good results of nature study. Properly handled, it may be a royal road to learning.

Emphasis should be laid at this point upon the real import of the nature diary, which is to lay the foundation for a subject record. It has, however, just been pointed out that the subject record may be independent of the daily journal notes.

The study of an individual plant may be made in the field, if opportunities occur, from a single observation. A whole series of phenomena may be observed, with good fortune, at a single sitting, as it were. But time and opportunity, or conditions, do not always allow this to be done.

Otherwise such extended observations, or details, of species or stages, etc., have to be compiled from isolated daily records in the journal.

Subject records have this further value, that they constitute a classified analysis of the facts observed, which can be arranged on the card system, in any manner desired.

Such separate records, moreover, can always be augmented—additions can always be made to them. The journal is a continuous seasonal chronological record. Its dissection into classified subject data serves to co-ordinate all facts of the same nature under a separate head, whilst the chronological record still remains intact.

A cross reference to each item in the subject record can be made by date, and the record in the journal is sufficiently connected with the subject record by the underlining of the material point of the note itself.

Cross reference to additional notes (journal) may be made either on the first date recorded by date—day, month, year—or by number, if the data are separately numbered, in which case reference in the subject record to the journal record may be also by number.

A final word may be said as to the value of nature diaries and similar records, in the effect they have of promoting the acquisition of habit. So valuable is this asset that in schools, at any rate, or where system can be applied, such a practice should be made compulsory.

The acquirement of a valuable habit in early days is ten times more useful (or more so) than if acquired much later in life. First impressions are admittedly the most powerful. Early habits gained seldom lose force as age advances if they are useful and advantageous. Moreover, the habit leads on progressively to the employment of still better and more scientific habits: in a word, the scientific method and means of studying things, either in the sphere of natural or physical science or in any other.

Furthermore, a great gain to be derived from such early methods of observation is the manner in which it gradually and naturally leads up to the acquirement of logical reasoning by deduction or induction. This alone is an achievement that no other branch—or *method*, rather—of study, does with the same ease and effectiveness. Therefore, the promotion of nature study is a nation's duty.

CHAPTER VI

HINTS TO THE TEACHER

In the following notes only general considerations are discussed, as every teacher has his or her own method of teaching. My object is merely to suggest, and also to emphasize, certain aspects, which may, to a layman, appear more important for the very reason that he is untrammelled by tradition and generally accepted notions that by worn-out practice are deemed essential and sufficient. In the process of getting pupils to assimilate new knowledge, always by the heuristic method, the greatest value is to be placed upon efforts directed along new channels, so long as the *modus operandi* is rational and attractive.

Such, then, is my aim in offering the following notes on the subject of nature study—for generally speaking it comes to this—and the application of botany to the school curriculum.

Always one should place to the fore field-work in all kinds of nature study work. For by its means one is brought at once into the presence of nature itself, to realities, to specimens, to things that can be seen, touched, handled. Thus we are at once at grips with experiment, and experiment is admittedly the best schoolmaster.

Little interest is evoked by a child in the scanning of pictures of objects it has never handled, whose form can only be guessed, the size of which is unknown, the colour of which is uncertain, the structure of which is hidden, and whose texture is dissembled by the surface of the paper used for printing. Neither is a child impressed by descriptions, however good, of a plant or an animal, for howsoever fertile and accurate its imagination may be, so much is left to chance that there is ample scope for misunderstanding, and thus the letting in at the first stages of an entirely erroneous opinion or idea, which may, perhaps, never be removed. Moreover, this is in no sense a heuristic method of approaching the question, and by any other means education is a failure—at least, in the subject under review. And we do not think we are very much mistaken in affirming that this applies to all subjects.

But what gives to field work its special value in this connection is the fact that it supplies at once *material* for study: material for the student to examine, material by aid of which the teacher can educe all the facts that can be expressed by the heuristic method. It goes a step farther than bringing such material to the school for the purpose of using it in the only manner possible, as we have just emphasized, in that it brings the student at once into the true surroundings of the object, and enables him or her to see it,* in its proper setting, alive and at work—in a word, filling its proper place in the scheme of Nature.

There the pupil can study it to its best advantage, under the best conditions, and instead of statements or pictures he has the real thing. Field work, in short, provides the pupil with all the material he or she needs for the illustration of his or her subject. Objects in the field serve as illustrations of what is acquired by learning. Taken home, if desired, they serve as everlasting memorials of pleasant work, of real know-

* In school isolated from such surroundings, and, if a flower, often withered or incomplete; if an animal, dead or lifeless in a sense.

ledge stored up for ever, and, not least, of delightful excursions into the realms of Nature, seen at first hand.

But the brain, however large and well developed, has its limits, in spite of the vast labyrinth of avenues leading to definite storehouses of knowledge, and memory, however good, is never infallible, as the best of educationists will confess at once, without hesitation.

It is therefore essential to all success, in whatever direction energy is directed, and to whatever end, that memory should be reinforced and assisted by means of memoranda that can be committed to writing, to serve for reference in the future whenever needed. For this purpose, emphasis is next laid upon the *second important point in my chain of suggestions.* The wise teacher will take care that his or her pupils are adequately provided with notebook and pencil in their walks abroad. The field botanist knows the value of such a precaution. In the field the pupil is in a world of unknown wonders, the multitude of phenomena is so large, and the rapid change of events and the number of incidents and points of interest so great, that the mind alone is unable to grasp so vast a concourse of happenings, or sights and sounds.

There is, then, little need to lay stress upon the necessity for providing for such emergencies by supplying one's charge with a ready means of seizing upon such a measure or proportion of the good things he has displayed before him, by enabling him to preserve a fair proportion of these delights for the future.

By aid of a notebook it is possible to note down all the plants seen. Few people could remember in a walk all the objects encountered, if trusting alone to memory. Apart from such notes, it is only in the field that one can see the numbers of a plant, their arrangement, and so forth. By means of the notebook (or map) all these and innumerable other features can be recorded. No painter can go and look at a landscape, and return home, without making a sketch of it, and paint the scene faithfully. So no child can go out for a walk and see a field full of flowers, or a wood, or marsh or lake, and depict in words, or writing, all he has seen, unless he makes notes on the spot.

What especially applies here is to the study of the object in the field. There it is possible to see it in its entirety, growing, and exhibiting all the phenomena of its type: its behaviour towards light, temperature, etc., its movement, if any (as in sensitive plants), its behaviour at the stage of pollination, or of dispersal, its size, form, colour, etc., its relation to other plants, its relationship to its surroundings.

None, or few, of these features can be made out indoors. They must be made upon the plant as it grows, in its habitat. Such a series of notes as the plant's activities, its characters, etc., afford cannot be seen and remembered unless the child has at hand a notebook. When the teacher asks for information on any point, and by the heuristic method obtains the answer, if correct this should be written down in the notebook, when it becomes part of the child's own knowledge. Such answers might, it is true, be elicited without regard to taking notes of them, but if the information is not at once put down it is liable to be forgotten.

Hence, let every teacher especially take pains to provide his pupils with notebook and pencil.

One of the most practical portions of field work that can be adapted for school work is the carrying out of survey work. The value of this lies in its systematic basis. It is generally carried out by means of ordnance maps of the district. These maps serve for surveys of all types, relating to the plant and animal life of the district, meteorology, physical or physiographical features, geology, archæology, etc. They are eminently suited to botanical work.

In many schools the plan followed is to take the ordnance maps of the district. These are hung up in the school. Each area is numbered. This gives at once a means of reference to a definite tract. Any notes made on that area can be referred to by number, any specimens collected can, similarly, be referred to a definite spot. The notes made may be entered in the nature diary or field notebook. By this method exactness is given to the data recorded.

Every child can be given one or more tracts to examine and to visit from time to time. The division into separate areas of a tract, and the apportionment of a portion to each child, brings home to the child the principle of the division of labour, the co-operation of each in a larger whole. It may also produce emulation. It certainly will produce interest, and confer on each a sense of responsibility. An *esprit de corps* will naturally grow up between the different workers. A desire to help one another will also spring up, and give the pupils an inkling of how their life-work should be carried on, not in a competitive spirit, but in a spirit of co-operation. Perhaps this will be the most valuable permanent result.

A feeling of proprietorship, based on the interest in the individual piece of work allotted to each, will gradually grow up, and an intelligent effort to make the most of the facilities afforded by each area will evolve itself.

It is needless to emphasize further the value of such work. Once adopted, it will become at once apparent. Survey work will pave the way to more detailed work later. The area each is given to examine may be further developed by the construction of a large-scale map of the tract, making it possible to record any features of special interest, as in the case of a large-scale map (six-inch) itself.

Another adjunct to nature work (botanical) which is supplementary to, or an adjunct of, the last, is the maintenance of a wild-flower table. The necessary materials, etc., for keeping this up will consist of a fair-sized table in an open space in the schoolroom, where flowers gathered each day by pupils or teachers can be effectively displayed without crowding. The vases and receptacles used for holding the flowers may consist of jam jars or smaller vases, such as paste jars (Gloy), or transparent bottles saved from the kitchen, and children can be asked to get their parents to save them for this purpose, so saving expense. If special flower vases are obtained there is a gain, from the point of view of uniformity, in the appearance of the tables. Each plant should have a clearly written label with the English name of the plant, and, if desired, the natural order below. It would be difficult to get children under fourteen years of age to appreciate the value of Latin names, or to use them intelligently without a knowledge of their meaning.

The most important point is to secure good and typical specimens in flower or fruit (or other stage), and to ensure that they are correctly named. There may be difficulty at the outset in achieving absolute perfection in this respect. If any doubt exists, it is better to leave out plants as to which there is uncertainty; it should be possible to discover some botanist in the neighbourhood to whom difficulties can be referred. If there is a museum in the neighbourhood the staff should be able to render help in this direction, and glad to do so.

There is one particular as to which great caution must be exercised. In asking children to bring in wild flowers it should be impressed upon them that they must do nothing to cause a plant to become exterminated. If a child only finds one, or two, or three specimens, and, after long search, can find no more, the rule should be that no specimens are to be gathered. The teacher may visit the spot and see if the plant is really rare.

Placed in their natural order on the flower table, the specimens may be used to help the children to learn the names of plants, and also to give lessons upon them from any special standpoint.

We have already emphasized the value of specimens in the field, as being concrete examples of things to be studied, in preference to teaching alone, or illustrations in books. One cannot do all the nature work in the field, and hence specimens are of equal value in the schoolroom.

They may be fresh, when obtainable, as in spring, summer, or autumn (*i.e.*, flowering plants in flower, fruit, or earlier stages), or preserved (in the form of dried specimens, either of the entire plant, or its parts, or in some preservative medium).

In school such specimens taken from the flower table may be utilized in a variety of ways. They may be taken as the theme for a lesson by the heuristic method. Enough specimens of the same plant (in this case a common one, as a pest, such as Charlock or Corn Buttercup) may be obtained for each pupil to have one, so that he, or she, may make a thorough examination of the plant, frame a description of it, and make a dissection of it. Handling of specimens, pulling them to pieces (like the child with a toy engine), is the surest way to lead to a proper understanding of them.

In most schools children are taught to draw or paint flowers, and this, again, is an excellent plan, making for accuracy, and impressing the details of the structure upon the mind, as a necessary result of the desire to draw the plant correctly, which, indeed, can only be done by studying the plant with close attention.

Specimens used in school may be obtained either from the field or from the garden. In many schools there is a school-garden. This is also another valuable adjunct. The habit of growing plants, sowing seeds, watching their growth, and tending them, gives a practical training in horticulture; and as many of the children will, later, engage in it for pleasure or profit, the sooner they grasp the principles on a sound basis the better.

One advantage of utilizing the school-garden for specimens is that it is possible to use the whole plant, if enough specimens have come up from seed, for examination. There is here no danger of exterminating a wild plant. Seeds can be obtained from wild plants and sown judiciously.

Furthermore, the practice of using garden plants enables one to get the material quite fresh, before it can possibly wither. This has many advantages. Also the plant is close at hand for the children to watch the stages of growth. The effect of cultivation may be noticed also where it occurs.

Then, since winter is a time when plants are few and far between—in flower—and as the outdoor study of the plant and its structure must be confined largely to trees (then, except evergreens, with their leaves shed so that the skeleton is better discerned), or to the relatively few plants that flower at all seasons of the year, it is necessary to have some material at hand for study, apart from the above. For this reason it is often the case that schools have a museum of their own, made up of dried plants, or seeds, or fruits, or of drawings, paintings, permanent dissections, and so on.

For the museum, children may be asked to collect specimens for drying and mounting, examples of the plants of the district. They may find abnormal structures, as ribbon growth, etc., and these may be preserved.

Fruit and seeds may be collected in season. Besides complete dried specimens, it is an excellent plan to mount the flower separately on a sheet, to show its outline and colour — *e.g.*, in the case of Orchids, Labiates, Pansies, etc.

Photographs of plants taken in the habitat are also wonderfully instructive, and of trees in winter and summer stages, with details of flowers, fruit, buds. And enlarged photographs of the flowers, or a section of them, are very valuable. Flowers may be taken indoors also, to show them on a larger scale than in the habitat.

There is, indeed, no limit to the amount of material that may be utilized for the museum, which will be a never-failing source of interest and instruction when outdoor work is impossible.

A further effect of field work is to provide material for answering many questions that arise in school. When plants are seen in their environment the relation of cause and effect is readily grasped. It may not be possible to give a reasoned explanation of cause and effect, or of adaptations, since in the main this is only to be demonstrated by careful experiment, but at the same time the regular association of the same conditions with the same type of plant, or the general occurrence of some special type of organ under identical circumstances, is a sufficient *a priori* reason for the correlation of cause and effect in most cases.

It would not be difficult in the study of water plants, for instance, to explain the features of aquatics by reference to the special nature of the aquatic habitat.

A comparison, for example, of terrestrial Buttercups with batrachian types would show the differences in the character of the stem—erect and rigid in the one, limp and floating in the other—or in the leaves—broad and even undivided in the one, and in the other heterophyllous—or of two types much divided, and more or less entire or lobed in the other; in still further cases ribbon-like, adapted to swift currents.

A comparison between the Lesser Celandine and the other land Buttercups would show that the Water Buttercups are descendants of the land forms, but that there are some water types that are becoming terrestrial, as the Lesser Celandine has pores on the upper surface, as in the normal aquatic types.

A judicious application of field work has other advantages besides its own immediate value, from the observational point of view.

By the encouragement of field work a great asset is the general increase in the child's interest in work as a whole. Outdoor study awakens the latent perception, quickens observation, and arouses a living interest in things.

It prompts a desire to find reasons. This, of course, develops the faculty of comparison, of contrast. Gradually, a natural process of reasoning is evolved, and the child automatically applies the process of deduction and induction. Thus nature work is eminently calculated to inculcate habits of logic. It is a preliminary stage to the acquirement of scientific methods of clear reasoning, with all the beneficial effects upon the work itself that this brings with it, as well as upon all other branches of study engaged in.

Therefore, the value of nature work cannot be overestimated. It makes for interest at the outset, and if it did nothing else that in itself is, we might almost say, half the battle won. For if once interest is aroused, a child then quickly acquires the power of application which is so necessary, and is henceforward capable of far greater sustained effort, which enables him or her to overcome greater and greater difficulties as they arise, and with this momentum confidence grows as the work grows harder and more complicated.

No two schools have exactly the same programme, so that it would be invidious to propose a scheme of field work that would suit each one. But, none the less, it is very necessary that some sort of a plan be followed, otherwise chaos will reign.

In offering the suggestions below, it is not supposed that the whole scheme can be carried out in one season, nor, perhaps, any part of it, but it would be well if work proceeded on some such lines if possible. The scope given is wide, and can be applied to elementary as well as to more advanced work.

General Survey of the District.—Physical agents, rain, heat, snow, frost, etc., and their work locally.

Physical Characters.—Surface, hills, valleys, etc.; river systems, watersheds; soils, rock-formations (general).

Physiognomy.—Woodlands, heaths, bogs, moors, pastures, etc.

Meteorology (Daily Record).

General Study of the Wild Flowers of the District.—Survey of each tract, by map; mapping of special areas; study of habitat, and its relation to the plants; trees (winter); bulbs (spring); autumn fruits; pollination; fruit dispersal; climbing plants; parasites; insectivorous plants.

Nature Diaries, Notes (daily).—There should, of course, be a correlation of the field work with the indoor study in the school. Notes made out of doors may be supplemented by school work. Material for indoor study will be collected during field work, briefly examined or studied on the spot, and carefully stored away till it is brought home for study in the classroom. There such material will be studied in detail; drawn, painted, dissected, etc.; but, though removed from its habitat, the flower must never be studied apart from that, if the idea of the plant's life-history is to be understood. The habitat of each plant is therefore carefully noted as each specimen is collected. There is, then, a perfect correlation between outdoor and indoor work. They are also complementary, as work can be done out of doors that is impossible indoors; and *vice versa*. Also, the facts relating to the habitat are supplementary to the features of the plant itself, just as all the factors that make up the environment are supplementary to the study of the habitat. All fit into a harmonious whole.

Let every teacher, therefore, study to fit him or her self to become an experienced field botanist, so that young pupils may be brought up in the right school of learning. For this is, we believe, the royal road to progress. If there is another it assuredly lies near this.

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GLOSSARY

The numbers in brackets refer to the first page where the terms explained below occur, and the Index supplies further references. Where a word is not explained in this glossary its meaning is obvious or explained in the text.

Absciss layer (59). The layer of cork intervening between the base of a petiole and the main stem, forming a leaf scar.

Absorption (45). A physiological process by which a plant obtains nutritive substances in solution from the soil through the root hairs.

Aeration (75). Ventilation of the soil, or water, giving free access to oxygen.

Aerophytes (74). Air plants, which, not being rooted in the soil or growing in water, obtain nutriment from the atmosphere.

Aggregation (184). Establishment of a community by dispersal and extension.

Air-spaces (45). Intercellular spaces for the entrance of oxygen for respiration.

Alien plants (13). Plants not native, but probably, or certainly, of foreign origin, though now more or less naturalized, as the Sycamore and Bird Cherry.

Alternation (181). When a plant formation is separated from one of the same type by a different plant formation.

Annuals (51). Of one year's duration.

Anthers (157). The distal extremity of a stamen containing the pollen.

Anthocyan (59). Purple colouring matter in plant cells.

Anticlines (212). Saddle-like folds in strata forming hills or domes.

Arenophilous (17). Growing best on a sandy soil.

Assimilation (82). Building up of plant substance from nutriment of the habitat, as of starch formation.

Association (41). A community associated with a definite type of habitat, recognized by the dominance of particular plants, as a damp Oak-wood.

Barren stem (12). As applied to Brambles, a stem which does not flower or produce a panicle.

Batrachian (265). Aquatic types of Buttercups.

Bulb (51). An underground bud with scale leaves, stored with reserves.

Calciphilous plants (17). Addicted to a lime soil.

Calcium (79). An element entering into the composition of lime salts, necessary to plant growth.

Carbon dioxide (74). The source of carbon in plants necessary for starch and sugar formation.

Chalk (17). A form of calcium carbonate or lime salts.

Chasmophytes (126). Plants that grow in crevices on bare rock, with only a little detritus.

Chemosynthesis (186). Process by which bacteria can form organic substances from carbonates, carbonic acid, etc.

Chersophytes (61). Plant formations of waste ground.

Chlorophyll (59). Green colouring matter in plants, enabling them to assimilate.

Chloroplasts (52). Chlorophyll cells.

Chomophytes (23). Plants growing on rock, with a subsoil of detritus on the surface or in crevices.

Cleavage planes (212). Strata with planes or joints at right angles to other planes.

Complementary association (104). Where plants develop successively and have their roots at different levels, as Bracken, Bluebell, and Soft Grass.

Cotyledon (33). The seed leaves, single in Monocotyledons, in pairs in Dicotyledons.

Cuticle (52). The outer surface of the epidermis.

Denudation (81). The wearing down of the surface of rocks by various agencies, such as rain, frost, etc.

Deposition (212). The formation of strata by various agencies, such as water, chemical action.

Depression (201). The opposite of elevation, or submergence by lowering of level.

Dimorphic (157). Exhibiting two forms, as of leaves—*e.g.*, those of Water Buttercups or of flowers with long and short styled forms.

Diœcious (157). Unisexual, where stamens are on one plant, carpels on another.

Dispersal (161). Method of distribution of plants by seeds or fruits through various agencies, such as wind, water, etc.

Dominant (103). The most frequent or characteristic member of a plant community, as the Oak in an Oakwood.

Drip Tips (60). Plants in tropical regions which convey the excessive water to the roots by special channels, and have developed special structures.

Ecesis (185). The process a plant adopts of establishing itself in a habitat.

Ecology (6). See definition.

Edaphic factors (57). The nature of the soil of the habitat.

Endemic (66). Confined to a certain area, or truly native. This can be said of few British plants.

Environment (40). The external factors, or an organism's surroundings, its habitat.

Epidermis (52). The enveloping layer of cells, sometimes a cork layer, as in trees.

Epiphytes (60). Plants growing on other plants (or animals), but not parasitic.

Eremophytes (61). Desert plants.

Erosion (130). A process of denudation, as where the sea sculptures the land surface at its margin.

Fault planes (212). Planes or divisions caused by faults or dislocations.

Foliation planes (212). Divisions due to subsequent folding, as in slates by metamorphic agency.

Frigophiles (77). Plants that flourish under low temperatures ; cold-lovers.

Frigophobes (77). Sun plants.

Genus (30). A group of individuals or species, all of which have some common character, thus of generic value.

Geophytes (51). Plants adapted to winter by dying down to underground buried structures, such as rhizomes—*e.g.*, herbaceous perennials.

Geotropism (149). A growth curvature due to the influence of gravity—*e.g.*, growing downward of root.

Germination (186). The development of an embryo into the seedling stage.

Glands (19). Slender wart-like outgrowths from the surface.

Growth form (12). Adaptation of plants to the habitat inducing a special type of habit—*e.g.*, heath plants on a heath.

Habitat (40). The natural haunt or home of a plant.

Halophilous (137). Suited to a saline soil—*e.g.*, salt-marsh plants.

Heliotropism (149). A growth curvature due to the influence of the sun or light—*e.g.*, of the stem upward.

Helophytes (60). Marsh plants.

Hemiparasites (94). Not entirely parasitic; green plants living on roots of others, but obtaining nutriment themselves—*e.g.*, Yellow Rattle.

Herbaria (18). A collection of dried and mounted plants arranged in order (=*hortus siccus* or *exsiccata*).

Heterophyllous (265). Having leaves of more than one type—*e.g.*, some Water Buttercups with submerged and floating leaves.

Host plant (157). A plant upon which another plant lives as a parasite.

Humus (78). Vegetable matter in the soil, also animal matter, in a state of decay.

Hydrophiles, Hydrophytes (44). Plants that live in water; aquatic plants.

Hydrosphere (195). The system of oceans and seas covering the crust of the earth.

Hygrophiles (44). Moisture-loving plants not necessarily living in saturated soil or in water.

Insolation (96). Exposure to sunshine.

Invasion (100). The encroachment of one plant formation upon another.

Joint planes (212). Divisions of strata formed by joints.

Laterals (137). Where from a shingle bank vegetation tends to extend in a lateral manner at right angles over shingle so deposited.

Lianes (60). Rope-like climbing plants in tropical forests—*e.g.*, Spanish Moss.

Limestone (17). A form of calcium carbonate, often of a crystalline character, formed by organic or chemical agency.

Lithophilous (82), **Lithophytes** (126). Plants suited to a rocky habitat.

Lithosphere (195). The rock surface or land portion of the earth's crust.

Llanos (61). Treeless tracts in South America, of the savannah type in Venezuela.

Loam (78). A mixture of clay and sand, with 30 to 50 per cent. clay; if 20 to 30 per cent. clay it is a sandy loam, if 10 to 20 per cent. clay a loamy sand.

Magnesium (79). A constituent of the ash of plants, and an element important in the formation of seed and of oil in plants, entering into the composition of chlorophyll.

Maquis (207). A sort of scrub characteristic of South Europe.

Marl (17). Clay or sand containing 5 to 20 per cent. of lime, and once much used for amelioration of soils.

Mesophytes (44). Plants that require a habitat with a well-watered and well-aerated soil, and one rich in nutritive substances.

Metamorphic (80). Applied to rocks altered since their original deposition by pressure, heat, etc.

Migration (185). The means by which a formation becomes extended through successive dispersal and colonization.

Monoclines (212). Folds in strata or hog backs.

Monœcious (157). A bisexual plant with male and female flowers on different parts of the same plant.

Mycelia (193). The filamentous vegetative part of a fungus.

Mycorhiza (80). When a plant obtains part of its nutriment through the fungal threads of a fungus which clothe its own root, as in the case of Heaths and many trees.

Nitrates (48). Nutritive substances or compounds in the soil from which a plant obtains its supply of nitrogen.

Nyctitropism (186). The faculty of exhibiting sleep movements in plants, as in the Wood Sorrel, the leaves closing up at night.

Osmosis (48). A tendency in fluids to pass from one solution to a denser through a porous membrane, promoting the flow of sap and assisting absorption from the soil.

Outcrop (212). The edges of strata at the surface.

Ovary (32). A structure enclosing the ovule, and part of the carpel.

Ovule (33). The embryo seed enclosed in angiosperms in an ovary.

Oxygen (96). Entering into the composition of many substances, as oxides, and as a constituent of the atmosphere necessary for respiration.

Palisade tissue (52). Water-conducting region of plant-stems.

Pampas (200). A type of grassland in South America.

Panicle (20). A form of inflorescence, a raceme with clusters of stalks and flowers.

Parasite (157). A plant which lives on another living plant, deriving nutriment from it.

Patanas (61). Barren grassland suited to desert plants.

Peat (17). Soil rich in humous acids.

Pelophilous plants (17). Suited to clay soil.

Petiole (59). The leaf-stalk.

Phenology (6). See definition.

Phosphates (79). The source of phosphorus in plants, promoting root development.

Photophiles (57). Sun plants.

Photosynthesis (186). Process by which, under the action of light, starch is formed in green cells by its action on chlorophyll in the cell sap, carbon dioxide being absorbed and carbon formed, then starch or sugar, etc.

Phototropism (186). Curvature of growth due to action of light.

Physical drought (50). Drought due to excess of heat, lack of water in soil.

Physiognomy of vegetation (16). The general character or structure of a floral region.

Physiographical divisions (16). Based on earth structure, such as valley, etc.

Plankton (45). Free swimming or floating community of algæ, etc.

Plant community (90). An assemblage of plants which, with other assemblages, make up a coherent whole—*e.g.*, heath plants.

Plant formation (90). A community of species such as that of clays and loams, associated together by virtue of a similar habitat.

Potash, potassium (79). An element essential to the formation of starch and fruit.

Prop-roots (49). Specialized roots of Mangrove adapted to growth in swamps.

Proteids (49). Food substances elaborated from nutrient salts.

Psammophytes (61). Sand-soil plants.

Psilophytes (61). Dry-soil types of South American savannahs.

Psychrophytes (61). Plants growing on a cold soil ; alpines.

Quadrat (180). A plot of ground staked out in a square for survey.

Radical leaves (12). Springing from the crown of the root.

Reed-swamp (47). Marginal aquatic vegetation, growing partly in, partly out of, water.

Renascent herbs (57). Perennial plants dying out to the root-stock, with underground rhizomes.

Respiration (186). A process whereby oxygen is taken in and carbon dioxide given off ; breathing.

Retrogression (130). The reverse of succession, or going back to an earlier stage.

Rhizome (47). An underground stem with roots and leafy shoots.

Ribbon growth (46). Where plants adapted to rapid currents develop linear leaves.

Root-hairs (80). The thread-like rootlets which are attached to soil particles when a plant is uprooted, and take part in absorption.

Rosette plants (52). Plants with short internodes and close-set leaves—*e.g.*, Dandelion.

Saprophytes (60). Plants growing on dead or decaying animal or vegetable matter.

Savannahs (61). Treeless plains or grassland in South America.

Saxicolous plants (82). Growing on rocks or walls.

Scape (12). A flower-stalk without leaves, and radical in origin.

Sclerophyllous (61). A term applied to bush or scrub on dry soils.

Scree (112). A sheet of loose stones on a hillside or at the base of a cliff.

Siliceous soils (104). Closer grained than sandy soils ; derived from slates, schists.

Sleep movements (52). Adaptations of plants to light and shade, with closing up of leaves.

Society (91). A community of plants of lesser importance than an association—*e.g.*, a Bluebell society in an Oakwood.

Sodium chloride (49). Another term for salt, which is inimical to most plants in excess.

Sphagna (96). Bog Mosses, influential in the formation of peat.

Spines (50). A thorn or sharp woody outgrowth, an adaptation for protection against animals or drought.

Stamens (19). The male part of a flower, consisting of filament and anther.

Steppe (54). A dry type of grassland in central Eastern Europe and elsewhere.

Stigma (157). The part of the pistil subtending the style which receives pollen.

Stomata (50). Ventilating pores in the epidermis with guard cells.

Strand plants (53). Marginal vegetation on the coast of the sea or a lake, adapted to dry conditions.

Stratification (212). The method by which strata or layers of sediment are laid down in the course of deposition.

Subsoil (68). A layer below the humus and soil proper, derived from the underlying rock.

Succession (81). The series of changes that a plant formation undergoes in passing from one stage to another.

Swamp plants (47). Marginal aquatic or marsh plants.

Synclines (212). Trough-like folds in strata.

Telluric water (96). Derived from underground sources.

Thermal constant (77). The amount of accumulated degrees of temperature required for various processes of plant growth.

Till (72). The moraine matter formed by glacial action or boulder clay.

Transect (181). A horizontal section across a piece of vegetation, and the plotting of it.

Translocation (186). The transfer of food materials and sap from one part of a plant to another.

Transpiration (48). Giving off of superfluous water as aqueous vapour by plants, through stomata or pores.

Trimorphic (157). Of three forms, as of flowers—*e.g.*, Purple Loosestrife.

Tropophytes (50). Plants that, like deciduous trees, exhibit in winter adaptations to resist drought caused by cold, by shedding of leaves.

Tubers (19). Subterranean fleshy shoots.

Tundras (125). Prairie-like areas liable to be frozen over for long periods.

Turfophilous plants (17). Growing on humus or peat.

Ultimate carr (116). A type of fen bush or fen wood, the final stage with a typical association.

Water plants (20). As opposed to land plants, those growing rooted in the soil or in water and with their aerial parts submerged or floating.

Weathering (81). The wearing down of rocks by water, atmosphere, etc.

Xerophytes (44). Dry-soil-loving plants.

Zonation (181). Associations growing in zones or bands.

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