TIGHT BINDING BOOK

Drenched Book

UNIVERSAL
LIBRARY
OU_162860
UNIVERSAL
LIBRARY

OUP—730—28-4-81—10,000.

OSMANIA UNIVERSITY LIBRARY

Call No. 581.5 T15P Accession No. 26878

Author Tansley, A.G.

Title Plant ecology and the school.

This book should be returned on or before the date last marked below

PLANT ECOLOGY
AND
THE SCHOOL

Also by A. G. TANSLEY

THE BRITISH ISLANDS AND THEIR VEGETATION

INTRODUCTION TO PLANT ECOLOGY

PLANT ECOLOGY
AND
THE SCHOOL

by

A. G. Tansley, M.A., F.R.S.

and

E. Price Evans, M.Sc., L.C.P.

WITH 10 FIGURES

LONDON
GEORGE ALLEN & UNWIN LTD
MUSEUM STREET

FIRST PUBLISHED IN 1946

ALL RIGHTS RESERVED

PRINTED IN GREAT BRITAIN
in 11-Point Old Style Type
BY UNWIN BROTHERS LIMITED
WOKING

PREFACE

THE new Education Act foreshadows many great advances in our national education. Among them a widened and deepened knowledge of rural things must take an important place if future citizens are to become more intelligently conscious of our British countryside. The actual processes of farming naturally and rightly stand in the first line, but besides the practical use of the land for agriculture the inherent interest of the whole country scene and the incomparable beauty of much of it must not be forgotten.

This little book may be regarded as a small contribution to the means of teaching and learning some part of rural knowledge. It is concerned with natural and semi-natural vegetation considered as part of the geography of the region in which a school is situated—a subject which the authors believe to be both suitable and valuable for school work.

By means of National Parks and Nature Reserves, efforts are now being made to secure the conservation of as much of our wild nature as it is practicable and reasonable to safeguard from destruction by "development." A greater and more widespread knowledge of what we want to preserve, and of its relations to the uses to which land may be put, will effectively strengthen and spread the desire for conservation and help to ensure the best use and enjoyment of our wild parks and reserves.

The present book is primarily intended for schoolmasters and schoolmistresses, but it may also be useful to senior pupils in secondary schools, to students in colleges and universities, to members of natural history societies, and in fact to all who are interested in *systematic* field work. The authors have a strong belief in the educational value of ecology in schools and would urge that this means of approach to the study of nature should be more widely adopted by teachers. But the special difficulties involved in the application of ecological methods must be understood and faced at the outset if any real success is to be attained.

In the first place ecology is essentially a *practical* study, the benefits of which must first be sought in the field, not in theoretical instruction in the classroom. This fact may seem to make ecology impossible as a school subject, even apart from the difficulty of squeezing it into the generally crowded curriculum. This difficulty is not however insuperable. Field work is certainly the first essential, but by bringing the subject into intimate relation with local geography (regional survey) so that the study of natural and

semi-natural vegetation in the field is treated equally with other physical aspects of the local area it is possible to use the time allotted to geography and at least part of that assigned to biology in the most economical way. The means of securing opportunities for field work must be left to the goodwill and ingenuity of the teacher and the head of the school.

The second difficulty is that of access to suitable vegetation. While this is easy for some country schools and probably not impossible for any, it must be recognised that town schools in large centres of population have to face the very serious consideration of the time occupied and the cost of transport to a suitable area in the country; and in the case of schools in large towns this may well prove an insuperable obstacle to undertaking such work during term time. The solution suggested in Chapter III is to take advantage of the growing vogue for holiday camps. If the Council for the Promotion of Field Studies succeeds in establishing an adequate number of Field Centres, these will form ideal places at which open-air ecological work can be carried out by the upper forms of schools.

Lastly, and this is perhaps the most important point of all, ecology is essentially systematic natural history, and unless the teacher is something of a naturalist—born or made—he or she will have little success. Fortunately the power of keen observation, with imagination, love of nature and desire to understand her, are not rare among our people, though it must be admitted that much of the current school and academic book work does little to foster these qualities.

Given a satisfactory solution of the difficulties, the practical study of ecology arouses keen interest among pupils and may be made a potent influence in broadening and deepening their outlook on nature and their understanding of the relationships of man to his complex environment. These things are, or should be, essential elements in education for citizenship.

In stressing the geographical approach to ecology we must not forget or underrate the importance of its physiological aspects, which are also of great educational value, and can be successfully pursued in school laboratories, and also in the field, either as a supplement to the sort of work suggested in this book, or as a stimulating branch of biology when that is a subject of school work. It is a cardinal principle of all scientific work, whether at school or at the university, that experiment should be employed

wherever it is possible, and certainly not least in ecology. Simple *field* experiments are suggested in some of the chapters which follow, and with imagination and ingenuity they may easily be multiplied to great advantage. But we have made no attempt to deal with laboratory work as such, which stands apart from the main topic of this book.

Following the introductory chapters, which set forth the general nature of the subject and the means of approach and methods of attack possible in schools, succeeding chapters give very brief descriptions of the main kinds of vegetation that can be studied by teacher and pupils and of what can be done with them—in other words of the field open to ecological work on different kinds of vegetation along the lines suggested. Fuller descriptions and discussions will be found in the forthcoming *Introduction to Plant Ecology* issued by the same publishers, to which references are made in the text. That book also contains two chapters on school work in plant ecology to some extent supplementing the contents of *Plant Ecology and the School.* We should also like to call attention to the book by Prof. R. C. McLean and Dr. Ivimey Cook, *Practical Field Ecology* (George Allen & Unwin Ltd. Price 8s. 6d.) which gives a detailed account, based on long practical experience, of survey methods and other ecological work on different kinds of vegetation in the field and laboratory. This is most suitable for the higher forms of schools and for university classes.

Owing to current hindrances to book production some of the other books referred to in the text may not be immediately obtainable, and prices of most have been omitted because of probable increases.

In regard to field as well as to laboratory experiments a word of warning may not be out of place. Though the experimental method is fundamental in the acquirement of scientific knowledge it is a grave mistake to insist, as some teachers and theorists have done, that every pupil should acquire knowledge *only* as the result of *his own* experiments. Such a practice, rigorously carried out, leads to much waste of time and a good deal of futility, a fact that pupils are not slow to recognise. Field experiments should be undertaken for the definite purpose of *solving particular problems and not for the sake of performing experiments.* To make a fetish of individual experiment is merely to abuse a vitally important thing.

A. G. T.
E. P. E.

June 1946

CONTENTS

		PAGE
PREFACE		7
CHAPTER		
I	Geography and Ecology	11
II	Plant Ecology	15
III	Practical Plant Ecology in the School	27
IV	Approach to Field Work	34
V	Woodland	42
VI	Scrub and Hedgerow. Hedgebank, Verge and Ditch	56
VII	Grassland	59
VIII	Heath and Moorland	64
IX	Freshwater Vegetation	68
X	Marsh, Fen and Bog	73
XI	Salt Marsh	75
XII	Sand Dune and Shingle Beach	79
XIII	Weeds of Arable Land	83
POSTSCRIPT		87
INDEX		93

FIGURES IN THE TEXT

		PAGE
Fig. 1	Birks Wood, near Huddersfield—Soil	48
Fig. 2	Birks Wood—Trees	48
Fig. 3	Birks Wood—Bracken and Bluebell	49
Fig. 4	Birks Wood—Grasses	49
Fig. 5	Ryhope Dene—Soil	52
Fig. 6	Ryhope Dene—Tree layer	52
Fig. 7	Ryhope Dene—Shrub layer	52
Fig. 8	Ryhope Dene—Field layer	52
Fig. 9	White Moss Loch—Profile	70
Fig. 10	Pond at Bramhope—Plan	70

Chapter I

GEOGRAPHY AND ECOLOGY

THE development of the scope of geography during the last half century has been very far-reaching, and there is now scarcely a single natural, economic, political or social phenomenon of importance whose distribution is not habitually mapped and analysed geographically. Geography has in fact become the sum of all the aspects of human knowledge that are concerned with the terrestrial distribution of phenomena. Those which involve the life and activity of man as the dominant inhabitant of this planet, are obviously of first importance. Unlike the "gazetteer" geography of early days—universally regarded as one of the least inspiring of subjects—the new geography is a science of great importance and absorbing interest: in the school curriculum it now has an established place as a cultural study far removed from the "capes and bays" geography of evil memory.

A notable aspect of the scientific renaissance of the later nineteenth century was the turning of men's minds towards the scientific study of their immediate surroundings, i.e. towards the practical study of *local* geography. This is exemplified in the so-called "regional surveys" that have been undertaken in different parts of the country, embracing the most various features of particular districts. An excellent recent example is the *Regional Atlas of Croydon and District*, edited by Mr. C. C. Fagg, the serial publication of which by the Croydon Natural History and Scientific Society was begun in 1936. This is planned on a very comprehensive basis, and the maps already issued, accompanied by full explanations, include topography, relief, geology, rainfall, distribution and growth of population, open spaces, Roman remains, and facsimiles of two eighteenth-century maps of the district. Future issues will include, among many other topics, maps of the distribution of vegetation in the still rural parts of the Croydon area. A general account of the aims and methods of regional survey will be found in *An Introduction to Regional Surveying* by C. C. Fagg and G. E. Hutchings (Camb. Univ. Press, 1930).

Local geography, which can be studied by direct observation, is one of the most fruitful aspects of the subject and also a very potent instrument of education in its most vital sense. The home

region serves in the first place two important purposes: it serves as a training ground where systematic field work gives actuality to school studies in geography and biology, and as a kind of "scale" or "unit of reference"—"yardstick", to use a popular word—which the teacher may employ to compare or contrast with the distant and the unfamiliar. A most valuable result of the survey and mapping of different data from the same region is the discovery of unsuspected correlations between them and the consequent development of knowledge of the structure and growth of the region as an organic whole. Recognition of the value of systematic study of the home region in schools as a means of training the intellect and of building up the pupil's first-hand knowledge of the environment of his own community, and thus helping to develop a true sense of citizenship, is in fact one of the most important recent advances in educational thought.

Furthermore, the accumulation of a body of organised knowledge obtained at first hand is of the utmost value to the pupil in studying regions of the world with which he cannot hope to have more than a second-hand acquaintance. The successful teacher is never slow in recognising this value, and in the course of teaching world geography he constantly seeks parallels—or sharp contrasts—in the local area, thus bringing the matter *home* in the most effective way.

Regional structure and development can of course be studied in a great city as well as in the countryside, though the things to be observed are very different. In many respects, however, country studies are better adapted than town studies to pupils of school age, and it is here that certain aspects of plant ecology come in. Natural vegetation was the most important feature of the country in which our ancestors originally settled, and though most of what remains has been profoundly modified to meet the vital needs of the inhabitants, these much altered remnants still form a conspicuous background to country life. And the study of the nature and distribution of vegetation and of the human relations to it is excellently adapted for school work.

Ecology may be broadly described as the study of the relationships of living beings to one another and to their environment, or alternatively, to the study of organisms as they live in their own homes. The term "ecology", like the common word "economy", is derived from the Greek *oikos*, a house, abode, dwelling, and is now applied to the "household affairs" (and also the

"community affairs") of all organisms—plants, animals and man. Thus we have plant ecology, animal ecology and human ecology, which must to a large extent be studied separately, but which are so closely interconnected that they may be said to form parts of a larger whole.

Ecology is not so much a *branch* of biological science as an attitude of mind, or a means of approach, to the study of living things, an approach through their natural gregarious existence in their own homes. Its study touches on most of the recognised branches of biology and so far as it deals with the distribution of plant communities and groups of animals or human societies is an aspect of geography. Plant ecology was the first branch of ecology to be developed as a systematic study, and in several respects it is the most suitable for school work. One important reason for this is that plants form natural well-defined units of vegetation (or plant communities) which constitute the basis and background of all natural life and are thus of direct and vital interest and concern to man. The composition and distribution of these plant communities are directly related to different environments, and a knowledge of them—"synecology" as it is sometimes called—is clearly an integral part of regional geography.

Up to nearly the end of the nineteenth century the attention of botanists had been focussed mainly on the structures and functions of plants as individuals and on the classification and distribution of species, i.e. on *flora* as distinct from *vegetation*. But with the growth of the conception that the plant "group", i.e. the plant community rather than the individual plant, is the real unit of the vegetation we see around us, attention was directed to the study of plant communities in the field; and the pioneer work in Great Britain, associated with the names of Robert Smith and his brother William, began to be published at the beginning of the century. Somewhat later, but on parallel lines, the geographers, perhaps partly inspired by the work of the botanists, began to make more comprehensive local studies, and the two movements gave rise to the important botanical and geographical surveys of more recent years. The volumes of *Geography* (formerly *The Geographical Teacher*) and the publications of various societies contain the results of many of the local geographical (regional) surveys. On the botanical side a very large amount of work has been carried out in building up our knowledge of the nature and origin, the composition and distribution, of our native plant

communities, not only by observational but by experimental methods. A comprehensive account of this work will be found in *The British Islands and Their Vegetation*, by A. G. Tansley (Camb. Univ. Press, 1939), and a much shorter and less technical summary by the same author will be found in *Britain's Green Mantle* shortly to be published by Messrs. George Allen and Unwin Ltd. Thus a framework of knowledge is now available which the school teacher can use for his purpose.

It cannot be too strongly emphasised that a survey of the plant communities present should find its place within the general regional survey. Ideally the correlation of all this work should be in the hands of one teacher, normally the geography teacher, whose business it would be to weld the material into an organic whole.

The different types of natural and semi-natural vegetation dealt with in later chapters—woodland, meadow and pasture, heath and moor, marsh, fen and bog, salt marsh and sand dune, as well as "artificial" types such as plantations and the crops of arable land—all have characteristic distributions in a sufficiently diversified region, depending partly on natural factors and partly on human needs and activities. The study of the nature, distribution and changes of these, with which we are particularly concerned in this volume, should never be divorced from—on the contrary it should be always kept in the closest relation to—the distribution of other regional features on which they depend, such as land relief and geology, soils, climate, agriculture and land utilisation generally; in other words the study of vegetation in the school should be treated as part of geography in its widest sense.

Chapter II

PLANT ECOLOGY

In this chapter the general nature and scope of plant ecology, as the subject may best be used in schools, are briefly described.

Plant ecology in the widest sense is the whole range of the study of plants as they grow in natural or quasi-natural surroundings. Not all of this vast field is suitable for school work, and here we deal mainly with the aspect of ecology most intimately connected with local geography: first, discrimination of the different kinds of vegetation that inhabit different kinds of terrain (*habitat*) and secondly study of the nature, composition, and where possible the origin, of samples of such kinds as may be accessible to the school.

In the first place we must briefly glance at the different factors which together make up what is called the *habitat*, i.e. the sum total of the environmental conditions that actually affect the vegetation.

Climate.—The natural vegetation of a country is well known to reflect its climate very closely. Indeed it is often maintained that vegetation is a better index of climate than are the readings of instruments, such as thermometers, rain gauges and hygrometers, which merely record the elements of climate—temperature, rainfall and air humidity—that are of greatest importance as climatic factors, whereas plants respond very closely to the whole complex of climatic factors and thus "integrate" all these elements. Within any minor natural region of a country like Great Britain the *general* climate is however fairly uniform and does not greatly influence the distribution of the main types of vegetation. The study of *local climates*, determined by land relief, hills, valleys and plains, north and south exposures, proximity to the sea, etc., and of *micro-climates*, i.e. of the differences within a few yards or even a few inches between the intensities and effects on plants of the essential factors of climate as determined by small physiographic features such as sharp rises or depressions of the ground, prominent rocks, etc., has however hitherto been too much neglected by ecologists, though it is undoubtedly of very real significance.

Soil.—Next to climate we must consider soil variation, which obviously differentiates the vegetation within a region of more or less uniform climate; and this is a factor which will at once catch the attention of a class working in the field. The significant kinds of soil variation affecting vegetation are depth, water content and aeration, texture (which largely determines water content and aeration) conspicuously seen in the different vegetation of sand and clay; soil reaction, when it is markedly acid or alkaline; quantity of soluble bases, especially calcium; quantity and nature of humus. Such differences determine for instance the habitats of marsh, fen, bog, heath, and various kinds of grassland. Behind the different types of soil lie the different constitutions of the rocks or deposits from which the soils are derived.

Biotic factors.—Thirdly there is what is generally known as the "biotic factor", i.e. the effects on vegetation of the activities of animals, including man. In this country the most important are man's grazing animals—sheep and cattle—together with rabbits, mice and voles. Persistent grazing accounts for the maintenance of certain semi-natural types of vegetation, especially "rough grazings" and "permanent pasture", the latter (until the intensive "ploughing campaign" of the war) actually covering most of the English lowlands. This grassland has all been brought into existence and is maintained entirely by man and his grazing animals. The cultivated and enclosed pasturelands have been largely "laid down to grass" by the sowing of seed mixtures, usually entirely composed of native grasses and clovers, on land which had previously been arable; but the so-called "rough grazings", except those lying above the altitudinal forest limit, are derived directly from original natural types of vegetation, largely forest and scrub, by clearing and the continued action of grazing animals, mainly sheep, which prevent the return of woody vegetation by constantly eating off the seedlings of trees and shrubs. Rabbits also maintain many areas as grassland. It is difficult to overestimate the universality and the immense effect of the "grazing factor" in a country like Great Britain.

In the second place we must consider the vegetation itself and its classification. The land of any region in which a country school or camp is situated, so far as it is not occupied by houses and other buildings, gardens, orchards or arable crops, is diversified by the

various factors mentioned above—climatic, edaphic (soil), and biotic. The study of the natural features of such a region and of the use man has made of them is the primary task of local geography, and it is on this that school work on the ecology of vegetation should be based. The Land Utilisation Survey maps on a scale of 1 inch to a mile issued by Dr. Dudley Stamp are of the greatest use as a starting point, but for the purpose we have in view they need to be elaborated on the lines indicated in the sequel. These maps distinguish (1) Forest and Woodland (including plantations), (2) Heathland, Moorlands, Commons and Rough Pastures, (3) Meadowland and Permanent Grass, (4) Arable land, (5) Gardens, Orchards and Allotments, (6) Land covered by buildings, yards, cemeteries, etc., and thus not occupied mainly by plant life. Of these six categories only the first three bear natural and semi-natural vegetation and are of primary interest in school work in plant ecology. They are dealt with in detail in later chapters. The weeds of arable land and of gardens and allotments (Chapter XIII) also provide valuable material.

Natural and semi-natural vegetation.—Most of the British vegetation which consists of native plants has either been more or less modified by man's activity or directly created by him, and it is this which we call "semi-natural". Truly "virgin" land vegetation unaltered by man is only found on some parts of the sea coast and in the more remote mountain regions. Some of our woodlands are directly derived from the old natural forests that once covered most of the country, but have been modified by selective felling or by coppicing. Apart from the recent activities of the Forestry Commission, many of the existing woods have of course been planted; but when native trees which would (or might) naturally dominate the planted site have been used, the plantation acquires, in course of time, most of the characters of a natural wood. Woodland of either origin (i.e. modified from natural forest or planted with natural indigenous trees) may fairly be called semi-natural, but we cannot extend the term to include plantations of exotic trees, for these introduce conditions alien to native British woodland.

British grasslands again are for the most part semi-natural. The "permanent pasture" which, before the war, occupied nearly half the total area of England and Wales had largely been originally sown with native species of grass and clover and acquired fresh

species by the natural invasion of plants ("weeds") that could find a footing, while other species died out. The ultimate character of "permanent pasture", subject to the influence of climate and soil (which may be modified by manuring), is determined jointly by those species which survive from the original seed mixture and the natural colonists which can establish and maintain themselves in the turf. The whole is controlled by the nature and intensity of grazing, the effects of which differ according to the kind and number of the animals grazed and the periods during which they are in the pasture. Though the causes of the composition of any particular pasture are so many and complex, it shows a well-marked character so long as all the conditions remain the same, and it must be regarded as a real semi-natural plant community. The *main* controlling "artificial" factor is the grazing, in the absence of which the land would usually be colonised by woody plants and "revert" to scrub and woodland, or heath, according to differences of soil.

Unenclosed "rough grazings" such as chalk down, "grass heath" and great areas of hill and mountain side in the west and north have never been sown, are not manured, and are rarely subject to anything like *intensive* grazing. They must also be classed as "semi-natural" for they are mostly originally derived from forest land by clearing and grazing, but they are several degrees more "natural" than "permanent grass". Like the latter, rough grazings would usually "revert" to the original heath, scrub or forest vegetation if grazing were withdrawn altogether. This process of "reversion" can indeed be seen often enough where grazing has become very light or negligible.

Grassland which is left for one or a few years only before reploughing is called "ley" and it is to be regarded as an arable crop, not a semi-natural plant community. Ley is the form of grass that has increased at the expense of "permanent" grass as a greater proportion of the lowlands comes under the plough.

Heath and moorland are also often used for grazing and thus kept free from shrubs and trees with which they were at one time covered, but in the higher lying regions of the north and west there are considerable areas of moorland and bog above the forest limits or where the drainage is too poor for the successful colonisation of trees. These are but slightly grazed, if at all, and are often preserved for grouse or deer. They bear strictly "natural" vegetation. And we may add to these last the entirely natural "arctic-alpine" vegetation of the higher mountains.

Inland aquatic vegetation is nearly all natural or semi-natural, for it is not subject to the same rigorous control as most land vegetation, and the processes of invasion of water plants and establishment of natural aquatic plant communities—subject to occasional or periodic "cleaning" of ponds, ditches, canal and river beds—afford excellent opportunities for study.

Finally we have the vegetation of parts of the sea coast—steep cliffs, salt marsh, sand dunes and shingle beaches—which is for the most part essentially natural, though some of it is affected by man's activities.

Thus it is obvious that comparatively few schools will have direct access to completely natural vegetation—with the exception perhaps of the freshwater aquatic—but the fact that any particular plant community is not entirely spontaneous but owes its present condition partly to human agency, is far from destroying its suitability and interest for ecological study, provided the human factors are taken into full account.

Plant communities.—Vegetation obviously falls into more or less well-marked units such as heath, chalk down, forest or marsh. So much is clear from the common names which are regularly used for them. Each of these units contains a particular collection of characteristic plants as well as a number of "indifferent" species which may be found in several different ones. Any such unit or aggregate of species, of whatever size or status, is called a *plant community*. Thus the collection of mosses and liverworts covering the boulders in a damp oakwood is a community, and so is the wood itself, the latter in this case including the former. A community in fact is any collection of plants naturally growing together which has sufficient individuality to be usefully considered as a whole.

Dominance.—A community is generally dominated by one or more species which determine its main appearance and structure, and control, to a greater or less extent, the presence and development of other species. Typical dominants are the oak trees of an oakwood, the beech trees of a beechwood, the dwarf shrubs of ling or bell heather on a heath, or the reeds or bulrushes of a reedswamp filling a pond or lining the banks of a lake or slow river. Dominants are generally the largest and especially the tallest plants of a community: usually their leafy shoots are in

lateral contact (*closed communities*). Thus they cut off some of the light from plants of lower growth and also increase the humidity of the air beneath their shade.

Stratification.—Excepting a few of the simplest, such as those consisting of a single species only, plant communities show a more or less definite *stratification* of the leafy shoots of their constituent individuals. Thus below the crowns of the trees (*canopy*) of a typical English oakwood we have the *shrub layer*, in which the hazel is often dominant, and below the shrubs the *field layer* consisting of herbs. A fourth or *ground layer* is generally dominated by mosses. Each layer really occupies a different "partial" habitat, owing to the diminution of light and increase of moisture as we pass downwards from the tree canopy to the soil. Thus each layer has its own dominants, which affect all the layers below, and its own characteristic species, and each layer represents a "partial" community within the complex community represented by the wood as a whole dominated by the trees. Any of the subordinate layers of a wood may be very sparsely developed, or even absent in particular cases, as for instance in many beechwoods.

Naming of plant communities. The plant formation.—The term *plant formation* is applied to the great world types of vegetation mainly determined by climate, and to other more local communities determined by other factors. All formations are distinguished by the characteristic *life forms* of their dominants, as for example the characteristic deciduous trees of our own native woods; the coniferous evergreen trees such as the pines and spruces of the northern forests; the small, leathery leaved evergreen trees and shrubs (*sclerophylls*) of the Mediterranean region; the heaths; the meadowgrasses; and so on. Four outstanding examples of the great climatic formations are the *equatorial rainforest*, developed in a hot and wet but equable climate, with its gigantic trees bearing large evergreen leaves, which is the most luxuriant and complex vegetation in the world; the *sclerophyll vegetation* of rather small leathery leaved trees and shrubs, developed in the Mediterranean and other regions of similar climate (the Cape Peninsula in South Africa, parts of California, Chile, and South and Western Australia) with hot dry summers and mild winters in which the rainy season falls; *temperate*

continental grassland (e.g. the prairies of North America and the steppes of southern Russia) with low rainfall, mostly in spring and early summer, and cold winters; *deciduous summer forest* in sub-oceanic climates with rainfall well distributed through the year, moderate summer heat, and winters in which frosts alternate with mild spells and snow-lie is not continuous.

The last-named type of formation is characteristic of western and central Europe (including most of the British Isles), of eastern North America, and parts of China; and to the European formation of deciduous summer forest our native oak, beech and ash woods belong. In the centre and north of Scotland another formation is represented by pine and birch forests which are part of the Northern Coniferous Forest of northern Europe. Here we have cooler summers and snow lies for long periods in winter.

Other formations represented in Great Britain are the heath formation commonly dominated by the ling and determined by climate and soil jointly; the arctic-alpine formation determined by the high mountain climate, largely dominated by lichens and mosses and marked by characteristic species of flowering plants; the freshwater aquatic formation of inland waters; the fen and marsh formation of wet ground with abundance of basic salts; the bog formation of wet ground poor in basic salts and acid in reaction; and the two "maritime" formations of salt marsh and sand dune respectively, each with its characteristic species and life forms. "Marine" vegetation (seaweeds), living mainly *in* the sea is to be distinguished from this "maritime" vegetation which inhabits its borders.

Consociation, association and society.—The smaller communities within a formation, dominated by particular species, are those with which school work will be immediately concerned. When a relatively large community is dominated by a single species of tree, as in a beechwood or oakwood, or when a heath is dominated by ling, or a sand dune by marram grass, it is called a *consociation*. When two or more species dominate such a community, as in an ash-oakwood, a reed-bulrush swamp, or when a meadow dominated by several species of grass, the community is called an *association*. A *society* is a local community with a subordinate dominant or dominants within a consociation or association, as for instance a bluebell, primrose or dog's mercury society in the field layer of an oakwood.

Seasonal aspects.—Most of the British natural and semi-natural plant communities look very different at different times of the year. Of these *seasonal aspects* we may conveniently distinguish five: the *pre-vernal* (March-April in southern England), *vernal* (April-May), *aestival* or summer (June-August), *autumnal* (September-November) and *hiemal* or winter (November-February). The different seasonal aspects are particularly well seen in the deciduous woods. Thus the pre-vernal aspect, before the leaves of the trees and shrubs have expanded, is marked by the flourishing of such gregarious plants as dog's mercury, lesser celandine, wood anemone, primrose; the vernal by bluebell, red campion, yellow deadnettle; the summer aspect by a great number of species which rarely form such great masses of one species as those which flourish in the spring; the autumnal by few flowering plants, but many of the larger fungi. The winter is of course mainly the "dead season" for vegetation, but a great number of plants with underground shoots go on growing slowly in our mild climate, and a few (mainly not native but sometimes naturalised), such as winter aconite and snowdrop, come into flower. The hazel, too, whose flowering belongs to the pre-vernal season, sometimes opens its catkins in January if the weather is very mild, and the common gorse (pre-vernal and vernal) may produce flowers at any time during the winter. The actual date of leafing and flowering of particular species is of course much affected by the weather, and especially by the temperature of the immediately preceding period.

The vegetative and flowering activities of a plant are often contemporaneous and confined to one season, though they may continue through more than one. Thus the lesser celandine and wood anemone are entirely pre-vernal, the bluebell vernal. On the other hand vegetative activity of the leafy shoots may extend far beyond the flowering period. Thus dog's mercury flowers in the pre-vernal aspect, while its leafy shoots are active from February right through the spring and summer. Sometimes the vegetative and flowering activities are widely separated. For example the leaves of meadow saffron (sometimes, though wrongly, called "autumn crocus") appear in the early spring but die off during the summer, while flowers do not appear till autumn. Meadowland which is unpastured shows a constant succession of species, both of grasses and other herbs, throughout the spring, summer and early autumn.

Following the seasonal succession of the leafing and flowering of different plants in any community is both instructive and of great interest, and visits to a community which is being studied should be paid as often as possible, so that the states of the different species at particular dates may be recorded. Only in this way can the life of a plant community be understood.

A plant community is not of course a fixed and unalterable thing, though some communities do maintain great general stability for very long periods, provided the main factors of the habitat do not change. Fluctuating changes in the habitat—produced for example by prolonged abnormal weather—find a response in fluctuating changes in the vegetation. For instance exceptionally high or exceptionally low seasonal temperatures, prolonged wet spells or prolonged droughts, affect the general luxuriance of growth and often favour some species at the expense of others; and so does heavy grazing of grassland, or on the other hand the absence of grazing. But besides such passing changes the larger plant communities show definite progressive development which follows an orderly sequence.

Primary succession.—When soil is artificially denuded of vegetation, or when a new bare soil or rock surface is created, e.g. by the accumulation of blown sand or of tidal mud or river alluvium, by the removal through the action of wind or water of the old surface soil, by landslips, or by the slow emergence of new land from the sea, it is sooner or later occupied by plants. The first plants to settle will nearly always, if the area remains undisturbed, give way to newcomers and these again to other species, so that successive plant populations or communities displace one another in turn, until a state of more or less stable equilibrium is reached and no further major change occurs so long as the environmental conditions remain unaltered. This condition of equilibrium is called a *climax*. As a general rule the size of the plants in the communities of such a *primary succession* increases through successive stages, because the larger plants cannot usually colonise or subsist upon the original bare soil,[1] and when they do come they tend to overshadow and kill out the smaller ones already present. Thus lichens and mosses often

[1] This rule has many exceptions: for example, large bulky weeds can immediately colonise bare new clay if it is not too dry, and on wet river alluvium such damp-living trees as poplars and willows can do the same.

dominate the earlier stages of such a succession, while in later stages herbs and shrubs are dominant, and the climaxes in all the most favourable climates are dominated by trees, forming forest communities.

Any given series of successional communities is called a *sere*, and the complete series of a primary succession is a *prisere*. There are two main kinds of prisere whose earlier stages are totally different according to whether the original bare soil is under water or very wet on the one hand, or whether it is dry on the other; and these are known respectively as *hydroseres* and *xeroseres*. In both types the soil gradually changes with the vegetation during the course of the succession. In a xerosere which starts on rock the rock surface is slowly disintegrated by the action of weather and of the first lowly plants such as lichens and algae which can colonise it. If the soil is loose from the first, as with blown sand dunes, the first colonists are generally grasses which bind the sand with their roots and underground shoots and thus produce a coherent surface which other plants can colonise. In either case *humus* is produced from the decaying debris of the plants, and becomes incorporated in the mineral soil. It is largely this change and the increasing depth of soil which lead to the progressive succession of plant communities, for the humus holds water and provides a better source of plant food than the crude mineral soil, so that larger and larger plants can maintain themselves. When the succession starts in water humus also accumulates from the debris of water plants, and the soil may be gradually built up above the water level either by this means or by the laying down of silt from moving water. As it is exposed to the air the soil dries and becomes aerated so that land plants can establish themselves. Thus the two types of prisere tend to converge and to culminate in the same climax vegetation, which in our climate is deciduous forest.

Secondary succession.—In a country like England, however, man has almost completely taken control of and altered the surface of the land, so that it is rarely, except on parts of the sea coast, on the higher mountains, and in many freshwaters that stages of the priseres can be found. When natural or semi-natural vegetation is destroyed or drastically disturbed, as by felling, partial clearing or burning, or very heavy grazing, and then the area left alone for a time, what is called a secondary sere

or *subsere* is initiated. The starting point of such a subsere—on the site of a felled forest or burned heath for instance—is very different from the bare rock or raw soil with which a prisere begins, so that the early stages are quite different and the course of succession is shorter, its length depending on the extent to which the original soil and vegetation have been destroyed. But the colonising plants behave in the same general way and a climax vegetation is eventually re-established. Such subseres, which are quite common, often afford good opportunities for the study of succession.

Biotic climaxes.—When human intervention takes the form, not of a single act destructive of vegetation, such as felling forest, clearing scrub or burning heath, but of continuing or regular periodic action, such as grazing or regular mowing or coppicing, the result is to introduce a new "biotic factor" (p. 16) as an essential part of the habitat. The vegetation of our grasslands, for example, is subject to regular grazing or mowing, just as it is subject to the particular climate in which it exists and to the particular soil on which it grows, and the community is determined by the whole of these factors together. It is however the biotic factor which actually differentiates the grassland vegetation from the other communities that may exist in the same climate and on the same soil. A grassy chalk down would in fact be covered by scrub or beechwood if animals were not grazed upon it, and an alluvial mowing meadow with oak or oak-alder or oak-ash wood if it were not regularly cut.

Thus we may call the down or meadow a *biotic climax.* When the biotic factor is withdrawn the vegetation changes again: if grazing or mowing ceases the area is invaded by woody plants, a "subsere" is initiated, and woodland will be ultimately established. Of course if human intervention is irregular and fluctuating the vegetation is never stabilised because no position of equilibrium can be reached.

In order to interpret and understand the different types of semi-natural vegetation, which, with crops and plantations, orchards, gardens, and villages, form the familiar patchwork or mosaic of the English countryside, it is essential to bear constantly in mind the different kinds of change and stability that have been

briefly touched upon, and to consider the status of each piece of vegetation in terms of these.

The first thing is to envisage as a whole the geographical region in which the work is to be undertaken, and to recognise the types of natural and semi-natural vegetation present. Those that are best developed and most convenient for the purpose can then be given more detailed study.

In working on these lines in schools it is important to remember the golden rule—observation first, then concepts, followed by terms and definitions. The actual things and processes must first be observed and talked about, investigated, identified and checked: concepts then develop almost unconsciously, and the need for terms to name them naturally follows. To reverse this rule by giving terms and definitions in the school followed by attempts to apply them in the field is the wrong way to teach and tends to defeat the object in view—to give the pupil a true insight into the workings of nature. Real nature study is the observation of nature where she is at work, not the talking or reading about nature in the classroom.

A fuller account of the topics dealt with in this chapter will be found in *Introduction to Plant Ecology*,[1] Chapters I to IV, and a more advanced treatment in *The British Islands and their Vegetation*, Parts I to III.

[1] London: George Allen & Unwin, Ltd. 1946.

Chapter III

PRACTICAL PLANT ECOLOGY IN THE SCHOOL

BEFORE dealing with the best methods of ecological work in schools, we must shortly consider the relation of the established subjects of botany, biology and geography to the study proposed. At present biology is taught in many schools, botany alone in others and geography in all. Where botany is taught or the biology course includes a sufficient treatment of plants it is clear that this work will form a foundation for the study of practical plant ecology. Unless enough elementary knowledge of plants is acquired in one way or another it will of course be impossible to follow the lines suggested in this book, though the ecological points of view developed should be helpful to the teacher of geography in his study of the local area. At present the teaching of geography in schools has on the whole reached a high level, and this is at least partly due to the modern tendency, which has not yet reached full development, to use the local area as the subject of objective study. Biology on the other hand still remains too exclusively in the laboratory, and although elementary morphology, anatomy and physiology of plants and animals are indeed an indispensable foundation, the object of this book is to introduce the vivifying and broadening influence of taking biological work to the field, in the same "local area" which has proved of such benefit to the geographer. In this way the two lines of work will converge and together will contribute to the building up of a synthetic knowledge of the highest educational value. In this book we are concerned with the best methods of ecological work on local vegetation, work in which the geographical setting is never lost sight of, though the facts studied are primarily botanical.

With the development of the ecological outlook and all that it implies the teacher's difficulties in organising satisfactory work in botany have increased enormously, but at the same time these opportunities of bringing the subject into relation with human life have greatly increased. In the past, when attention was focussed entirely on plants as individuals, their morphology and physiology, and on plants as species, i.e. on flora as distinct from vegetation, occasional excursions or rambles sufficed,

because the requisite material for study could be brought from the country to the school. But with the growth of the concept that the plant community rather than the individual plant is the real unit of vegetation, and with the realisation of the great educative value of field work as such, this method proves inadequate: in short the school has to be taken to the country.

The problem that confronts the teacher is twofold—of the place or ground on which to do the field work, and of the time in which to do it. The first is external—the home region is beyond the teacher's selective control, a matter of the geographical position of the school, though the teacher will of course select the best areas for work if several are available within its boundaries. The second is internal and is in the teacher's own hands, a matter of organisation within the school, depending on his own initiative and on the goodwill and co-operation of the authorities in control.

It is now proposed to discuss this problem, and in later chapters there are given some definite examples of suitable methods for the study of vegetation in the field—methods which have been actually applied and have proved practicable and successful.

In rural districts the problem of "ground" is relatively simple, the "local area", i.e. the part of the countryside within easy reach of the school, will serve as a training ground, and in a favourable area most of the school course can be based on the study of the plant communities within it. In urban areas the case is quite different and the teacher may be forced to rely mainly on the old method of occasional rambles, though with the new outlook these will be more than mere pleasant diversions from school work. There is, however, another possible way of meeting the difficulties of schools situated in urban areas and this will be referred to in the sequel.

Even in rural parts of the country local areas vary considerably in suitability for ecological work, but most places can be made to teach important lessons. The aim should be to make the fullest use as instruments of education of whatever natural resources exist in the neighbourhood.

As we have already insisted, the work on vegetation must find its place within the framework of local geography. First of all the whole of the neighbouring countryside must be envisaged. The "local area" referred to above is simply that part of the surrounding country which is easy of access and suitable for school study. It will not necessarily have any natural boundaries, but will find

its proper setting within the (minor) "natural region" in which the school is situated. This "setting" can be dealt with in school *after* the general exploratory work and a certain amount of detailed field study has been completed, and most advantageously in the geography class in connexion with work on natural regions and their subdivisions.

In very favourable and varied regions the ideal method is to make a general survey ("reconnaissance"—see *Introduction to Plant Ecology*, pp. 88–91) of the whole of the major plant communities within the region, such as semi-natural woodland, plantations, arable land, "permanent grass", heath, etc., and then to concentrate study on one (or more) that is available and suitable. Such a region is indicated in Chapter IV as a hypothetical case. It may not be possible for the preliminary reconnaissance to be made as school work, but in any case it will be necessary for the teacher to familiarise himself with the principal types of vegetation in the region so that the proper background of the more detailed work is present to his mind throughout.

The nature of the material available and the best means of study are described in Chapters V–XIII for most of the principal types of semi-natural vegetation. If a really good piece of vegetation exists close to the school, and one to which free access can be had at all times, this may well be used as the basis of most of the botany teaching in the school, while detailed studies—observational and experimental—may be carried out on the area. An example of such use of an area is described in "Local Ecology as a basis of School Botany" (*School Science Review*, June 1920). A narrow wooded valley—Ryhope Dene—within a few minutes' walk of the school was studied intensively by simple methods, the varieties of soil distinguished, the different communities described and charted, and specimens of the different plants taken to the school for further examination. Each class visited the valley in school hours as often as possible during term throughout the school year, and the botanical work done in school was to a large extent based on observations made and material collected during these visits. The various seasonal phases through which the vegetation passed could thus be observed and recorded. Special stress was laid on the writing of short essays on the state of the vegetation at each visit, with suggestions as to changes likely to take place before the next. With more advanced pupils the forecasting of seasonal changes led to discussion of likely

alterations in the composition of the community and of simple problems in plant succession (cf. pp. 53–5). In the teaching the woodland of Ryhope Dene was very useful as a kind of "unit of reference" for comparison with other types of wood in the district and outside it. A brief description of the nature of this woodland will be found on pp. 51–3.

The simple intensive study of one small area which can supply living examples of plant communities that can be related to problems of light, soil, water and temperature, forms the best foundation on which knowledge can be extended to a wider field, besides relating the general study of botany more closely to native plants growing under natural conditions.

When the school is situated in a very highly cultivated or extensively suburbanised countryside it may be difficult or impossible to find semi-natural plant communities for study. Where the land is almost entirely arable recourse may be had to the crops themselves and to the population of arable weeds, which furnish much material of interest (see Chapter XIII).

It is better to avoid fragmentary and degraded examples of semi-natural vegetation which often still exist in closely cultivated and suburban districts, such as, for example, degenerate woodland or severely rabbit-eaten, trampled or burned areas of heathland: To attempt work on such an area is more or less futile and even harmful for pupils who have not had previous experience of well-developed and unspoiled vegetation of the type to which it belongs, since interpretation of the action of the factors responsible for degradation is required, and there will be no sufficient basis of knowledge for such interpretation until after an unspoiled example has been studied.

In districts where no unspoiled country is left in the neighbourhood of the school so that it is impossible to obtain easy access to semi-natural communities or to arable land, a possibility is the utilisation of a holiday camp. Such camps, which have increased in number of late years and are likely to increase further, are generally situated in places where good semi-natural vegetation is easily accessible. Some general geographical study of the camp region should first be undertaken, and the plant communities fitted into this background just as with a "home region". A definite scheme of study will of course be necessary, but this is quite practicable and successful in camp life if interest is aroused in sufficient measure. And if the work is approached and directed

in the true naturalist's spirit it is so inherently interesting and attractive that difficulties, at first sight formidable, will be overcome. But enthusiasm and "drive" are essential. The advantage to pupils of having a knowledge of two regions so widely different as a highly urban or industrialised area and one which is relatively unspoiled requires no emphasis.

Vacation work of the kind suggested has been undertaken with great success by university botanical departments in various districts for a number of years, and with the growth of the school camp habit there is no reason why it should not be more widely practised by schools. But the presence of teachers who have the naturalist's outlook and are themselves field workers is a necessary condition.

In default of easy access to unspoiled country either from the school itself or from a holiday camp, ecological work is possible where a garden is available. Lawns are excellent examples of plant communities dominated by grasses and under very complete human control. It is quite easy for school classes to carry out instructive studies on a lawn in the school garden or other accessible place. Permission to work on lawns in public parks may be sought from the municipal authority, but the definite allocation of a piece of lawn not accessible to the general public would be necessary if effective work is to be carried out. (For further details see pp. 62–3.)

The method of making artificial plant communities in ground adjoining a school garden was adopted by the late Dr. Lilian Clarke at the James Allen Girls' School, Dulwich, with considerable success. By importing suitable soil from natural habitats she established in the school grounds a number of "artificial habitats" and planted them with the species which are naturally found in each. The plants were largely collected and brought in by the girls themselves. In this way an artificial heath, marsh, bog, sand dune, shingle beach, salt marsh, and also an oakwood were established. Miss Clarke preferred to train her pupils' powers of observation and sound reasoning on these artificial plant communities rather than to rely on the more hurried studies which were alone possible during occasional visits to natural vegetation. For many years previously the school garden had been used with great success for systematic observations on growth, transpiration, pollination, fertility, etc. A full account of the whole of this work is contained in *Botany as an Experimental Science in*

Laboratory and Garden (Oxford University Press, 1935), and it is an inspiring record of successful work by a really great practical teacher which should be in the hands of all teachers of biology, not only for its matter and the methods described but because it is instinct with the spirit of adventure without which teaching is too apt to degenerate into lifeless routine. Miss Clarke was a woman of indomitable enthusiasm, energy and perseverance, combined with shrewd practical sense and extraordinary ingenuity in the adaptation of means to ends. She succeeded in enlisting the sympathy of the governors of the school, of inspectors from the Board of Education and of many outside authorities. In this way she obtained considerable sums of money for the purpose of making and improving the experimental garden and the artificial plant communities. It is doubtful however if many teachers would be well advised to pursue exactly the same lines, though all would benefit by working in the same spirit. Artificial plant communities, however carefully made and tended—and they require constant weeding because of the multitude of undesired plants which invade them in their unnatural surroundings—cannot replace, as subjects of study, the natural and semi-natural vegetation found in the field.

The problem of *time* referred to above is one for the individual school and the individual teacher. In most schools ecology is not likely to find a place as a separate subject, nor is it desirable that it should be so treated. As we have already remarked in Chapter I, ecology is much more than a branch of biological science: it is an attitude of mind, which should inspire both geographical and biological teaching.

It is however clear that where good plant communities are easily accessible time should be found for field work within school hours. If regional study is to be of real educational value each individual pupil must take part in actual field work appropriate to his age and attainments, for it is participation in such work, however crude the results, that gives the benefits which only accrue from individual effort. In this way a first-hand knowledge of the home region will be gradually built up. A danger to be studiously avoided is the use of "potted" information about the home region, doled out in school. The teacher will, however, naturally summarise with his class the results of their work in the field, and will use the data and the knowledge so obtained to illustrate his teaching as occasion arises.

Chapter IV

APPROACH TO. FIELD WORK

IN the last two chapters the nature of the study of vegetation has been described and the conditions in which it can be undertaken in schools discussed: in the present chapter the best approach to actual fieldwork is considered.

If the work on vegetation is to find its proper place within the framework of local geography it is necessary first to envisage, as it were, the whole countryside in which a school or camp is situated and to distinguish within it the geographical regions into which it naturally falls. These will be determined primarily by geological structure and topographical relief.

For example, let us suppose a school to be located in a wide plain based on a soil derived from a clay or shale, overlain in places by Tertiary or Quaternary Sands, and bordered on one or both sides by hill ranges of harder rock, not exceeding 1,000 or 1,500 feet in height. Further let us suppose that the plain is traversed by a river which flows into a tidal estuary bordered by salt marshes and that the coast beyond shows sea cliffs where a hill range is cut off by the sea, with a sand dune area between the hills and the estuary.

This picture represents a sufficiently diversified region affording wide scope for ecological work. Apart from the towns and factories or works which have locally destroyed the vegetation, the plain itself will be mainly occupied by pasture or arable with semi-natural woods or plantations here and there and freshwater marshes and ponds (though many of these have probably been partly or entirely drained) in the lowest lying areas. The overlying sands, being less fertile, are likely to be waste or common land, occupied by heath or heathy grassland. The lower slopes of the hills are probably enclosed and devoted to pasture or arable crops, but different from those of the clay plain. These are very likely to be interspersed with semi-natural woodland, while the upper slopes are open pasture (rough grazing), either limestone or siliceous grassland, with heath or moorland.

In such a region there should be ample choice of good subjects for vegetational study, and the decision on which to select will depend partly on the scope offered by particular communities

and partly on accessibility and the possibility of getting permission to work on enclosed land. Open commonland and rough hill grazings have the advantage of freedom from objection by land owners and the same is usually true of salt marshes and sand dunes. On the other hand woodland offers more extensive scope for study, but work can only be undertaken without special permission in a few unenclosed woods in the wilder and more remote regions. To carry on systematic work in most enclosed woods, even if they are not strictly preserved for pheasant shooting, it is necessary to obtain the goodwill of the landlord, agent or tenant, and in preserved woods, even after formal permission has been obtained, it is highly desirable to make friends with the gamekeeper. Freshwater ponds and marshes are excellent subjects for study because the vegetation is so largely natural, but they have the drawback that the worker always gets more or less wet, and this may be a real obstacle in some schools, though others may be indifferent to it.

In mountainous country, as in Wales, parts of the north of England and much of Scotland, a great deal of the vegetation is semi-natural and there is likely to be more freedom to work upon it. Interspersed with the higher lying cultivation there may be woods, some of which at least may be freely entered, and there are sure to be wide areas used for grazing and bearing semi-natural plant communities well worthy of study. The only restrictions in such regions are likely to be due to grouse preserving on upland heaths and moors, and in the Scottish Highlands it is sometimes difficult or impossible to get access to deer forests.

In teaching the geography of a region in which a school or camp is situated the actual utilisation of the land is of course a primary datum; and the causes of the different kinds of utilisation as determined by climate, physiography, soil, population and economic conditions, will be an important part of the subject. A general knowledge of land utilisation will thus form a necessary introduction to detailed study of any of the kinds of semi-natural vegetation that are present. These must be given their proper place within the geographical framework of the whole region in order that their real nature and the general causes of their existence may be understood.

Structure and composition of a community.—When a particular area of vegetation has been chosen for detailed

work the teacher must decide exactly what is to be done and how the work should proceed.

After accurate notes have been made on the location and size of the area the first thing to be undertaken is a record of the *structure* and *composition* of the vegetation. Structure should come first, i.e. notes should be made of the spacing of the plants both in the horizontal and vertical dimension (see p. 44) before a list of the species is begun. This record is most important in woodland, the study of which is dealt with in the next chapter. In well stratified communities the list of species should always be made in each layer or stratum separately.

Naming of species.—A full listing of the plants of a community presupposes a knowledge of their names, and a considerable acquaintance with the flora of the countryside must eventually be acquired. But it is perfectly possible to begin the study of a particular plant community with a minimum of such knowledge and to build it up gradually from the material collected. An initial lack of knowledge of species should not be allowed to act as a deterrent to undertaking field work. The teacher must of course learn (if he does not know already) how to to use a Flora, and the senior pupils will naturally learn also. It is not necessary that every pupil should become expert in the use of a Flora any more than it is necessary or desirable for every pupil to perform every experiment for himself (Preface, p. 9). Those who show a natural interest in the distinctions between species will quickly learn how to "run down" the easier ones, and all should become acquainted with the general method employed. The part played by the lower (non-vascular) plants, especially the mosses, lichens and larger fungi, which are integral, and often important, elements of many plant communities, must not be neglected, though it may not be possible at first to name all the species.

While every effort should be made to name all the plants met with in the community studied a certain number will remain doubtful, or impossible for the non-expert to determine. These may be sent to one of the great national departments of taxonomic botany—the Herbarium, Royal Botanic Gardens, Kew, and the Department of Botany, British Museum (Natural History), London, S.W.7—or to some known private authority who specialises in a particular group of plants. The public authorities always

do their best to furnish the information asked for, but in sending specimens for determination the following points should be carefully attended to.

(1) The specimens should be as complete as possible: when the plant is of moderate size the whole should be included. As a rule, of course, flowers will be included and fruit also if it can be obtained. If the plant is "over flower" a fruiting specimen is generally satisfactory.

(2) The specimens should be carefully pressed and dried, with both locality and habitat as well as date of collection written on the accompanying label.

(3) The accompanying letter should state the nature of the work for which the identification is required.

(4) A stamped envelope should be sent for the reply, or if the return of the specimens is desired, stamps should be enclosed to cover the return postage.

In asking for this kind of help it is perhaps unnecessary to say that the utmost care, courtesy and consideration should be shown. The staffs of the national departments of botany are generally overworked, and fragmentary or ill-preserved specimens of plants which are quite easy for their correspondents to name for themselves should not be sent for determination. Reasonable requests for expert help always meet with a willing response.

Frequencies.—A record of the frequency of occurrence of each species in the particular community studied should be added to the name of the species. This may either be the common "subjective" method of estimating the frequency by eye and using a letter to show its degree: *d* = dominant, *a* = abundant, *f* = frequent, *o* = occasional, *r* = rare (see *Introduction to Plant Ecology*, pp. 101–3, for further explanation). A more objective method which may be used in detailed study when time is available is to mark off a number of small areas of uniform size, well scattered and taken at random, and list all the species found in each. Not less than fifty such samples are required to give good results. The percentage occurrence of each species can then be entered against its name. Thus if a species occurs in fifteen out of fifty samples its percentage occurrence will be thirty. The size of the sample areas must vary with the kind of vegetation. In

well grazed grassland a square foot is a suitable size: for the frequency of trees and shrubs in woodland much larger samples are required.

In woods trees and shrubs can be given a good quantitative record by actual counting of the number of individuals met with in traversing the wood in different directions and reducing to percentages. Thus if 37 hazel bushes, 21 hawthorns, 18 maples, 9 dogwoods, 5 spindles and 2 buckthorns are counted and no other shrubs are seen, the percentages of these shrubs will be approximately 40, 23, 20, 10, 5 and 2 respectively. These *percentages of composition* do not of course mean quite the same thing as the *percentage occurrences* described above, but both are good measures of frequency.

Societies.—When the distribution of a particular species is *localised*, i.e. its individuals are aggregated in particular places within the general community, *l* is prefixed to the symbol of frequency. If the particular species is dominant in its own layer in those places (*ld*) we have to recognise the existence of a minor community or *society* within the general one, and the local dominance may bring about special conditions which will affect the flora within its area. The occurrence of such a society may be caused by a local difference of habitat, for example a wet patch of ground, or it may be caused merely by a chance aggregation of some vigorous species which has found the opportunity to establish local dominance. Each kind of society that is met with in the general community should be recognised, recorded and studied separately, so far as time permits.

Habitat (see *Introduction to Plant Ecology*, Chapters XIII–XV).—The study of the habitat of a plant community offers an almost inexhaustible field, and how much can be attempted in school work must depend on available time and opportunity.

Of the different classes of habitat factors that we distinguished (see pp. 15, 16) the edaphic (soil) and biotic (animal) factors are of the greatest significance in work of the kind contemplated in this book, and at least an elementary study of them cannot be neglected. In woodland the light and air-humidity factors differ greatly in the different layers and can be studied without great difficulty, though simple instruments are necessary (see Chapter V).

Soil (the "edaphic factor").—The study of the soil for its own sake has made enormous advances during the last

quarter of a century, and is now an important part of the modern geography which is the framework into which we hold that plant ecology in the school should be fitted. Some of the elements of this subject—*pedology* as it is now generally called—should, we believe, be taught in the geography course in schools, and probably best in immediate connexion with plant ecology because it has a close relation both to agriculture and to the habitats of natural vegetation. A brief account of those "world groups" of soils which occur in Britain will be found in *Plant Ecology for the Student of British Vegetation* by W. Leach (Methuen), and a fuller treatment in *The British Islands and their Vegetation* (Chapter IV).[1] Technical modern books on soil are G. W. Robinson's *Soils, their Origin, Constitution and Classification* (Murby, 16s.) and G. R. Clarke's *The Study of the Soil in the Field* (Clarendon Press), but these contain far more material than could be used in school work, and much of it is difficult. Robinson's *Mother Earth* (Murby, 6s. 6d.) however, is an excellent and attractive introduction to the study of soil for its own sake and is well worth reading by all teachers of geography or ecology. What follows is merely a brief indication of the work that may be done on the soil on which a plant community is growing, and of the features of greatest importance in relation to the growth of plants.

Natural Soils.—In the first place a semi-natural community such as an old wood, heath or rough grazing on old undisturbed soil should be chosen and as a preliminary the underlying rock or deposit identified on a geological drift map. Then a hole should be dug through the *soil proper*, i.e. the stratified layers of "earth" in which plant roots live and which is "weathered", i.e. directly altered by sun, rain, frost and by the vegetation itself. Below the soil is the *subsoil*, i.e. the underlying rock or deposit from which the soil is formed, and which is comparatively little altered by weathering. If possible the hole should be dug down to the subsoil, so that the whole of the stratified soil, called the *soil profile*, with its separate layers or *soil horizons*, is exposed. The side of the hole should be cut clean and vertical so that a clear view of the soil horizons can be obtained. Careful sketches, measurements and notes of the different horizons should than be made so that a scale drawing of the profile can be prepared later. The notes should include the depths at which the roots and

[1] See also *Introduction to Plant Ecology*, Chapter XIV.

rhizomes of the various plants are seen. A good scale drawing of the soil profile below any plant community growing on a "natural" (i.e. not a "made"), soil gives a great deal of the information required. With practice the observation of the characters (colour, texture, and so on) of the different horizons rapidly improves.

A well-developed soil profile is only seen in a *natural* soil, that is a soil which is undisturbed by man and has thus developed its natural stratification under the influence of weathering and of the vegetation it bears. All agricultural soils, of course, are constantly disturbed, primarily by ploughing, so that the soil is uniform to a depth of about 8 inches, its constituents being repeatedly mixed. Semi-natural communities which have recently arisen on land that was formerly ploughed, such as new grassland or plantations, are growing on soils which have not recovered from the effects of this mixing. Natural soils must be sought in old woodland, on rough grazings, and on heaths and moors, and it is the relation of the different horizons of these natural soils to the vegetation they bear that is particularly interesting and instructive. Examples are found in the "podsols" of heathland and of the northern and western climates, the "meadow soils" of alluvial grassland with a high water-table, and the "rendzinas" of chalk downs. The soil type on which most natural deciduous woodland is found belongs to the "brown earth" or "brown forest soil" group, and these are the best soils for arable cultivation. For further details see *Introduction to Plant Ecology*, Chapter XIV.

General features of soil.—Besides the characteristics of these natural stratified soils there are also of course general features of water and air content, texture, consistency and chemical composition which apply to all soils—natural or "made" —corresponding with their designations in ordinary language as clay, loam, silt, sand, limestone soil, and organic soils such as peat. These can be studied equally well on homogeneous "made" soils like the top 8 inches of arable land or a deep garden soil, as on the individual "horizons" of a "podsol" or "brown earth".

A general account of the soil factors in relation to vegetation is given in *Introduction to Plant Ecology*, Chapter XIV. One of the best simple introductions to these fundamental aspects of soil study is Sir John Russell's *Lessons on Soil* (Camb. Univ. Press, 3s.). This little book is intended for quite young pupils,

but the points to be studied are so clearly brought out and illustrated by simple experiments that all teachers would be well advised to read it, whether or not they can use it in their classes. The most important things are water content, humus content and sizes of mineral particles (on both of which the water-holding capacity depends), lime content, and the effect of humus and lime on the vegetation. All these are dealt with in *Lessons on Soil.*

Chemical processes in the soil.—In regard to the chemical composition of the soil, the "reaction", i.e. the degree of acidity or alkalinity of the soil solution, commonly expressed as the "*p*H value", is significant. For an explanation of this *Introduction to Plant Ecology*, p. 176, should be consulted. Podsols and bog peats are very acid soils, shallow limestone soils are markedly alkaline, while "brown earths" are usually slightly acid. The actual determination of the *p*H value of a "made" soil, or of each horizon of a stratified "natural" soil, gives concreteness to this significant chemical feature, but it is not essential for an elementary knowledge of a soil. The other important *chemical* characteristic of a soil in its effect on plants is the amount of "exchangeable" calcium, and to a less degree of "exchangeable" potassium and magnesium, that it contains. These exchangeable bases are held in the clay-humus "weathering complex" of the soil in which all the important chemical processes occur, and on them depends the actual fertility of the soil, i.e. its capacity to support luxuriant growth of most kinds of plants, including crop plants. If there is excess of lime (calcium carbonate) in a soil, as in shallow limestone soils, which can easily be demonstrated by its "fizzing" with hydrochloric acid, the reaction will be alkaline, the soil will be "base-saturated" (in this case "calcium-saturated") and there will be plenty of exchangeable calcium in the weathering complex. But a soil may contain a considerable amount of exchangeable calcium but no free calcium carbonate, as in many brown earths, and it may then also be very fertile, even though the reaction is acid. On the other hand a *very* acid soil, such as a podsol, is always deficient in lime in any form,[1] and is markedly infertile. A coarse siliceous

[1] The ambiguous use of the word "lime", sometimes for calcium carbonate, sometimes for exchangeable calcium held in the humus-clay complex, is apt to be confusing.

sandstone, containing very little or no clay, weathers to a soil which is also acid and sterile, because it contains little or no lime in any form.

Thus the determination of exchangeable calcium gives more direct information about the fertility of a soil than the determination of *p*H value, though very low *p*H values are only found in soils which are sterile.

The nature and "look" of the vegetation itself gives a very trustworthy indication of fertility. Besides high "base status", moderate water content and good aeration are essential factors of fertility. Fertile soils support a rich soil flora and fauna—algae, many kinds of bacteria, earthworms and other invertebrate animals—because the conditions are favourable not only to plant roots but to most kinds of life. The flowering plants that naturally grow on them include what are called "exacting" species because they do not flourish on the less fertile soils.

Animals (the biotic factors).—Vegetation is affected by a wide variety of animals—ranging from protozoa, earthworms and other soil animals to the herbivorous vertebrates—some of which always form an important part of the environment of plants. Some account of the action of the biotic factors on vegetation will be found in *Introduction to Plant Ecology*, Chapter XV and in Chapter VI of *The British Islands and their Vegetation*. No general method of studying the effects of animals can be given, for they are necessarily quite different according to the kind of animals involved. By far the most conspicuous is the "grazing factor", in which we may include not only the action of sheep and cattle on permanent pastures and "rough grazings" but also of rabbits, mice and voles on both woodland and grassland. The primary method of studying the effects of these is of course to exclude them by adequate fencing. Details of the work that has been done and the methods employed will be found in the books mentioned above.

Chapter V

WOODLAND

Of all the types of British vegetation woodland offers the widest scope for study because it is the most complex. On the other hand many woods are unsuitable for school work. Conifer plantations may be ruled out, for the primary work at least, not only because they are essentially artificial plant communities but for several other reasons. Of deciduous woods composed of native trees many have been planted on the sites of old native woodlands, while others have been established on grass or arable land. Some deciduous woods are derived directly from old native woods with few or no planted trees, but are kept in a modified condition by regular felling and coppicing. In addition there are a very few more or less undisturbed fragments of natural woodland in remote places where the trees are not worth systematic exploitation. Apart from these last the woods that can be used for school work are either old plantations of native trees on soils which they might have inhabited naturally, or woods derived from old native forest, regularly exploited but with a minimum of planting. These two types tend to approximate in course of time and both are what we call "semi-natural". In default of trustworthy evidence of their history, which is often difficult to obtain, it is frequently impossible to say to which type a particular wood belongs. The old native woods, however, sometimes contain more or less rare woodland species that are absent from plantations even when these have assumed the aspect of a natural wood.

If permission can be obtained for work in an accessible and apparently suitable wood it is desirable first to determine its status by comparison with other woods in the district. Thus if completely natural woods are absent, as is commonly the case, and all the semi-natural woods are oakwoods it is probable that oakwood is the natural woodland type of the district. Such woods may be developed on fairly uniform soil and show a uniform vegetation, or a large wood may extend over different underlying rocks and show a fairly wide range of soil, varying for example from a sandy loam to a heavy clay, while the field layer and probably the shrub layer will differ accordingly. The particular wood chosen for study should be given its place within such an

observed range. On the other hand different woods of the district may be developed on markedly divergent soils with different dominant and subordinate vegetation. Thus there may be oak-hazel woods on clays and loams, ash- (or in the south, beech-) woods on chalk or limestone, oak-birch with pine and sometimes beech on sands. When markedly different dominant trees are found on the same soil and under identical conditions, e.g. a pure ashwood side by side with a pure oakwood, either planting or different stages of succession may be fairly inferred. A preliminary knowledge of the different types of wood that occur in the region is necessary in order that the particular wood to be studied in detail may be given its proper status and seen in proper perspective.

Alien trees, especially the more commonly planted conifers such as pine, spruce and larch, are often present in a perfectly good semi-natural wood. The two former, which are evergreen, are frequently planted as cover for pheasants and so are various evergreen shrubs. Pine regenerates freely on sandy soils and on heathland forms pure stands or mixed woods with oak and birch and sometimes beech. Larch has long been planted either as single trees or in groups (often in considerable stands) for the sake of the timber, which old-time farmers used for gate posts and the like, as a quicker growing though inferior substitute for oak. Sycamore is another tree very often met with in semi-natural woods on a wide range of soils. This is not a native tree, but has been occasionally planted for a very long time, and often regenerates so freely that it invades woods where it finds the space and competes with the native trees, sometimes becoming dominant owing to its quick growth and the deep shade cast by its foliage. In such cases it must be treated as if it were a natural constituent of the wood. Beech is often planted throughout the country outside its existing natural range of dominance, which is confined to the south of England, and it always alters the subordinate vegetation owing to its surface rooting habit and the deep shade which it casts, so that the floors of some beechwoods are almost bare of plants. Sweet chestnut, like sycamore, is not a native, but has been much planted locally and is generally treated as coppice. On sandy soils in the south it sometimes regenerates from seed. Several other alien trees such as horse chestnut, Turkey oak and various American oaks are occasionally met with in semi-natural woods, but they have little or no vegetational importance because they are not planted in bulk.

On entering a wood that has been selected for detailed study with a class notes should first be made of its local name (if any), its exact location, approximate size, the "rock" (geological formation) on which it is situated, and the general nature of the soil.

Structure.—The *structure* of the wood must then be described. British deciduous woods commonly show four (sometimes five) layers or strata of vegetation (see Chapter II, p. 20) and each of these should be described and listed separately, beginning with the tree layer or canopy.

Tree layer.—The following points should be noted: canopy open or closed, approximate height of mature trees, average distance apart, average diameter at breast height. In the case of semi-natural woods that have been completely planted up these data should be related to anything which is known about the date of planting, information that can often be obtained from a keeper or agent. The dominant tree or trees should first be recorded and then a list made of other trees present, with the approximate frequency letters or counts shown as percentages (see Chapter IV, p. 37). Trees such as holly, mountain ash, or crab apple which do not reach the height of the canopy and thus form a second tree layer, should be noted separately, with their frequencies. A second tree (or shrub) layer is sometimes due to *underplanting* of "nurses" for the "main crop", the nurses being afterwards cut out—thus conifers may be underplanted with beech. Such plantations are not suitable for primary study, which should be confined to woods that approximate to a "natural" character.

Shrub layer.—This should be dealt with in the same way as the tree layer. In the typical "oak-hazel" woods of the south and east and of much of the midlands of England the oaks are in "open canopy" and hazel is the dominant in the shrub layer. The old plan, dating from the Middle Ages, was to coppice the hazel on a 10-year rotation and fell the oaks at or near maturity. In many of these woods both oaks and hazels have been planted, but this type of wood, though it owes its character to a specific kind of exploitation, is a characteristic semi-natural type and very suitable for study. Associated with the hazel are other shrubs which have sown themselves naturally, such as dogwood, hawthorn, guelder rose, etc., and often trees such as ash and field maple, which are usually, though not always, coppiced along with the shrubs.

In close canopy woods the shrub layer is rarely continuous, and in woods with deep shade or in young woods or plantations, where the saplings or "poles" are close set, it is typically absent. This is often due as much or more to the severe root competition of the thickly set trees as to the shade they cast.

Field layer.—This is mainly composed of herbs, grasses and ferns, though it may include dwarf shrubs and the self-sown seedlings of trees. Quite often an upper and a lower field layer can be distinguished, the former consisting of tall herbs or grasses or bracken and bramble, the latter of low-growing herbs such as primrose, wood anemone, dog's mercury, sanicle, etc.

Just as a dense tree canopy inhibits the development of a shrub layer, so the field layer is poorly represented when the shrub layer is very dense. In coppiced oak-hazel woods or in coppices without standard trees there is a marked periodicity in the field layer, which is most luxuriant in the second or third year after coppicing owing to stimulation of the growth, and especially the flowering, of the herbs when light is admitted by cutting down the shrubs.

Ground layer.—In many woods a well-developed low-growing layer only an inch or two high, mainly consisting of mosses, with which liverworts and occasionally dwarf herbs may be associated, forms a more or less continuous carpet. Just as in the higher strata of vegetation, this is sparsely developed or absent when the layer immediately above (here the field layer) is densely packed.

The field and ground layers usually contain far more numerous species than the tree and shrub layers. Determinations of them should be carefully made so that the lists are as complete and accurate as possible.

Alien species of the field layer.—In woods that have been disturbed and are partly open, especially those which are closely surrounded by arable land, various species that are not woodland plants may be found. These are often wayside or arable "weeds" whose seeds have blown into the wood or been brought in on the boots or clothes of woodmen, keepers or shooters, and have found opportunity to germinate and produce plants. They are very rarely found in undisturbed woodland vegetation. Such species should be included in the lists, but their status will soon become obvious, and they can then be separately marked.

Seasonal aspects.—A wood that is being studied in detail should be visited as often as possible, and at least once in very early

spring, in late spring, near midsummer, and in late summer or early autumn. One visit should also be paid in the depth of winter. The species found in selected areas should be listed at all these times and the lists for the different seasons in the same area compared. It will often be found that different species occupy the same area at different seasons ("seasonal aspects", see p. 22), and though the leafy shoots of some plants may persist throughout most or the whole of the growing season, the relative development of the shoots of the various species occurring in a given area will be very different at different times of year. The number of different species and the extent of their seasonal succession are greatest in woods on clayey or loamy soil, and less marked on sands.

The systematic record of the structure of a particular wood contemplated in the preceding paragraphs involves the assumption that the whole of its vegetation is more or less uniform. Except in quite small woods on uniform soil with uniform exploitation (and uniform planting if the whole has been planted) this is, however, rarely the case. Local differences in the nature of the soil or in its average water content, differences in slope and exposure, differences in the nature and density of the tree and shrub layers, will create corresponding differences in the vegetation of the field layer, and such differences afford excellent and indispensable material for study. As a rule there is a general type of vegetation occupying most of the area of a wood, and this should first be systematically recorded, the local differences being taken up later. There may of course be variations within the "general type", particularly in the field and ground layers, which do not correspond with differences of habitat but are determined by "accidental" dominance of particular species; and these cannot always be distinguished at first sight from variations depending on differences of habitat. The best rule to follow is to record separately each well-marked "society" (see p. 21), whether it occurs in a single layer or involves more than one, and leave attempts at correlation with habitat (unless very obvious) till later. Thus within the general field layer of an oakwood on light sandy soil there may be local societies of bracken and bramble and others of bluebell and of wood anemone, and on heavier soil societies of primrose, of sanicle or of dog's mercury. Very often however the species are mingled indiscriminately, suggesting that occasional local dominance of one or another does not depend

on difference of habitat, but is rather due to chance mass occupation by particular species.

A few examples will illustrate the kinds of difference that occur.

Many years ago Adamson showed that in Gamlingay Wood Cambs. ("An ecological study of a Cambridgeshire woodland" *J. Linn. Soc.* (*Bot.*) 40, 1912) there were two main types of soil —heavy calcareous boulder clay, occupying most of its area, and a sandy loam covering a considerable patch of ground surrounded by the boulder clay. The former was dominated by oak in open canopy, with coppiced ash, aspen, field maple, hazel, guelder rose and wayfaring tree, the latter by oak with some aspen and birch but most of the shrubs absent and much lighter shade. In the field layer of the former meadowsweet (*Filipendula ulmaria*), a plant usually found in wet meadows, and here, under the heavy shade of the shrubs, not flowering, was generally dominant alone in the deepest shade and on the wettest soil. With more light the tufted hair-grass (*Deschampsia caespitosa*) was co-dominant with meadowsweet. With a lower summer soil water content (averaging 30 per cent) a society of wild strawberry (*Fragaria vesca*) replaced these, and on drier soil still (average summer water content 20 per cent) dog's mercury (*Mercurialis perennis*) was dominant.

On the sandy loam the field layer was for the most part dominated by bracken (*Pteridium aquilinum*) in late summer, with wood soft-grass (*Holcus mollis*) dominant in June before the bracken fronds had reached their full development. On part of the area, however, bracken was absent and here the wood soft-grass was dominant throughout the growing season, accompanied by a much greater variety of species than existed in the bracken area. Locally sweet vernal grass (*Anthoxanthum odoratum*) was dominant, with very few accompanying species. The soil and light of the two sandy loam societies differed very little, and it may be conjectured (though Adamson does not mention the possibility) that bracken, which is an aggressive plant, would ultimately occupy the *Holcus* area. Adamson's chart of the distribution of the two species suggests invasion of the *Holcus* society by bracken.

Woodhead's study of Birks Wood near Huddersfield ("Ecology of Woodland plants in the neighbourhood of Huddersfield," *J. Linn. Soc.* (*Bot.*), 37, 1906) brought out the relations between the tree canopy, the soil and the field layer of vegetation. This wood was situated on steeply sloping ground belonging to the Coal

BIRKS WOOD

325
350
375
325
350
375
400
425
450
475

Sandy loam
Dark sandy loam
Clayey loam
Humus over loam

Fig 1. SOIL

N
W
E
S

325
350
375
325
350
375
400
425
450
475

Shade trees (elm, sycamore, beech)
Oak dominant
Conifers

0 500 FEET
Contour lines in feet

Fig 2. TREES

SOILS AND TREES OF BIRKS WOOD, NEAR HUDDERSFIELD (WOODHEAD)

BIRKS WOOD

325
350
375
325
350
375
400
425
450
475

Bluebell

Bracken

Fig 3. BRACKEN & BLUEBELL

N
W
E
S

325
350
375
325
350
375
400
425
450
475

Wavy hair-grass

Wood soft-grass

Fig 4. GRASSES

0 500 FEET

Contour lines in feet

BRACKEN, BLUEBELL AND GRASSES IN BIRKS WOOD (WOODHEAD)

Measure series of rocks. The soil of the north-western half, on Elland flagstone, was a shallow sandy loam, while the south-eastern strip was a heavier clayey loam covered in places by at least 6 inches of humus. Between the two was a strip of loam containing a considerable amount of humus (Fig. 1).

The trees were sycamore, wych elm, beech, oak and birch, with a few planted conifers (Fig. 2). The wood was almost certainly at one time an oakwood, the trees other than oak, birch and possibly wych elm, being planted. Shrubs were practically absent, though Woodhead states that there was at one time a well-developed shrub layer, since destroyed by rabbits. In the field layer bracken was dominant over most of the wood but rarely where the trees casting heavy shade (sycamore, elm and beech) were dominant in the canopy (cf. Figs. 2 and 3). Woodhead says the invasion of bracken was consequent on the increased light in the oakwood resulting from the destruction of the former shrub layer by rabbits, bracken itself being practically immune from rabbit attack.

Another important member of the field layer over a considerable part of the wood was the bluebell (*Scilla nonscripta*) (Fig. 3); but the dominance of this was not determined by differences of light, since it occurred both below the shade trees and below oak and birch. It also extended over the different soil types but was most abundant where deep humus covered the loam; where the soil was shallow and sandy above the flagstones bluebell occurred only in straggling patches (Figs. 1 and 3). On the heavy clayey loam with little humus the bluebell had to compete with "exacting" woodland plants[1] such as dog's mercury, cuckoo-pint or wild arum (*Arum maculatum*) and yellow dead-nettle (*Galeobdolon luteum*), and was much more sparsely developed.

Two species of grass, wood soft-grass (*Holcus mollis*) and wavy hair-grass (*Deschampsia flexuosa*) were also important as dominants of the field layer (Fig. 4). As in Gamlingay Wood (p. 47) *Holcus mollis* was closely associated with bracken, both on deep humus and on the less heavy humus loam, and here bluebell (absent at Gamlingay) was also a member of the community. These three species or any two of them are in fact constant dominants of one of the most ubiquitous field layer woodland societies on the lighter non-calcareous soils throughout the country. Where all of them

[1] By an "exacting" plant is meant one which only flourishes on a rich soil, containing abundant "exchangeable" bases and assimilable nitrogen (see p. 41).

are present together bluebell is the first to vegetate and flower (April-May in the south, May-June in the north). Next comes *Holcus mollis* (May-July) and finally the bracken fronds, which only develop during June, expand in July, and make the continued vegetation of other species impossible beneath their dense shade for the rest of the summer. The bluebell bulbs penetrate most deeply into the soil, the bracken rhizomes often occupy a higher level, while those of *Holcus* run just below the surface. Thus the three species tend to avoid direct competition both in time and space, and all may develop luxuriantly in the same area.

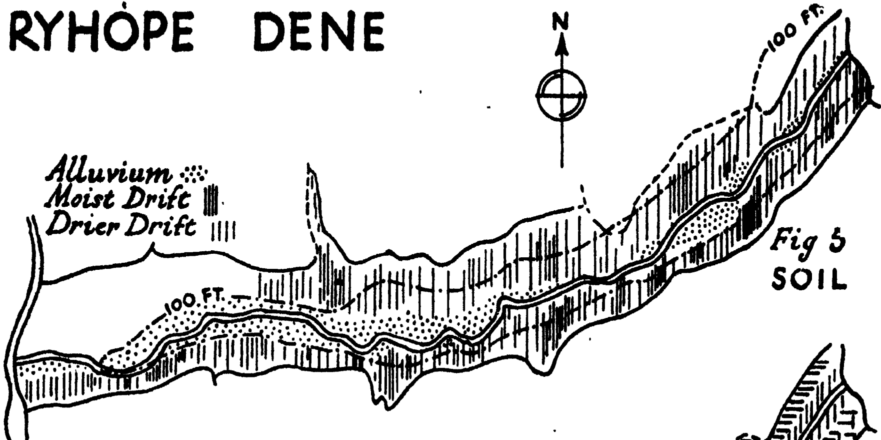
The *Scilla-Holcus-Pteridium* society belongs to "medium" soils, in texture, "richness" and acidity, and thus stands between the more exacting societies of such species as sanicle, mercury, primrose, cuckoo-pint, etc., which are characteristic of clayey, calcareous or other soils rich in bases, on the one hand, and the field layer communities of poor acid soils on the other. In Birks Wood this last type was represented by the dominance of wavy hair-grass (*Deschampsia flexuosa*), which occupied the centre of the north-western half of the wood (Fig. 4) on shallow well-drained sandy soil almost certainly very acid and poor in nutritive bases. This was accompanied by heath bedstraw, bilberry, ling (three very characteristic plants of such soils) and wood-sage, the last named a ubiquitous plant on a wide range of the drier soils.

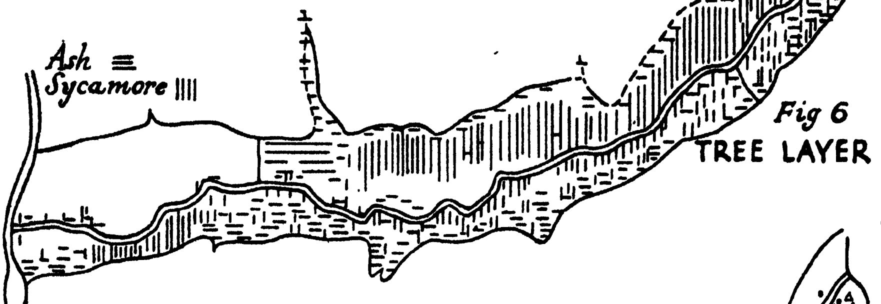
The distribution of dominant plants in these two woods has been described in some little detail because it illustrates the kind of correlations that can readily be observed between kinds of soil and vegetation and between the various layers or strata of the latter. For further information and quantitative results the reader is referred to the original papers.

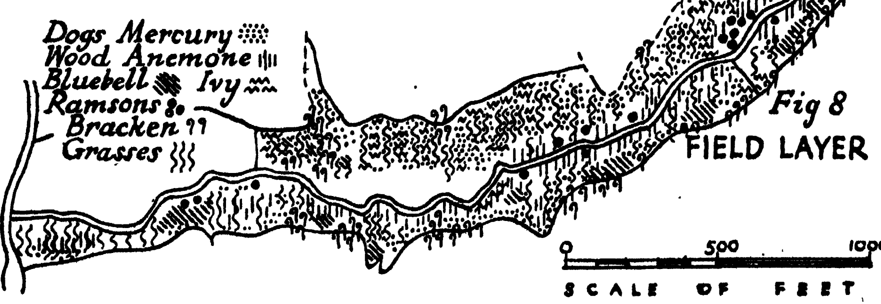
A third study of this kind was later carried out by one of us (E. Price Evans, "Local ecology as a basis for school botany," *School Science Review*, June 1920) with classes of secondary school pupils, and thus illustrates what can be done in actual school work.

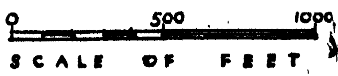
Ryhope Dene is a small, ravine-like, wooded valley in Co. Durham. The stream has cut through glacial drift overlying Magnesian Limestone, which is exposed in places. The drift soil is a distinctly calcareous loam of medium texture with a good mixture of mineral particles of different diameters. By the side of the stream there are tracts of alluvium (Fig. 5).

The dominant trees were ash and sycamore (Fig. 6), and it may be conjectured that the wood was originally an ashwood—a type









SOIL AND VEGETATION OF RYHOPE DENE, CO. DURHAM (PRICE EVANS)

(Simplified)

we should expect on the calcareous soil—in which (or near which) sycamore had been extensively planted. Where sycamore succeeds the shade cast by its heavy foliage suppresses the light-demanding ash, and in Ryhope Dene it was spreading from seed, as was shown by the abundance of seedlings and saplings. The other trees present, few in number and poorly developed, were oak, elm, beech, birch and mountain ash.

The shrub layer, sparse or absent under sycamore, was well developed in the ashwood (Figs. 6 and 7), and was dominated, as usual in ashwoods, by hawthorn and hazel, with a good deal of guelder rose and some elder. Towards the exposed southern edge, and invading the grassland outside the wood itself, were gorse and rose, with a little hawthorn and blackthorn.

The field layer (Fig. 8) also showed the marked difference between the shaded area under sycamore and the much better illuminated ground below the light ash canopy. In the former the species were few, consisting of dense, nearly pure societies of one or two species: bluebells in moist hollows (Figs. 5 and 8, several places on the south side) where humus had collected, dog's mercury and ivy in drier parts, ramsons (*Allium ursinum*), meadow-sweet and marsh marigold (*Caltha palustris*)—not shown—in wet ground near the stream. Under ash the vegetation was much more varied, consisting of many flowering plants, including wood-edge and genuine woodland (shade) species, e.g. wood anemone (*Anemone nemorosa*), and lesser celandine (*Ficaria verna*), sometimes in definite societies, but often mixed. Bracken was invading the grassland from the edge of the wood. The ground layer was represented by the liverworts—*Marchantia* on the Magnesian Limestone rocks and *Pellia* on the slope of the valley.

The plants of Ryhope Dene were used as the foundation of the teaching of botany in the school and were found to provide excellent and abundant material, while the fact that they were known to the pupils under the ecological conditions in which they grew in nature added to the interest and value of their study.

Succession.—The studies of woodland communities described in the preceding pages treated them on the whole statically. Apart from seasonal changes little enquiry was made as to progressive changes, the origin or fate of the woodland vegetation. Where a mature natural wood is growing under constant conditions there may in fact be little or no observable

successional change. As the older trees die (or are felled) new ones take their place and the composition of the wood remains substantially the same. And where a wood is exploited on a regular system by selective felling or periodic coppicing the same is true. Clear felling and replanting of course introduce quite different conditions, and woods recently treated in this way are much less suitable as subjects of primary study.

On the borders of woods which are not sharply bounded by arable land or well grazed pasture, however, successional changes illustrating the formation of natural woodland from grassland or heath may frequently be observed. Thus on slightly grazed or ungrazed commons abutting on woodland, shrubs, seedling and sapling trees may be found in all stages of development; and the same thing may be seen on neglected grass "verges" by the sides of roads where the seeds of trees and shrubs sow themselves from an adjacent wood. Here are excellent opportunities for the study of woodland succession.

Investigation of the following points will give interesting information on the method and course of colonisation by woody plants.

(1) The first woody plants (shrubs or trees) to appear in the grassland or heath.

(2) Whether the first woody colonists are generally distributed or whether they are only or mainly associated with particular herbaceous vegetation or with patches of open soil.

(3) The first appearance of various tree seedlings. Do these occur in the open grassland or heath or only in the shelter of shrubs already established?

(4) Changes in the field layer as the result of the establishment of woody plants. This is likely to cause an increase of "wood-edge" or "marginal" plants, and later with increasing shade a tendency for the soil to become bare.

(5) The further course of the succession: changes in the composition of the young woody vegetation: the first appearance of a true woodland field layer.

Tracing the whole course of succession up to the establishment of genuine woodland will necessarily occupy many years, and it is rarely that such an area will remain free from interference for so long. After a time it is likely that the shrubs and young trees will be cleared, partially or wholly, or that grazing will increase

and stop the succession. It is sometimes possible to induce a landowner or tenant to leave a small piece of developing woodland untouched, and if it can be fenced against grazing animals (including rabbits if these are numerous) so much the better. It is then worth while to mark off one or more small areas of which charts can be made showing the progress of the woody vegetation in successive years (see *Introduction to Plant Ecology*, Chapter X, pp. 112–37).

The habitats of woodland.—Natural and semi-natural woodland grows on all but the least favourable soils in our climate: on the fertile soils oak, beech and ash—the two latter especially on limestone—on the less fertile sands birch and pine. The natural soil of an old woodland shows the typical stratification of "brown earth" on the clays and loams, of "rendzina" on the limestones, and of "podsol" on the sands, three of the great groups of soils mentioned on p. 39. A layer of pure humus derived from the litter of fallen leaves accumulates on the soil surface of the chalk beechwoods and also on the podsols, though there it is of very different nature. On clays and loams most of the humus is incorporated in the mineral soil.

The aerial shoots of the different "layers" of a wood live in what have been called "partial habitats" because they are exposed to very different conditions of light and of air-moisture. Light diminishes within the wood from above downwards, while air humidity increases. Thus the tree canopy is the most brightly illuminated and the ground layer the least, while the former is exposed to the driest air and the latter to the moistest. The light intensity is very easily measured by the time taken to darken photographic paper, as in the "exposure meter" used by photographers. This of course measures mainly the active rays at the blue end of the spectrum. The photo-electric cell gives a truer measure of the total light, but its use is of course much less convenient. Air humidity can be measured by any convenient form of evaporimeter (or "atmometer"). See *Introduction to Plant Ecology*, pp. 162–5. Instructive information can thus be obtained by making light and humidity readings at different levels, e.g. close to the ground, above the field layer but below the shrubs, above the shrub layer but below the tree canopy, and in the open. The higher levels of the wood are not of course easv of access with the instruments.

Chapter VI

SCRUB AND HEDGEROW. HEDGEBANK, VERGE AND DITCH

Scrub, i.e. woody vegetation in which shrubs are dominant, often occurs on the edges of woods and on common or "waste" land near woods. It is usually to be regarded as a stage in the succession to woodland, often arrested in the scrub stage by the removal of the tree saplings. Scrub that is actively progressing to woodland, in which young trees would normally be found if the scrub is let alone is often called "woodland scrub". This is usually "loose" in structure, with clumps of shrubs or scattered shrubs and herbaceous vegetation in between. Another kind of scrub is "thicket scrub" which is dense and usually largely or entirely composed of spiny shrubs such as gorse, hawthorn and blackthorn, with roses and brambles. The shade cast by the closely packed shrubs is commonly so deep that little or nothing can grow beneath them and there is therefore no field layer, nor can tree seedlings establish themselves.

Woodland scrub, as a stage in the development of woodland, has a mixed field layer, consisting partly of the original grassland or heath plants, partly of the "marginal" or "wood-edge" species which flourish in light shade, with a few pioneers of the woodland flora. It is a most instructive and interesting subject for study, particularly if its development can be followed for several years, as suggested in the last chapter.

"Static" scrub occurs on exposed coasts and on mountains above the forest limits, where the wind makes tree growth impossible.

Hedgerows and hedgebanks.—In those parts of the country where the enclosed fields are bounded by planted hedgerows the vegetation associated with these forms an excellent subject for study.

A planted hedgerow is really an artificial form of scrub, and on each side of it there grow up plant communities which are quite characteristic. By far the commonest planted hedge-shrub is the hawthorn, and in the "quick" or "quickset" hedge which is kept closely cut, it may be almost the only shrub present. But most

hedges are not so drastically handled, and when they are neglected and become overgrown a great variety of woody plants may establish themselves, especially in the south of England, including most of the common native shrubs, such as hazel, blackthorn, dogwood, spindle, sallow, privet, guelder rose, with brambles and roses, and the woody climbers honeysuckle, ivy and bittersweet or woody nightshade. With these come trees, notably oak, ash and field maple—the two last often cut back with the shrubs when the hedge is trimmed; but many of the oaks, and often the ashes, are allowed to grow up into trees.

Hedges are very often planted on the top of a bank thrown up in digging a ditch at the edge of the field or road, and the *hedge-bank* is a habitat of herbaceous plant communities, largely those marginal or "semi-shade" communities characteristic of scrub or coppice, together with a few true woodland species. The vegetation of hedgebanks shows marked differences according to the soil of which the bank is composed, and, where they run east and west, between the well-lighted and the shaded sides. It must be realised, of course, that the vegetation of hedges and hedge-banks is subject to constant interference by hedge-cutting and by the throwing up of soil from the ditch when this is cleaned.

Verges and ditches.—Akin to the hedgebank vegetation is that of the *grass verge* which often exists between the ditch and an adjacent road, and this also is subject to constant interference by grazing, by annual cutting, and by the deposit of road metal or of soil from the ditch. On the whole the hedgebank vegetation is more "natural" and less mixed with wayside "weeds" and "casuals" than that of the verge. The hedgebank is also of course naturally well drained, while on heavy land the soil of the verge may be wet or even marshy, with corresponding differences in the plant communities.

The vegetation of the roadside or hedgeside *ditch* is naturally mainly composed of plants more adapted to wet habitats than those of the bank or verge; but it shows a wide range of variation. Ditches which contain free water for a large part of the year possess a true aquatic or marsh vegetation which does not differ in essentials from that of a small shallow pond. Those which are dry except after heavy rain, on the other hand, often possess a curious mixture of plants which differs strikingly at different seasons.

On the whole hedges, hedgebanks and ditches, because they are very characteristic habitats and show a considerable variety of conditions, are excellently adapted for comparative observation of their plant communities, which should be followed through the growing season; but because they are constantly subject to human operations they are not so suitable as woodland or woodland scrub for continuous study in successive years.

Chapter VII

GRASSLAND

GRASSLAND of one sort or another covers so much of the country that it is always among the most accessible kinds of semi-natural vegetation. But most of it—though very much less than before the war—is in so-called "permanent pasture" (see pp. 16–18) and the grasses of permanent pasture are seldom able to flower because they are constantly eaten back by the grazing animals, and thus the species present (which are fairly numerous) have to be determined from their vegetative parts. This can quite well be done with the help of the "keys" published in such books as Armstrong's *British Grasses* (Camb. Univ. Press) Percival's *Agricultural Botany* or McLean and Cook's *Practical Field Ecology*, but it involves somewhat specialised study which many teachers may not be able to undertake, though it affords a training in the discrimination of small differences which is both useful and interesting.

When grassland is "put up for hay" the case is different. The hay is not cut till June or July, by which time most of the species have flowered or are flowering and can be determined in the ordinary way. A hayfield just before cutting—and indeed from April onwards—with its wealth of grasses and other flowers is a most interesting and attractive object of study. The only trouble is that the hayis spoiled if it is trampled; but it may be possible to obtain permission from the farmer to work on a narrow strip bordering a pathway. If this can be arranged, the succession of grasses and other plants which develop and come into flower from April to June or July should be recorded with their dates: those which are generally dominant (several species are often co-dominant) should be distinguished from those which are more sparsely scattered, and the occurrence of local "societies" or patches in which particular species are highly gregarious should be noted. The fine fibrous roots, confined to the top 2 or 3 inches of soil and forming the basis of turf, is a constant feature of most species of grass.

If it is decided to attempt the study of the enclosed permanent pastures of a district in which there are considerable differences of soil or of soil water content it will be easy to recognise distinct

types marked by different dominant grasses, and associated species of flowering plants, on the various soils. Thus the dominant grasses and other plants on clay soil will differ from those on sandy soil, while the limestone grassland vegetation is different from both and is highly characteristic. Again the flora of a wet alluvial meadow is widely different from that of a dry upland pasture. But apart from such differences determined by the soil habitat it must always be borne in mind that the major determinants of different types of enclosed permanent grassland are manuring and grazing. A well manured and well grazed pasture on anything like good soil will probably have perennial rye-grass (*Lolium perenne*) and white clover (*Trifolium repens*) dominant, with an admixture of such species as cocksfoot (*Dactylis*), meadow fescue (*Festuca pratensis*), meadow grasses (*Poa*), etc., well represented. At the other extreme, in a neglected unmanured and undergrazed pasture on poor soil, we shall probably find dominance of common bent (*Agrostis tenuis*). Both the best and some of the worst pastures have a limited number of species (twenty to twenty-five) while in those of intermediate status there is a much greater variety of grasses and other flowering plants.

Thus the study of permanent grasslands is largely an agricultural study because of the predominant influence of the manuring and grazing factors, and it is essential to obtain as much information as possible about the actual treatment of the pastures studied before they can be understood.

Neglected and undergrazed pastures tend to be invaded by shrubs, notably spiny shrubs, especially roses, brambles and hawthorns, which come from neighbouring hedgerows, and these, when once established, resist attack by grazing animals. Unless the shrubs are cleared and the grazing regime improved trees will eventually come in and the pasture will "revert" to scrub and woodland, i.e. will advance a stage in the natural succession.

Contrasting with the enclosed permanent grasslands we have the "rough grazings" which are not manured or enclosed, and will only carry a much smaller population of grazing animals than good tended pasture. In the south-east these rough grazings are mainly chalk down which is traditional sheep pasture, but is now increasingly used for cattle; while considerable areas are rendered worthless by the immense populations of rabbits. The chalk grassland bears a distinctive flora and vegetation The sheep's

and red fescues or the erect brome are the dominant grasses, and these are accompanied by an interesting and beautiful set of flowering plants including many orchids. In the hilly and mountainous regions of the west and north the well-drained slopes of the limestone hills are very largely grassland—"calcareous grassland" similar to that of the chalk though not so rich in species—"siliceous grassland" on hills composed of noncalcareous rocks. This latter, typically dominated by the common bent (*Agrostis tenuis*) and sheep's fescue (*Festuca ovina*), forms most of the great sheep grazing regions of Wales, the Lake District, the Northumbrian Fells and the Southern Uplands of Scotland.

The bent-fescue grassland, when it is undergrazed, is commonly invaded by heath plants such as the common ling (*Calluna*) or the bilberry (*Vaccinium*) or both, so that it may become an upland heath or moor: at the lower altitudes scrub may invade it. Much of this grassland was at one time forest. In badly drained places, and generally where peat tends to accumulate in the soil, the bent-fescue grassland is invaded and may be replaced by more or less pure communities of "white bent" or matgrass (*Nardus stricta*), and in wetter places where the soil water is moving, by "flying bent" or purple moorgrass (*Molinia caerulea*) often with rushes (*Juncus*). In the wettest and most stagnant situations bog develops, with bogmoss (*Sphagnum*) and associated plants such as cottongrass (*Eriophorum*) and deergrass (*Scirpus caespitosus*)—both belonging to the sedge family (see Chapter X).

These hill grasslands, dominated by bent and sheep's fescue, by matgrass or by purple moorgrass, are of course much more "natural" plant communities than the enclosed "permanent grass" of our fields and meadows, and since they are accessible to many schools in the north and west, would form, together with the moor and bog communities with which they are usually closely associated, excellent subjects for school study. Here the only "artificial" factor is the grazing, which is often very light. The vegetation itself is entirely "natural", being composed of plants which naturally invade an area where forest has been destroyed and is prevented from returning by grazing or other conditions unfavourable to tree growth.

Conspicuous features of many bent-fescue rough grazing areas are the extensive societies of gorse, and especially of bracken, which invade the grassland and seriously decrease its grazing value.

Bracken indeed, which is a very aggressive plant and has greatly extended its area during the last few decades, cannot be checked by grazing because it is quite unpalatable to most animals, and is recognised as a formidable pest. Various means are now taken to combat it, with some success. It cannot however colonise waterlogged ground, and does not succeed when exposed to violent winds, so that the dense bracken societies covering many slopes stop abruptly at wet ground and at the exposed crests of the ridges.

Probably the most interesting and instructive line of study in these hillside areas is the relation of the different communities mentioned to soil, exposure, and grazing, and to one another. After the species of the various types of grassland have been recognised, their relations can be studied by means of transects crossing the boundaries of different communities (see *Introduction to Plant Ecology*, pp. 122–4). Before undertaking such study it will be well to become acquainted with what is known about the hillside vegetation, of which accounts will be found in *The British Islands and their Vegetation*, Chapters XXV–XXVIII, XXXVI, XXXVII.

Lawns.—The opportunities which lawns afford for school study have already been alluded to (p. 31). An excellent article on the study of lawns appeared in the *School Science Review* for June 1939 (Vol. XX), pp. 577–87, by J. Gillespie. The author points out that lawns are composed of light-loving grasses, that the more fully they are exposed to light the shorter and firmer are the blades of grass, and that different species of grass do best on different types of soil. But the most important factors at work are those which actually maintain a lawn in good condition—cutting, rolling and manuring. Cutting a lawn corresponds of course to grazing a pasture, but the mowing machine cuts much more closely and uniformly than animals (except rabbits) graze, and this contributes to the uniformity of the vegetation. Both cutting and rolling increase the "tillering" of the grasses, by removing or crushing the leading buds, so that fresh lateral shoots (*tillers*) are formed. This is the main cause of the formation of a compact turf and can be verified by comparing the number of grass shoots in a rolled and unrolled portion of a lawn. Sometimes, especially on clay soils, the surface becomes too compact, preventing the penetration of air and water. Forking or pricking

the soil will counteract this tendency and stimulate the root growth of the grasses. Manuring is necessary to replace the large amounts of plant food in the leaves and shoots removed by the lawn cutter. Phosphates, potash and nitrogen are the main substances that have to be supplied. The nitrogen is usually given in the form of ammonium sulphate, and this encourages leaching of lime from the surface soil and consequent development of acidity, which has to be counteracted by the addition of some lime compound.

The *weeds* of different lawns form an interesting study. They vary according to the soil, but the most ubiquitous are two species of plantain, dandelion and daisy—all "rosette plants" whose spreading leaves tend to overlay and kill the shoots of the surrounding grasses. When the weed is deep-rooted it is able to draw supplies of water and nutritive salts from deep layers of soil which the surface-rooting grasses cannot reach.

At schools which possess a lawn part of which can be devoted to ecological study it is clear that opportunities for good work are numerous. First of all it is essential to recognise the species which are present in the turf. This can be done either by determining the grasses from their leaf characters, or better by allowing a sample patch or strip to grow up and flower. Then various experiments can be tried on different sample patches, rolling and forking, manuring with different "artificial" manures, "liming", etc. In all cases a "control plot" should be left. The combinations of different possible treatments are obviously very numerous. The composition of the turf after each experiment should be recorded and compared with that of the part of the lawn under "normal" treatment.

Chapter VIII

HEATH AND MOORLAND

THE vegetation composed of dwarf shrubs belonging to the heath family (Ericaceae), though not nearly so extensive as the grassland, is still a characteristic and widespread feature of the British Isles. Most of it is dominated by the common ling or heather (*Calluna*) associated with other species of heath (*Erica*) and of *Vaccinium*, of which one species, the bilberry (*Vaccinium myrtillus*) is frequently dominant in large stretches especially at high altitudes. On areas where grazing is slight or absent and the soil is acid the heaths tend to replace grasses and often form a stage of vegetation preceding occupation by forest. At altitudes above the forest limit heath may form the climax vegetation.

We may distinguish between *lowland heath* developed on sandy or gravelly soils and generally open to invasion by trees, and *upland heath* occurring on well drained hillsides, often where strong winds prevent or limit tree growth. In the wetter climates some thickness of peat (up to 12 inches) develops on such soils. And wherever drainage is increased, so that the soil becomes drier, deep peat, originally formed by bogmoss or other bog plants, tends to become colonised and dominated by ling or other heath plants. Heaths with pure peaty soils, whether deep or comparatively shallow, are often known as *heather moors*, but these are not sharply distinguishable from upland heaths. Thus various stages of different successions—the replacement of one plant community by another with changing conditions—can be recognised and followed in connexion with heathland.

Lowland heath, the characteristic heath of sandy and gravelly soils so familiar in the south and east of England, represents very largely the vegetation of areas—usually sandy—too infertile to repay cultivation. In the neighbourhood of woodland such heath is frequently invaded by trees, mainly birch and pine, but also oak and beech, and if left alone develops into woodland. Some heaths do not readily support tree growth owing to causes which are not fully understood, but which may sometimes be the presence of toxic substances in the soil, and sometimes deficiency of water; and many others are too remote from seed parents adequate in number to provide tree seed in sufficient

quantity. Most lowland heaths, however, are prevented from developing woodland by removal of the young tree growth or by the frequent accidental fires that sweep over them after a drought. Mature heath regenerates fully from a severe fire in about twenty years, but much of the area of the southern heaths is burned more frequently than that. In the north, where the upland heaths are used for preserving grouse, they are regularly fired at intervals of a few years to provide young growth for the birds.

The structure of a typical heath is quite characteristic. The dominant heath or ling (*Calluna*) forms small closely set bushes growing to a height of about 2 or 3 feet, and gradually becoming "leggy" with age. Dead or moribund areas are sometimes encountered, the bushes apparently dying of old age at about twenty-five or thirty years, but the details have never been investigated. Mixed with the ling is often the purple bell heath (*Erica cinerea*) which frequently occurs also in pure patches, particularly on dry sunny slopes. After burning, the purple heath usually comes back quicker than ling and the evidence is that it eventually gives way to the latter in competition if the heath is left undisturbed for a sufficient time. Below the ling canopy small deeply-shaded plants of the bilberry (*Vaccinium myrtillus*) —which do not flower—are often found, but they do not occur on all heaths. Bilberry is more often met with in regions of higher rainfall, and here it is sometimes dominant, replacing the ling. There is also a well-marked ground layer of mosses (*Polytrichum* and *Hypnum*) and notably lichens (*Cladonia* spp.) whose grey branching thalli are a characteristic feature of nearly all heaths. Some species of *Cladonia* become epiphytic on the heather, especially on the leggy shoots and twigs of old plants.

The soil shows a thin layer of dry peat formed from the dead lichens and mosses and the shed leaves and twigs of the heaths, and this overlies the sand or gravel soil, the upper layers of which are often bleached white by percolating acidified rainwater. Below the bleached layer is a dark-coloured and sometimes hard "pan" of accumulated humus compounds and iron salts and below this the yellow or reddish sand or gravel subsoil. This is a typical "podsol" profile (see pp. 39, 40).

The flora of a typical mature heath is usually very poor in species of flowering plants, but in a recently burned or otherwise disturbed heath they are more numerous. Among them are the wavy hair-grass (*Deschampsia flexuosa*), a characteristic heath

grass, with common bent (*Agrostis tenuis*), sheep's fescue (*Festuca ovina*), and sometimes other grasses such as wood soft-grass. When a heath is pastured and trampled the grasses increase, and if they become dominant the community is called *grass heath.* In damp places the purple moor-grass (*Molinia caerulea*) is often found. In the south of England the dwarf gorse (*Ulex minor*) is a characteristic heath plant as well as the less frequent petty whin (*Genista anglica*). The common gorse (*Ulex europaeus*) invades heath as well as common grassland when it is disturbed, and so does the broom (*Sarothamnus scoparius*). Bracken (*Pteridium*) is abundant on many heaths and invades disturbed areas, often becoming dominant and suppressing the ling; but it is doubtful if bracken can invade vigorous untouched heath. In many heaths ling and bracken seem to have arrived at a position of equilibrium, holding one another in check, and neither able to obtain complete dominance. On such areas the bracken fronds are scattered among the heath plants and do not grow more than about a foot high.

In wet hollows on a heath there is found the characteristic "wet heath" community, really the same thing as the bog community (see Chapter X). Species of bogmoss (*Sphagnum*) usually occur, with cross-leaved heath (*Erica tetralix*), cottongrass (*Eriophorum*), often bog asphodel (*Narthecium*), and sundew (*Drosera*). On the edges of such wet areas *Molinia* is frequent and sometimes bog myrtle (*Myrica*).

Besides the vegetation characteristic of undisturbed and disturbed heath, which has been briefly described, lowland heath, as already mentioned, is frequently invaded by trees. Young birches, and in the south pines, are frequently found scattered freely in the heath, and these may close up to form a young birch wood or pinewood with partial or almost complete suppression of the heath plants. Oak and sometimes beech may come later, more slowly and in smaller numbers, corresponding with their fewer and heavier seeds. But eventually all stages of succession from heath to a mixed woodland may occur if the area is not interfered with. Under birch and oakwood the heath plants largely maintain themselves, though they become sparser and "drawn up" in the weakened light, but under pine or beech they are largely or entirely suppressed owing to the deep shade cast by these trees. Bilberry is one of the few heath plants which persists in such deep shade.

It is thus obvious that while mature untouched heath does not give much opportunity for study, beyond the recording of its vertical structure, disturbed and burned areas as well as local bogs and all the phenomena of invasion by shrubs and trees afford ample and interesting material. As in all such cases *transects* (see *Introduction to Plant Ecology*, pp. 122–4) laid down so as to intersect various phases of vegetation are the best method to employ for record.

Upland heath and heather moor cover very wide areas on the siliceous hills of the north, for example in the Pennines, on the Clevelands and in parts of Scotland. They are generally used as grouse moors. At the higher altitudes, above the tree limit, from 2,000 to 3,000 feet, bilberry moor tends to replace heather moor. On the whole heath and heather moor are more prevalent in the east than in the west of Great Britain and Ireland. Heather (*Calluna*) is typically dominant only on well-drained ground though it may be quite abundant among the dominants of other species, such as cottongrass, when the soil is wet.

The *structure* of upland heath is very similar to that of lowland heath. There is the same overwhelming dominance of the ling, and the same ground layer usually dominated by *Cladonia*. There is also the same poverty in flowering plants, which are mostly the same species as are found on the southern heaths, though there are some which occur in the south but not in the north, and others, for example crowberry (*Empetrum*) and bearberry (*Arctostaphylos*), both dwarf shrubs like the heaths themselves, which are common in the north and very rare or absent in the south. The liverwort and moss flora of the northern upland heaths is very much richer than that of the southern lowland heaths in correspondence with the wetter climate, but the common species are nearly the same.

The relation of upland heath to bent-fescue grassland has already been referred to (Chapter VII) and is practically the same as that between lowland *Calluna* heath and grass heath, i.e. it depends on the incidence of grazing.

The most interesting features to study are the relation of the heath or moor to grazing and burning.

Chapter IX

FRESHWATER VEGETATION

FRESHWATER vegetation is a specially attractive field of study, both because aquatic plants show peculiar and interesting structural features and because the communities they form are less liable than land vegetation to be twisted by human interference away from their natural course of development. As an object of school study we must set against these advantages the fact that serious work on water plants as they grow in nature almost always involves getting wet and muddy!

If it is decided to attempt such work, and good freshwater vegetation—in ponds, canals, or slow rivers—is available within easy reach of the school, the first thing that will strike an observer is the clear *zonation* of the communities. Examining the plants of a pond or slow river, completely submerged water plants, such as the Canadian waterweed (*Elodea*) and the submerged kinds of pondweed (*Potamogeton*), will be seen to occupy the deeper water; next to them will come plants with floating leaves, such as the floating pondweed (*Potamogeton natans*) or the yellow waterlily (*Nuphar luteum*); then a belt of plants with upright shoots rising above the water, such as *Eleocharis palustris* (an aquatic plant belonging to the sedge family), *Equisetum fluviatile* (one of the horsetails), of comparatively low growth, and then, nearest the shore, taller plants such as bur-reed (*Sparganium erectum*), the handsome grass *Glyceria aquatica*, and the typical reedswamp plants such as the reedmace (*Typha*), the bulrush (*Scirpus lacustris*), and the common reed (*Phragmites communis*), which is the most widely spread of them all.

These three zones, the *submerged*, the *floating leaf* and the *reedswamp* respectively, are often not sharply separated. Thus completely submerged plants may occur among those with floating leaves, and the latter (such as waterlilies) may be found among the tall reeds of a loose reedswamp; but the dominance of the three types in separate zones is usually very well marked.

If the ground on the edge of the water is flat, or very slightly sloping, a marsh community (see Chapter X) will be found on the landward side of the reedswamp where the water reaches or nearly reaches the surface of the soil. The aquatic communities

proper are those showing a continuous free water surface between the plants.

This well-marked *zonation* of water plants may represent stages of *succession* from water to land vegetation. On the floor of a pond plant debris accumulates and also rainwash from the surrounding land. Silt is deposited on the beds of slow rivers, and is brought down and deposited on the floor of a lake fed by inflowing streams. Both these processes—the accumulation of dead plant remains and the deposition of silt—raise the level of the bottom and bring it nearer to the water surface. This progressive shallowing of the water gradually renders any given area of the submerged floor less fit for its former occupants and more fit for those of the next landward zone. Thus the submerged species will tend to be replaced by those with floating leaves and those by reedswamp plants, which, in their turn, will eventually give way to marsh plants. In this manner a small isolated pond will ultimately fill up or "grow up", and if it is to be maintained as a pond will have to be cleaned out every few years. Similarly canals and slow rivers will become choked with vegetation and have to be dredged if the channel is to be kept open. Otherwise the waters of the river will spread over surrounding flat land and eventually the river will lose itself in a tract of marsh. Embanking will check its tendency to overflow in times of flood, but the bed must also be periodically cleared of vegetation and excessive silt.

For these reasons the natural zonation and succession of plant communities in a pond can best be studied when the vegetation has been left alone for some years so that the development of the successive zones has had time to become established. Observation on such a pond at sufficiently long intervals will generally reveal the progress of succession.

The best means of recording the zonation is by means of a profile transect such as the one illustrated in Fig. 9. In this figure the vertical scale is enormously exaggerated compared with the horizontal, the width of the small lake being several hundred yards. Fig. 10 shows the plan of a small artificial pond which had been allowed to "grow up", and in which there was no distinct submerged community, the centre of the pond being dominated by the floating pondweed, which in both pond and lake, as will be seen, grew in water from one to two feet deep..

In order to make a plan or transect accurately it is necessary to get among the vegetation. In a lake or large pond the sub-

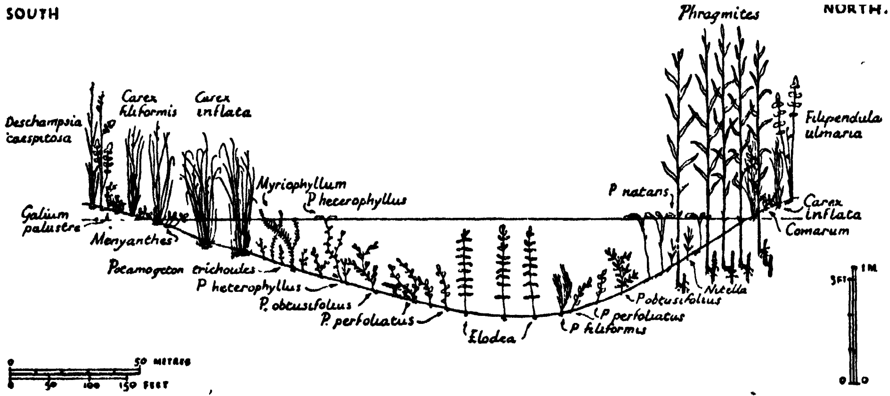


FIG. 9—PROFILE TRANSECT OF WHITE MOSS LOCH (MATTHEWS)

J = *Juncus effusus*
G = *Glyceria fluitans*
O = *Œnanthe fistulosa*
C = *Carex goodenowii*
E = *Eleocharis palustris*
S = *Sparganium erectum*
P = *Potamogeton natans*

FIG. 10.—PLAN OF POND AT BRAMHOPE, NEAR LEEDS (WALKER)

merged and floating leaf communities can be recorded from a boat from which soundings can be taken, but the reedswamp, unless very narrow, must be entered from the shore. When a boat is available a cord should be stretched from a long stake planted in deeper water to a peg on the shore, and the plants noted which are in contact with or within a few inches of the cord. A small and comparatively shallow pond can be dealt with by entering the water in gumboots and using stakes and cords in a similar way.

The structure of the water plants collected during ecological survey of a pond makes a very instructive study in schools where botany is taught. The two conspicuous features they show are the reduction of the vascular system—most marked in the submerged forms—and the great development of air spaces. The former is related to the lack of need for water conduction and the latter to the increased need of aeration because the supply of free oxygen is much less in water than in the air. The vascular system of the tall reeds and similar plants is much better developed, because water has to be raised several feet into the air to supply the leaves. A cross-section of the stem of one of the white-flowered water crowfoots should be compared with that of one of the terrestrial species (buttercups) of the same genus (*Ranunculus*). Much of the structure of a water plant can be made out with the naked eye and a hand lens, but more of course can be seen with the microscope.

The very favourable conditions of life in freshwaters—other than those which are acid and extremely poor in nutritive salts—lead to rapid and luxuriant growth and vigorous vegetative propagation, so that ponds and streams frequently become quickly choked with vegetation. Most water plants also are able to grow from detached fragments of the plant body—sometimes even from part of a single leaf.

Nearly all water plants are perennial, and they pass the winter in various ways. Some retain their leaves and go on growing slowly except when actually frozen. Others "overwinter" in the form of rhizomes or tubers, others again by means of specialised winter buds or *turions*, which are shoots stored with food materials and protected externally by scales. These turions become detached from the parent plant and pass the winter either floating or resting on the bottom. In spring they "germinate" to form ordinary vegetative plants. Highly specialised turions occur in the submerged pondweeds with linear leaves, in the duckweeds,

the frogbit and the water milfoil. Turions differ very much in their capacity to withstand freezing; some can endure inclusion in ice for several days or perhaps weeks. Unfavourable conditions of various kinds encourage the formation of turions.

All these features form interesting subjects of study, and experiments on the modes of reproduction and on the survival of water plants that can be carried out in schools where facilities exist will suggest themselves.

Chapter X

MARSH, FEN AND BOG

THESE communities are composed of plants growing in soil that is saturated with water for most of the year but without a free water surface between their shoots during the growing season. The vegetation of marsh and fen is closely akin and most of the species are the same. The root systems of both have a constant supply of water so that they never suffer from drought, but the saturated soil cuts off the free supply of oxygen for respiration enjoyed by the roots of most ordinary land plants. In both the supply of nutritive salts is adequate or more than adequate. The result is that both are inhabited by "exacting" species (see note on p. 41), but the plants have, like water plants, abundant intercellular channels which facilitate the passage of air through their tissues. The difference between marsh and fen is that the former has a mineral soil, the latter a purely organic soil, composed of peat produced by the partial decay of the debris and dead bodies of the successive generations of plants.

Marsh vegetation develops on any saturated mineral soil, and is most extensive on the (undrained) flat alluvial plains of rivers, especially those subject to periodical flooding and heavy silting before the river has been embanked or the land drained. Fen develops where silting is slight or negligible so that the soil is formed from the accumulation of plant debris alone. Both are often developed in immediate contact with reedswamp, and some species, for example the common reed (*Phragmites*), are common to all three communities—reedswamp, fen and marsh. Marsh and fen are dominated largely by members of the sedge and rush families, with some grasses and a variety of other flowering plants.

Bog resembles fen in having a peat soil, but this differs from fen-peat in several ways, for instance the great poverty in nutritive salts and markedly acid reaction of bog-peat. The plants inhabiting bog are highly specialised and the number of species present is very limited. The most characteristic and often the most abundant are various species of bog-moss (*Sphagnum*) which are actually dominant in many bogs. Other characteristic and common species are cotton-grass (*Eriophorum*), sundew (*Drosera*), bog asphodel (*Narthecium*), white beaked sedge (*Rhynchospora alba*), cross-leaved heath (*Erica tetralix*). In the north of England and southern Scotland bogs are known as "mosses".

An important point about these communities is that they may be developed in natural succession following upon the freshwater succession described in the last chapter. Thus on the flat shore of a pond, lake, or slow river, which is liable to flooding and silting, marsh will develop. When silting ceases to be heavy or stops altogether but the soil remains waterlogged, peat begins to be formed and typical fen develops. When the soil level has risen above the influence of the "ground water" carrying nutritive salts the bog plants, up to that point excluded, begin to colonise the surface of the fen, and *if the climate is damp enough to prevent excessive evaporation of water*, typical bog will develop on the top of the fen. Such bogs are met with all over the Central Plain of Ireland, and once they were also abundant in western England, Wales and south-western Scotland, though most of these have been drained or destroyed by removal of the peat. In the drier climate of eastern England only indications of bog formation are seen on fens. In very wet climates, such as those of western Scotland and western Ireland, bog tends to spread over the whole surface of the country except on well-drained sites. Local bogs (wet heath) also occur throughout the British Isles in wet hollows on soils poor in lime (cf. Chapter VIII, p. 66). Drained bog is nearly always colonised by heather (*Calluna*) in quantity and is thus converted into heath, with a dry soil of deep peat.

Marsh, fen and bog are not among the most obviously suitable communities for school work, but where one or other of them is within easy reach of the school, there is no reason why it should not be tackled. If all of them are present together the fact of the relationships mentioned above will greatly enhance the interest and instructiveness of the work. The transect is certainly the best method of study. It must however be borne in mind that most marshes and fens, and very many bogs, have been more or less completely drained, and draining brings about fundamental changes in the vegetation, eliminating many of the native species and leading to the invasion of many land plants that do not belong to the natural marsh, fen and bog communities. Thorough drainage results of course in the complete destruction of these communities, and the land is then either used for pasture or for arable crops, as over nearly the whole of the East Anglian Fenland. The conditions involved in *partial* drainage, which is very common, are complicated, and partially drained marsh or fen is not an easy or straightforward subject for study.

Chapter XI

SALT MARSH

SALT marshes are developed on the sea coast, mainly on the flat shores of estuaries and in sheltered bays where tidal silt accumulates. Tidal mud and sand exposed to the full force of tidal scour is far too mobile to permit of colonisation by rooted plants, and it is only where the force of the tide is diminished that the first salt marsh plants can establish themselves. Thus this vegetation is limited to the upper part of the "tidal belt" which lies between the extreme upper and lower tidemarks, and can only be developed in relatively protected areas. On fully exposed coasts, where the breakers reach the upper tidal limit, salt marsh is absent.

The salt marsh communities are composed of highly specialised plants, most of which grow nowhere else in this country, except locally, close to inland salt springs. In the interior of the great continents they dominate the very salty soils of old lake basins in arid regions. These plants are known as *halophytes* (salt plants) and a common structural character is the succulence of their leaves and stems. Halophytes are adapted to life on soil which is periodically saturated with salt water, for longer or shorter periods according to their position in the tidal belt. Thus the salt marsh vegetation is characteristically *zoned*, the different zones corresponding with the different periods of immersion in sea water. The times of submergence by the tide are much shorter than is generally recognised. Even the lowest zone is only submerged for less than a quarter of the time, while the uppermost is only covered by the highest spring tides for about three hours per month. All the upper communities, which are submerged for less than thirty hours in the month, suffer from drought during rainless periods in the summer.

Different salt marshes vary to a certain extent in the composition of their vegetation, largely according to whether sand or mud forms the main substratum. In nearly all cases the lowest zone of the salt marsh proper is a practically pure community of marsh samphire or glasswort (*Salicornia herbacea*), a very succulent annual plant which establishes itself with some difficulty as a sparse pioneer where it is reached every day by the tide, and is more closely set above this level. The community ranges

through the zone which is submerged for between one hundred and one hundred and fifty hours in the month. In some of the southern muddy salt marshes the glasswort is replaced by the tall "rice-grass" (*Spartina townsendii*) which has very rapidly spread over and bound the mobile mud of Southampton Water, Poole Harbour, and many other southern tidal inlets during the last few decades.

The upper edge of the glasswort community is invaded by the vigorous perennial grass *Glyceria maritima*, which quickly extends horizontally, collecting silt and beginning to form a turf, thus restricting the space available for colonisation by the single plants of glasswort. Very occasionally glasswort is absent and *Glyceria* is the pioneer. Most commonly associated with both is the annual sea-blite (*Suaeda maritima*) with very succulent leaves. Where *Glyceria* is absent or present in insignificant amount the taller sea aster (*Aster tripolium*), another plant with succulent leaves and with conspicuous lilac and yellow flowers, succeeds glasswort. Sea aster readily colonises open mud, either at this level or on the edges of drainage channels higher up on the marsh, and often becomes dominant.

Up to this point the salt marsh vegetation is submerged for more than fifty hours a month, and it will be noted that most of the plants are very succulent. Above this critical level come the communities of the middle and upper salt marsh where the soil is usually thickly covered with vegetation, which may suffer from drought, and marked succulence is less common. Sea lavender (*Limonium vulgare*), with its beautiful lavender-purple flowers in later summer, often invades the upper edge of the *Glyceria* zone, and forms a typical community of what may be called the "middle marsh".

Thrift or sea pink (*Armeria maritima*) with its rose-pink flowers (April-June) often dominates a slightly higher level than sea lavender, and like it is often co-dominant with *Glyceria*, forming a close turf composed of a number of species and commonly used as sheep pasture. Sometimes in fact there is no dominant species in the middle marsh but half-a-dozen or more are equally important. The mealy, greyish-white undershrub *Obione portulacoides* is another plant of the middle marsh which plays a conspicuous part in many salt marshes of the east coast of England. It is dominant especially on the banks of the tidal channels up which the high spring tides flow to gain access to the

upper levels of the marsh. As the water overflows the edges of these channels some of the silt it bears is strained off, raising the level of the bank and thus providing the specially well-drained habitat favoured by *Obione*. From these banks it may spread and cover considerable tracts of flat marsh. Other common plants of the middle marsh are sea plantain (*Plantago maritima*) and sea spurrey (*Spergularia salina* and *S. marginata*).

An upper zone of sandy salt marshes, sometimes called "sea meadow" and generally pastured, is dominated by varieties of the red fescue (*Festuca rubra*) with several species of the middle marsh and others, such as buck's-horn plantain (*Plantago coronopus*), sea milkwort (*Glaux maritima*) and "pungent couch-grass" (*Agropyron pungens*) with sharp tips to the leaves. This community often occurs on the sides of sandy banks towards the upper edge of the marsh. Where the upper edge is relatively undisturbed it is commonly occupied by a community dominated by the sea rush (*Junvus maritimus*). This plant is much taller than any of the accompanying species and its dense stands tend to destroy the close turf of the sea meadow and to provide more open and better soil and moister air between the shoots of the rushes. A consequence is that many plants of the lower marsh reappear here.

When tidal silt accumulates continuously in a bay or estuary the surface is gradually raised, is less violently affected by the tidal flow, the water flooding in much more gently, and is exposed to the air for longer periods because it is reached by fewer tides. Thus the communities of the lower marsh are gradually replaced by those of the middle, and these by those of the upper marsh, so that the zonation described represents a succession (the *halosere*), as in the case of the freshwater aquatic, marsh and fen vegetation (*hydrosere*) described in the last chapter. As silting proceeds and the level of the marsh is raised a given zonal community will be gradually replaced by one standing higher in the order of succession. This process is not however uniform and continuous. Salt marshes rarely show perfectly even zonation parallel to the shore line. They are practically always broken up by creeks and lesser drainage channels which give ingress and egress to the tides. Separate individual marshes are often developed in the bays formed by shingle spits, and such bays may have wide or narrow entrances. All these factors modify the access and action of the silt-bearing tides, so that the marshes develop at different rates.

Again, owing to changes in the direction or the strength of tidal

currents an old salt marsh in a relatively advanced stage of development is often eroded, so that a vertical cliff is formed with a mature marsh community on the top and soft mud deposited at its foot. This last is often recolonised by pioneer communities. Similar phenomena are seen on the edges of creeks in which erosion is taking place. Thus any considerable extent of salt marsh shows a complex structure and requires to be interpreted in detail.

It will be obvious from what has been written that the study of salt marsh vegetation is both interesting and instructive, because it shows very clearly the physiographic and vegetational effects of active dynamic factors. Where it is easily accessible it is eminently well adapted for school work. Transects should be laid down across successive zones. The lower zones and the soft mud of the drainage channels and creeks are of course wet and often treacherous and have to be approached with discretion, but the upper levels are commonly dry for long periods during neap tides and quite easy to work upon. Salt marsh should also be visited during the flow and the ebb of a high spring tide—an exciting and very instructive experience from which much can be learned by direct observation about the silting and erosion of a marsh by the tide.

Chapter XII

SAND DUNE AND SHINGLE BEACH

THE other principal "maritime" plant formation is that composed of the communities inhabiting sand dunes. Unlike salt-marsh plants the sand dune plants are not halophytes, except those which grow on the actual shore line where they are exposed to much salt spray and occasional inundations by the highest tides. Communities similar to those of the British coastal dunes, and even some of the same species, grow on the sand dunes which form on the edges of big inland freshwater lakes in other countries, e.g. the Great Lakes of North America, and there are plants of similar life-form on continental sand dunes of arid regions. The common factor of these habitats is, in fact, mobile wind-driven sand, and to this the dominant plants inhabiting the chief masses of mobile sand throughout the world are adapted.

In practically all the British coastal sand dune complexes the main mass of the dunes is dominated by the marram-grass (*Ammophila arenaria*). This plant, owing to its power of growing through loose sand in which it has been buried, and to its richly ramified system of underground shoots and roots, which penetrate the sand in all directions, is conspicuously well adapted to surviving in and fixing masses of blowing sand, provided of course this is not piled on top of the plants too rapidly and in overwhelming quantity When the marram has grown up through the sand deposited upon it the great bunches of long narrow dark green leaves are able to arrest fresh sand brought by the wind. Through this the plant grows up again, and a gradual rise of dunes or sand hills of considerable height is thus brought about. On the cut vertical face of such a high dune bared by violent wind erosion and carrying living marram on the surface, the sand is seen to be penetrated from base to summit by the underground shoot systems of the grass. The lower systems gradually die, but their skeletons hold the sand in a compacted state.

Though the marram can thus fix the main bulk of blown sand by rooting in the constantly damp sand just below the surface, it cannot fix the air-dry surface sand, which remains loose and liable to removal by the wind. Thus unless there is a constant supply of fresh sand the underlying layers will be attacked and

dried by the wind when the loose cover has gone, and the dune will be eroded and finally destroyed.

The loose surface sand between the tufts of marram may remain quite bare; but with a little shelter, especially during periods of wet weather, it may be colonised by a variety of species, some of which, such as the sand fescue (*Festuca rubra*, var. *arenaria*) and the sand sedge (*Carex arenaria*), have creeping stems running just below the surface, and are able to fix the sand, at least partially. Definitive fixation is however carried out on the sheltered side of the seaward range of dunes, mainly by mosses, later reinforced by lichens, which cover the soil with a continuous carpet. Lichens often become dominant on the fixed dunes, and it is species belonging to the genus *Cladonia*, and sometimes *Cetraria*, that give the name of "grey dunes" to many fixed sand hills in contrast to the "white" or "yellow" dunes dominated by the marram grass and so called from the bare white or yellow sand between the scattered tufts of marram.

The marram usually persists in the fixed dunes for a long time, but the plants become dingy and impoverished and eventually disappear, since for luxuriant growth they depend on constant supplies of fresh windblown sand. A number of other species of flowering plants appear in the moss and lichen carpets and on the small patches of bare but stable sand not as yet overgrown. Among these are small "ephemerals", tiny annual plants which vegetate and flower in the spring while the soil is still damp from winter rains, but dry up and disappear during the summer.

The ultimate vegetation of fixed dunes varies according to different conditions of climate and exposure, and especially according to the use to which the dune area is put. Sometimes "grass heath" is established, sometimes ling heath (Callunetum), and sometimes shrubs establish themselves in quantity, forming thickets of scrub, in which the grey, mealy-leaved sea buckthorn (*Hippophäe*) is dominant on parts of the east coast. Naturally established trees are rarely found on our coastal dunes, and natural forest does not develop on sand dunes in these islands as it does in other parts of the world. This is largely because of the paucity of adequate seed parents near the coast. The commonest uses of fixed dunes are as rabbit warren or as golf links, more rarely as sheep or cattle pasture; and all these favour the establishment and maintenance of a grass vegetation, which, because of the sandy soil, usually takes the form of grass heath.

Where dunes overlie an impermeable soil, water collects in the low-lying areas between the dune ridges and forms pools or marshes, known as "slacks." These contain an ordinary fresh-water or marsh vegetation. On parts of the west coast of England the creeping willow (*Salix repens*) establishes itself in the slacks, and the shoots capture sand blowing across the slack and build up quite considerable dunes capped by living willow which has grown up through the sand, just as most dunes are capped by marram.

On the seaward side of the main dune ridges dominated by marram grass there are often low dunes ("foredunes") dominated by the sea couch-grass (*Agropyron junceum*). This grass has a similar habit to the marram and is even superior in its powers of burrowing into shingly sand, though its powers of dune building are much less. *Agropyron* is also able to stand fairly prolonged immersion in salt water (which marram cannot survive), so that it can grow below the line where it is reached by the high spring tides.

At the foot of the foredunes we often find a sparsely scattered foreshore community of annual halophytes, among which the saltwort (*Salsola*), the sea-rocket (*Cakile*), the sea sandwort (*Honckenya peploides*) and species of *Atriplex* are the commonest plants. *Honckenya* has creeping shoots and is able to form miniature dunes.

From this very brief outline description of dune vegetation it will be seen that it shows a well-marked zonation, and this, as in salt marsh, largely represents a succession of communities as the habitat changes from the halophytic conditions of the shore line through the accretion of blown sand which is gradually fixed, to the non-maritime conditions which allow the establishment of grassland, heath or scrub.

Besides the formative processes involved in the primary succession—the accretion of sand and progressive occupation by plants —many cases of "retrogression" due to erosion by wind of dunes already formed will be encountered. "Blow-outs", i.e. hollows of various sizes excavated by wind, are common, and "rejuvenation" of dunes by the accumulation of fresh sand in such hollows and its reoccupation by marram, etc., are often seen.

There is probably no more suitable vegetation for school work, and none more interesting and instructive, than the sand dune formation. Where it is easily accessible it should certainly take

a high place in the attention of teachers, for here the effects of the interaction of wind, sand and vegetation are unmistakably clear. The succession of plant communities can readily be traced, transects across the zones are easy to lay out, soil and root systems are easy to investigate.

Shingle beach vegetation is closely related to that of sand dunes; where the shingle is much mixed with sand most of the species are the same, and dunes are often developed on the top of old shingle beaches. Marram grass is however absent or very local, since it depends for its success on blowing sand. Certain species, such as sea campion (*Silene maritima*) and a dock (*Rumex crispus*, var. *trigranulatus*), as well as (locally, as on Chesil Beach in Dorsetshire) the rare sea pea (*Lathyrus maritimus*), are particularly conspicuous on stabilised shingle beaches.

The dynamics of coastal shingle are of course very different from those of blown sand, and afford an equally interesting study in dynamic physical geography. Our knowledge of shingle beaches, their formation, development and vegetation, has been built up almost entirely in England (see *The British Islands and their Vegetation*, Chapter XLII, pp. 868–94). But since they are far less extensively developed than sand dunes only a few schools within easy reach of parts of the south and east coasts of England will be able to use shingle beaches for practical study.

Chapter XIII

WEEDS OF ARABLE LAND

IN regions of close cultivation, where examples of natural and semi-natural vegetation are few and far between, recourse may be had to the study of the weeds of the ploughland, which forms a very good subject for school work. The factors determining the species of weeds occurring in any arable field are partly soil (and climate) and partly the particular crops cultivated and the methods of cultivation. It is not in fact possible to divorce the study of arable weeds from a knowledge of cropping and cultivation, and information, as full as possible, must be obtained from the farmers about the history and treatment of the land it is proposed to work upon. An example of such effects may be cited from a study made by one of us on the weeds of arable wheatland established on an old drained peat moss. One part of a field was found to have a somewhat different list of weeds from the rest and the species common to the whole field showed different frequencies in this portion, which was also more fertile. On enquiry it was found to have been reclaimed and cultivated many years before the remainder and to have been heavily "marled" from pits dug in neighbouring glacial clay. This treatment had greatly modified the original peat soil and thus affected both the crops and the weed flora.

Some weeds are almost ubiquitous on a wide range of soils, e.g. chickweed, groundsel, shepherd's purse, annual meadow grass (*Poa annua*), and these are all annuals. Others are good "indicators" of the soil on which they grow, just as are many of the plants found in particular types of woodland or grassland. Thus abundance of sheep's sorrel (*Rumex acetosella*) and of spurrey (*Spergula arvensis*) nearly always means that the soil is light and deficient in lime. Other weeds indicate abundance of lime, heavy soil, wet soil, etc.

Annual weeds depend for their distribution entirely on seed dispersal, and if they are destroyed before they flower cannot propagate themselves; but the seeds of many (e.g. charlock) can lie dormant in the soil for long periods, and when turned up by the plough will germinate and produce a new crop of weeds. Most soils contain great numbers of dormant buried seeds.

Perennial weeds, especially those with deep-seated rhizomes, present other problems to the farmer, because they constantly spread by the growth of these underground shoots besides dispersing themselves by seed. Hoeing will destroy the annuals and the leafy shoots of the perennials, while nothing but deep ploughing and collection or drying out of the exposed rhizomes will eradicate such plants as couch-grass or "twitch" (*Agropyron repens*)[1] or field thistle (*Cirsium arvense*). And if broken pieces of rhizome remain in the soil they will shoot again and produce new plants. The practical effect is that these species are rarely exterminated where they have once taken hold, though they can be kept down. Exactly the same weed problems confront the gardener, though in a garden weeds are more effectively controlled by the more intensive cultivation.

The larger weeds, which are also markedly gregarious, such as field thistle (perennial) and charlock (*Sinapis arvensis*) (annual) do immense harm to crops. In different cases it has been estimated that they have reduced the crop by something between a quarter and a half. Agriculture has indeed been called "a perpetual controversy with weeds."

R. Lloyd Praeger's *Weeds* (Camb. Univ. Press), may be recommended as an elementary book containing much useful information, and W. E. Brenchley's *Weeds of the Farmland* (Longmans, Green & Co.), is a standard work.

The common weeds of arable land are rarely found in established natural or semi-natural communities in this country, and the question "where did they come from originally?" naturally arises. They are really "pioneer plants" on bare soil, and several have spread from drier climates, e.g. the Mediterranean region, where they formed "open" communities belonging to early phases of various successions, or on dry soils unable to support closed vegetation. Some were originally sea-shore plants.

Weeds may be studied in many different ways. Lists should be made at different times of year of the species found in an arable field chosen for investigation. The frequencies of the different species are best recorded by counting the individuals of each present in several plots taken at random, and averaging. A *general* survey of the weeds in several fields can be made by walking over them between the rows of the sown crop and listing

[1] Forms of fiorin (*Agrostis stolonifera*) and also wood soft-grass (*Holcus mollis*) are sometimes called "twitch".

the weed species with their relative frequencies, just as in a primary survey of a natural plant community. A sample of surface soil from a measured area (say a square foot to the depth of an inch) may be removed in winter, spread out in the school laboratory or other convenient place, kept moist, and the seedlings appearing counted. Another sample can be kept in a pot or box and the seedlings appearing allowed to grow up till the species can be identified. In such ways, and others which will readily suggest themselves, much can be learned about weeds and their ways. It is scarcely necessary to say that the goodwill of the farmer must be obtained and nothing must be done in his fields without his express permission.

Weeds of arable land include any plant growing upon it other than the sown crop, for all such plants, in various degrees, compete with the crop plants and diminish their power of development. But different species of weed injure the crops with which they compete to very different extents, depending upon their size, height, rooting depths, and the numbers of individuals present. Large bulky plants tend to choke out the neighbouring crop plants by actually occupying the space above ground, and tall weeds cut off light from the young crop. Weeds which root at the same level in the soil actively compete with the crop plants for water and mineral food, while if they root at different depths the primary incidence of competition is between the shoots—as with poppies in a wheat crop. Isolated weeds do little harm, but where their numbers approach those of the plants forming the crop they are highly injurious.

The ubiquitous and abundant weeds are a select group of plants which are able to grow on a wide range of soils and are so well equipped for holding their ground and reproducing their kind that methods of combating them are never more than partially successful. The perennial weeds of this class maintain their hold primarily by their subterranean organs such as rhizomes, underground runners and tubers which are capable of free growth and vegetative reproduction and cannot be exterminated without deep cultivation of the ground and collection of the propagating organs, and this is impossible while the crop is growing. A field badly infested with such weeds has to be fallowed and weeded while the ground is bare, though something can be done in a rootcrop by deep hoeing between the rows. Ubiquitous annual weeds can of course be destroyed by surface cultivation, but

those which flower and set seed at all times of the year when the weather is suitable are again impossible to exterminate because seeds are always present in the soil. Chickweed, groundsel and the annual speedwells are good examples. These small low-growing annuals however certainly do much less harm to crops than the large annuals such as charlock and poppies, and perennials like the docks and thistles.

Rotation of crops helps very much in the war against weeds because the different natures of the crops grown in a cycle present varied conditions inimical to the weeds (Brenchley). Thus in the standard four-course rotation—barley, "seeds" (clover or similar plants), wheat, roots—the thick growth of young barley keeps down weeds, while the clover with which it is also sown remains after the barley is cut, and in the second year its thick leafage continues to suppress the weeds. If these crops have been good the weeds are not bad when wheat is sown in the autumn of the second year, but now they arrive in quantity and cannot be effectively attacked till after the wheat crop is harvested, so that the wheaten stubble in August of the third year may be a veritable flower garden of weeds. The root crop of the fourth year gives an opportunity of thoroughly cleaning the ground.

POSTSCRIPT

It has been emphasised in Chapter II that plant ecology, at least so far as it concerns the school, is not so much a "subject" with "periods" or "half-periods" allotted to it in the time-table—a subject, so to speak, begun in September and finished in July—as a method of approach to the study of plants, a way of looking at them as members of plant communities forming vegetation. Ecology should never be divorced in teaching from the actual study of plants, their structure, development and functions, but the relative importance of their various characters must be interpreted from the ecological point of view; and the actual parts they play in vegetation, their vegetative habits of growth and powers of reproduction, are of more importance than the morphological characters which separate species and genera.

In saying this we are as far as possible from wishing to advocate superficial generalisations which sometimes masquerade as "ecology", to defend such practices, still too common, as describing in the classroom so-called "adaptations" of plants, teaching for example that a whole series of structural features are "protective" without attempting to find out what they "protect" against or whether they are actually effective against particular inimical factors; or again, the practice of classifying plants into xerophytes, mesophytes and hydrophytes and leaving it at that; above all the insistence upon finding, at all costs, a "use" for every part and every feature of a plant. This kind of teaching is most mischievous, for it quite literally corrupts (scientifically) the minds of pupils by substituting facile and largely inaccurate generalisations for observation of nature and sound reasoning. It is "all too human" a tendency to find a "use" for everything and to put things into mental pigeonholes and leave them there as finished with. The correction of such bad mental habits should be the first function of the teaching of science, and especially of biology, in schools. Of course it is true that most of the parts and organs of plants and animals *have* "uses" and that they are, for the most part, excellently "adapted" to their conditions of existence. Indeed the process of evolution has consisted largely in the organisation and elaboration of adaptive mechanisms. And we need not deny that pigeonholes are admirable temporary conveniences provided we do not take pigeonholing as an end in itself.

But what we want to aim at is first of all to observe the facts of nature as they are, and then to find out how they came to be so and not otherwise.

The ecological outlook (using the term ecology in its widest sense as including human ecology) has had a profound effect on the study of geography, and, largely through the influence of the Geographical Association, on the teaching of geography in the schools of this country. This teaching has passed from an early stage of memorising geographical facts, through an intermediate stage when the branches of geography (descriptive, physical, economic, etc.) were taught separately, to the unified study which it is to-day. So much progress cannot be conceded to the teaching of science at large, which is still taught mainly as separate branches, i.e. the teacher is not teaching science but chemistry, physics or biology. In chemistry and physics especially, which, as school subjects, are older than biology, this teaching has reached a high standard; but *for the average boy* it may be questioned whether these specialised subjects have as great an educational value as a properly designed and unified course in *science.*

A recent writer has remarked:[1] "It is unfortunately still true that the great majority of secondary school pupils leave school ignorant of many of the common facts of modern science. If they are classical pupils they may be entirely ignorant. If they are science pupils they often have only an elementary specialist knowledge of two science subjects, usually chemistry and physics."

The introduction of "Nature Study" was an early attempt to broaden the basis of science teaching without impairing the teaching of chemistry and physics already established: the introduction of "General Science" which is now taking place is a more far-reaching attempt to do the same thing for somewhat older pupils. The teaching of General Science to all pupils in the preliminary stages of the secondary school course should raise the cultural level of education in the school, should greatly benefit the *average* pupil and tend to check over-specialisation in the upper school, not only in science but in all subjects; and should thus also avoid encroachment on advanced work that properly belongs to the university.

These remarks on "General Science" have been introduced because the subject has a close analogy with Geography taught with an ecological bias, and the proper relation of the two

demands careful consideration. Since ecological geography involves an elementary knowledge of biology and of the physical and chemical processes at work in the action of climate and soil on plants and animals, and *vice versa*, and since it has close relations with Geology also, it would be quite possible to frame a General Science course with a geographical and ecological bias. Such an experiment would be well worth making. Though it is essential to a good General Science course that the teaching should be unified, any attempt at standardisation should be avoided. It is important that it should vary according to the bias of the school and to some extent according to the gifts and knowledge of the teaching personnel available. One type of General Science course might well be based on ecological geography, the early part being devoted to simple physical, chemical and biological facts taught in the closest relationship, and leading up naturally to a study of the earth's surface and its inhabitants, with the home region as an example. In a school where such a course was established considerably more time could be given to it, and it would in fact become one of the most important parts of the curriculum.

In other schools, where it was desired to go more deeply into physics and chemistry, or alternatively into biology, in the General Science course, the geography teaching would be separate, but would supplement the General Science course; for close co-ordination between the two and active co-operation between the teachers should always be maintained. Work on Geology and Astronomy, if materials from these subjects were used in the General Science course, could often best be carried out in a well-equipped geography room by the teacher of geography.

In the development of General Science teaching one important lesson can be learned from the mistakes of the early teaching of geography, before the true value of the study had been realised. The subject was often relegated to the "failures" in specialised science or to the "General Knowledge" man (or woman), in the belief that "anybody could teach geography" with resulting inefficiency and greatly retarded progress. General Science will need the full-time attention of the *best* of the science teachers and we venture the opinion that it will be harder, though much more interesting, to teach effectively than the specialised sciences.

Whether used as the framework of a General Science course

or taught separately with an ecological bias, geography holds, or should hold, a key position in the school, for through ecology it has close linkages with physical and biological science on one side, and on the other, through history, with human culture and the humanities.

The teaching of ecological geography should retain the best features of the best "nature study" teaching. These are spontaneity, general lack of school conventions, and the intense interest often aroused in the pupils. This is of vital importance to the teacher: with it teaching becomes a pleasure, without it the work may easily degenerate into mere drudgery. On the teacher's power to create such lively interest hangs, to a large extent, the success or failure of his undertaking. It would seem that the possession of this power, together with the ability to make things clear to others, is the attribute of the "born teacher". In the study of the local area, much of which has often to be done in spare time, the teacher's real interest in nature is indispensable. The local area must be a playground as well as a working ground. Pupils have been known to give up much of their leisure to help in the completion of a local survey, simply because they wanted to. Others, interested in farming, have made surveys of the weeds of arable land on the home farms. Others again have bought one-inch ordnance maps of a district to be visited during holidays, and have returned with notes.

In one or another of such ways real interest in the countryside may lead, and has led, to spontaneous simple research work on the part both of pupils and teachers. Though the teacher, if he is to be really efficient, must of necessity devote by far the greater part of his time to his profession, he will do well to take a genuine interest not only in the choice of his material but also in its making, though he usually has very little time for creative work of this nature. Yet it can be said with truth that teachers in both secondary and elementary schools (leaving aside university teachers, from whom research is expected) have contributed in no small degree to the advancement of knowledge. For the teacher of geography such work will not only be of value in itself, but the doing of it will have a broadening effect on his teaching and on his pupils. If carried out (in the laboratory or in the field) where the pupils can see it in progress, it often stimulates them to help, or to "go and do likewise". Full-time research workers have put it on record that they owed their first impulse towards research

to the example of a teacher, and the effect on the rank and file of the pupils cannot but be good.

Elaborate and systematic research is of course beyond the province of school work as such, whatever benefits may come from spare-time original investigations by teachers or pupils, but the most successful teachers are always of the "pioneering" as contrasted with the "official" type of mind. There is room for both in our system of education but the latter is at his best *outside* the school. Freedom from officialism is essential to the school, and if the teacher is adventurous, but not too much of a rebel to adapt himself in the main to our established system of education, he is the salt of the earth in the school. Different types of school with freedom to experiment in the approach to an ideal system of education, though sometimes inconvenient to officialism, are essential to vital progress, and with generous goodwill they are quite possible within the system of secondary schools governed by local authorities, the establishment of which marked an important step forward in our national education.

Finally a word may be said about examinations and text books. Undue interference with the curriculum by outside bodies, over-emphasis on the results of examinations by prospective employers of the pupils, and especially teaching expressly *for* examinations and examination results—all these have a pernicious effect on a school. The function of the school is to educate, and public examinations should be elastically adapted to good teaching, not teaching to the examinations. If this principle is adhered to—and genuine efforts in that direction are now made—there should be no qualms about examination results in schools where the teaching is good of its kind. Some science teachers have no use for text-books in the early stages of school work: the pupils are encouraged to build up their own. But for most teachers text-books are implements necessary to their work: it is the misuse of text-books, e.g. slavish adherence to the text and to the order of presentation, that is harmful, because it destroys the freedom and elasticity which are the essence of good teaching.

In this little book we have called attention to the important part that the study of natural and semi-natural vegetation can play in connexion with the teaching of science and geography in secondary schools. It is hoped that enough has been written about the materials and methods of this study to be of real use to

teachers who may share our belief in its interest and educational value.

The study of vegetation in the field brings biology into touch with the actual life of plants both when they are undisturbed by man and when they are subject to his control, and the life of plants under these two conditions forms much of the background of human existence. For this reason also ecology forms an essential part of that study of the "local area" which is the secure basis of practical geographical teaching.

We do not for a moment suppose that all schools—or even all country schools—will be able to undertake the whole of the work suggested, but we have tried to place the possibilities before teachers. In this postscript we have touched on the relation of ecology to the recent proposals for the general introduction of courses in "General Science", proposals which we believe are of great importance for the future education of the citizen, and have indicated how such courses can be combined with the study of modern geography which has rightly attained a dominant position in the modern school. Into this framework we believe ecology should be fitted, because it is a framework which provides a basis for education in man's relation to nature, to his home region, to his country and to the world in which he lives.

INDEX

acid soils, 40
Adamson R. S., 47
aeration, 71
aestival (summer) aspect, 22
agricultural soils, 39
agriculture, 7
air humidity, 55
alkaline soils, 40
American oaks, 43
annual meadowgrass, 83
  speedwells, 86
  weeds, 83, 85
aquatic vegetation, 19
arable crops, 18
  land, 16, 29, 30, 33, 39, 45
  weeds, 30, 45
arctic-alpine vegetation, 18, 21
Armstrong, 59
artificial habitats, 31
  plant communities, 32, 42
arum, 50
ash, 47, 51
ash-oakwood, 21
ashwood, 21, 51, 53
aspen, 47
association, 21
Astronomy, 89
atmometer, 55
autumnal aspect, 22

bacteria (soil), 41
barley, 86
base-status, 41
bearberry, 67
beech, 19, 43, 44, 50, 53, 55, 64, 66
beechwood, 19, 21, 43
Bell-heather, 19, 65
bent, common, 60, 61, 66
bilberry, 51, 61, 64, 65, 66
Biology, 27
biotic climax, 25
  factors, 16, 17, 25, 37
birch, 43, 50, 53, 55, 64, 66
  forest, 21
Birks Wood, **47–51** (Figs. 1–4)
bittersweet, 57
blackthorn, 53, 56, 57
blow-out, 81
blowing sand, 79
blown sand, 24
bluebell, 22, 46, 50, 51
bog, 16, 73, 74
  asphodel, 66, 73
  formation, 21, 74
  moss, 61, 64, 73
  myrtle, 66
  peat, 40, 73
boulder clay, 47
Botany, 27, 29, 30
bracken, 45, 46, 47, 50, 51, 53, 61, 62, 66
bramble, 45, 46, 56, 57, 60
Brenchley, W. E., 84, 86
British Museum (Nat. Hist.), 35
brome-grass, erect, 61
broom, 66
brown earths, 39, 40, 55
bulrush, 19
bur-reed, 68
buttercups, 71

calcareous loam, 51
  soil, 53
calcium, 40
  carbonate, 40
  exchangeable, 40, 41
California, 20
Canadian waterweed, 68
canals, 68
canopy (tree), 20, 44, 55
  close, 44, 45
  open, 44, 47
Cape Peninsula, 20
"casuals," 57
cattle, 41, 60
Central Irish plain, 74
chalk, 43
chalk downs, 18, 19, 25, 29, 60
charlock, 83, 84, 86
Chemistry and Physics, 88, 89
Cheshire Plain, 29
Chesil Beach, 82
chickweed, 83, 86
Chile, 20
Clarke, G. R., 38
Clarke, Dr. Lilian, 31, 32
clay, 39, 43
clay-humus complex, 40
clay-loam, 50
climate, **15**
climatic factors, 15, 17
climax vegetation, 23, 24, 25
closed communities, 20
clover, 86
cocksfoot, 60
common land, 33
competition (of weeds), 85
conifers, 44, 50
conservation of nature, 7
consociation, **21**
Cook, Ivimey, 9
coppice, 44
coppicing, 45, 54
cottongrass, 61, 73
couch-grass, 84

crab apple, 44
creeks (in salt marsh), 77, 78
creeping willow, 81
critical level (in salt marsh), 76
cross-leaved heath, 66, 73
crowberry, 67
crown (of a tree), 20
Croydon and District. Regional Atlas of, 11
cuckoo-pint, 50, 51

daisy, 63
dandelion, 63
deciduous summer forest, 21
  trees, 20
  woods, 22
deer, 18
  forests, 34
deergrass, 61
ditches, 57
dock, 86
  sea, 82
dog's mercury, 22, 45, 46, 47, 50, 51, 53
dogwood, 44, 57
dominance, **19**
dominant trees, 44
dormant seeds, 83
drainage, 74
  channels (in salt marsh), 77
drift map (geological), 38
drought (in salt marsh), 75, 76
duckweed, 71

East Anglian Fenland, 74
Ecological Geography, 89, 90
Ecology, 12, 32, 92
  Plant, 13, 27
edaphic factors, 17, 37
elder, 53
ephemerals, 80
equatorial rain-forest, 20
erosion, 78, 81
evaporimeter, 55
"exacting" plants, 41, 50, 73
examinations, 91
exchangeable bases, 40, 50 n.
exposure meter, 55
Fagg, C. C., 11
farming, 7
felling, clear, 54
  selective, 54
fen, 16, 73, 74
  and marsh formation, 21
Fenland, 29
fescue, meadow 60
  red, 61
  sheep's, 60, 61, 66
field experiments, 8, 9
  layer, 20, 42, 45, 46
  maple, 47
  thistle, 84
field work, 7, 8, 28, 32
fiorin, 84 n.
fixation of dunes, 59, 80
fixed dunes, 80
floating leaf community, 68, 71
flora, 13, 28
Flora, 35
foredunes, 81
Forestry Commission, 17
frequencies, 36
freshwater vegetation, 21, **68–72**
frogbit, 72
fungi, 22, 35

Gamlingay Wood, 47, 50
garden soil, 39
"General knowledge" teacher, 89
General Science, 88, 89, 92
Geographical Association, 88
Geographical teaching, 92
Geography, 8, 11, 27, 88, 89, 90
  ecological, 89, 90
  local, 8, 11, 28
  regional, 7, 13
Geography, 13
Geology, 89
glacial drift, 51
glasswort, 75
Glyceria maritima, 76
golf links, 80
gorse, 22, 53, 56, 61, 66
  dwarf, 66
grass heath, 18, 67, 80
  verges, 54
grassland, 16, **59–63**
  bent-fescue, 61, 67
  calcareous, 61
  siliceous, 61
grazing, 18
  animals, 16, 41, 55, 59, 60
  factor, 16, 41
  regime, 60
Great Lakes of North America, 79
grey dunes, 80
ground layer, 20, 45
groundsel, 86
grouse, 18
guelder rose, 44, 47, 53, 57

habitat, 15, 37
hair-grass, tufted, 47
  wavy, 50, 51, 65
halophytes, 75
halosere, 77
hawthorn, 53, 56, 57, 60
hay, 59
hayfield, 59
hazel, 22, 44, 47, 53, 57
heath, 16, 18, 19, 29, 33, 39, **64–7**, 74
  bedstraw, 51
  family, 64
  formation, 21

heather, 74
  moor, 64
heavy clay, 42, 43
hedgebanks, 57
hedgerows, 56–7
hiemal (winter) aspect, 22
holiday camps, 8, 30, 31
holly, 44
honeysuckle, 57
horse chestnut, 43
horsetails, 68
humus, 40, 50
Hutchings, G. E., 11
hydrosere, 24, 77

indifferent species, 19
ivy, 53, 57

Kew (Royal Botanic Gardens), 35

lake, 74
  floor, 69
Land Utilization Survey, 17
larch, 43
lawns, 31, **62–3**
Leach, W., 38
lesser celandine, 22, 53
ley, 18
lichen, 35, 65, 80
life forms, 20
light intensity, 55
limestone, 43
  soil, 39, 40
ling, 19, 21, 51, 61, 64, 65, 80
liverworts, 45, 53
loam, 39, 43
local area, 27, 28
  climate, 15
  geography, 33
lower salt marsh, 77
lowland heath, 64

McLean, R. C., 9
"made" soil, 39
manuring, 62, 63
"marginal" (wood edge) plants, 54, 56
marine vegetation, 21
maritime formations, 21
marram grass, 21, 79, 80, 82
marsh, 16, 33, 34, 69, 73, 74
  community, 68, 73, 74
  marigold, 53
  samphire, 75
matgrass, 61
meadow fescue, 60
  saffron, 22
  -sweet, 47, 53
  soils, 39
Mediterranean, 20, 84
mice, 41
microclimate, 15
middle salt marsh, 76
mineral particles, 40, 51
moorland, 18, 33
moorpan, 65
moors, 39
mosses, 20, 35, 45, 80
mountain ash, 44
mountainous country, 34

National Parks, 7
Nature Reserves, 7
Nature Study, 88, 90
natural and semi-natural vegetation, 91
natural region, 29
Northern Coniferous Forest, 21

oak, 19, 43, 44, 47, 50, 53, 55, 64, 66
oak-hazel wood, 43, 44, 45
oakwood, 19, 20, 21, 42, 43, 46
Obione, 76
officialism, 91
open communities, 84
organic soil, 39
over-specialisation, 88
oxygen, 71, 73

*p*H value, 40
partial habitat, 20, 55
peat, 39, 64, 73
  bog–, 40, 73
  fen–, 73
Pedology, 38
Pennine Range, 29
percentage composition, 37
  occurrences, 36
Percival, J, 59
perennial rye-grass, 60
  weeds, 84, 85
permanent grass, 17, 18, 29
  pasture, 16, 17, 18, 41, 59
petty whin, 66
pheasant shooting, 34
pheasants, 43
photo-electric cell, 55
physiographic features, 15
pine, 55, 64, 66
  forest, 21
pioneer plants, 84
plant communities, 13, 14, **19**
  formation, **20**
plantain, 63
plantations, 17, 29
podsols, 39, 40, 55, 65
ponds, 33, 64, 68, 69, 74
pondweed, 68
  floating, 68
Poole Harbour, 76
poppies, 85, 86
Praeger, R. Lloyd, 84
prevernal aspect, 22
Price Evans, E., 51

primrose, 22, 45, 46, 51
privet, 57
profile transect, 69
protozoa (soil), 41
purple moorgrass, 61, 66

quickset hedge, 56

rabbit warren, 80
rabbits, 16, 41, 50, 55, 60
ramsons, 53
red campion, 22
reed, common, 68, 73
reedswamp, 19, 68, 71, 73
regional survey, 8, 11, 14
rendzina, 39, 55
research work, 90, 91
rice grass, 76
river alluvium, 23
Robinson, G. W., 38
root crops, 86
rose, 53, 56, 57, 60
rosette plants, 63
rotation of crops, 86
rough grazing, 16, 18, 33, 39, 41, 60
rush family, 73
rushes, 61
Russell, Sir John, 39
Ryhope Dene, 29, 30, **51–3**, (Figs. 5–8)

sallow, 57
salt marsh, 19, 21, 33, **75–8**
saltwort, 81
sand, 39, 43, 75
sand dune, 19, 21, 33, **79–82**
sand fescue, 80
  sedge, 80
sandy loam, 42, 47, 50
  salt marsh, 77
  soils, 43
sanicle, 45, 46, 51
school garden, 31
School Science Review, 29, 51, 62
science teaching, 87
sclerophylls, 20
Scottish Highlands, 34
scrub, 18, **56**
  thicket, 56
  woodland, 56
sea aster, 76
  blite, 76
  buckthorn, 80
  campion, 82
  cliffs, 33
  couch-grass, 81
  dock, 82
  lavender, 76
  meadow, 77
  milkwort, 77
  pea, 82
  pink, 76
sea plantain, 77
  rocket, 81
  sandwort, 81
  spurrey, 77
seasonal aspects, 22, **45–6**
  phases, 29
sedge family, 61, 68, 73
sedge, white beaked, 73
seed mixtures, 16, 18
selective felling, 17
semi-natural vegetation, **17–19**
  woodland, 29, 33, 42
sere, 24
sheep, 41
sheep's fescue, 60, 61, 66
  sorrel, 83
shepherd's purse, 83
shingle beach, 19, **82**
  spit, 77
shrub layer, 20, 42, 44
silt, 39, 69, 75, 77
silting, 73, 74, 77, 78
"slacks" (in dunes), 81
slow rivers, 68, 69, 74
Smith, Robert, 13
  William G., 13
snowdrop, 22
society, **21**, 37, 46, 50, 59
soil, 16, **37–41**
  aeration, 16
  algae, 41
  animals, 41
  bacteria, 41
  flora and fauna, 41
  horizons, 38
  profile, 38
  stratification, 38
  water content, 16
soils, natural, **38–9**
South Australia, 29
Southampton Water, 76
species, naming of, 35
specimens, 36
spindle, 57
spiny shrubs, 60
spring tides, 75, 78
spruce, 43
spurrey, 83
Stamp, L. Dudley, 17
strata of vegetation, 44, 45
stratification of soil, 38
  of vegetation, **20**
strawberry, wild, 47
structure of vegetation, 35
  of a wood, **44–5**
submerged community, 68, 69, 71
subsere, 25
subsoil, 38
succession, 69, 81
  primary, 23
  secondary, 24

sundew, 66, 73
sweet chestnut, 43
sweet vernal grass, 47
sycamore, 43, 50, 51, 53
synecology, 13

Tansley, A. G., 9, 13
text-books, 91
thistles, 86
thrift, 76
tidal belt, 75
  estuary, 33
  mud, 23, 75
  zone
tillers, 62
transect, 74, 78, 82
tree layer, **44**
turf, 62
turions, 71, 72
Turkey oak 43
twitch, 84

underplanting, 44
upland heath, 64
upper salt marsh, 76

vegetation, 13, 28
  degraded, 30
  natural, 7, 12, 14, **17–19**, 26
  semi-natural, 7, 14, 16, **17–19**, 25, 26, 30
vernal aspect, 22
voles, 41

waste land, 33
water content, 40, 46, 47
  crowfoot, 71
  milfoil, 72
  plants, 68, 71
waterlilies, 68
wayfaring tree, 47
weathering complex, 40
weeds, 17, 57, 63
  of arable land, **83–6**
Western Australia, 20
wheat, 85, 86
white clover, 60
  dunes, 80
White Moss Loch, (Fig. 9), 70
willows, 23 n.
winter aconite, 22
wood anemone, 22, 45, 46, 53
  sage, 51
  soft-grass, 47, 50, 66
Woodhead, T. W., 47, 50
woodland, 17, 18, **42–55**
  succession, 54
wych elm, 50, 53

xerosere, 24

yellow dead nettle, 22, 50
  dunes, 80
  waterlily, 68

zonation, 68, 69, 75, 77, 81

GEORGE ALLEN & UNWIN LTD
LONDON: 40 MUSEUM STREET, W.C.1
CAPE TOWN: 58-60 LONG STREET
TORONTO: 91 WELLINGTON STREET WEST
BOMBAY: 15 GRAHAM ROAD, BALLARD ESTATE
WELLINGTON, N.Z.: 8 KINGS CRESCENT, LOWER HUTT
SYDNEY, N.S.W.: BRADBURY HOUSE, 55 YORK STREET