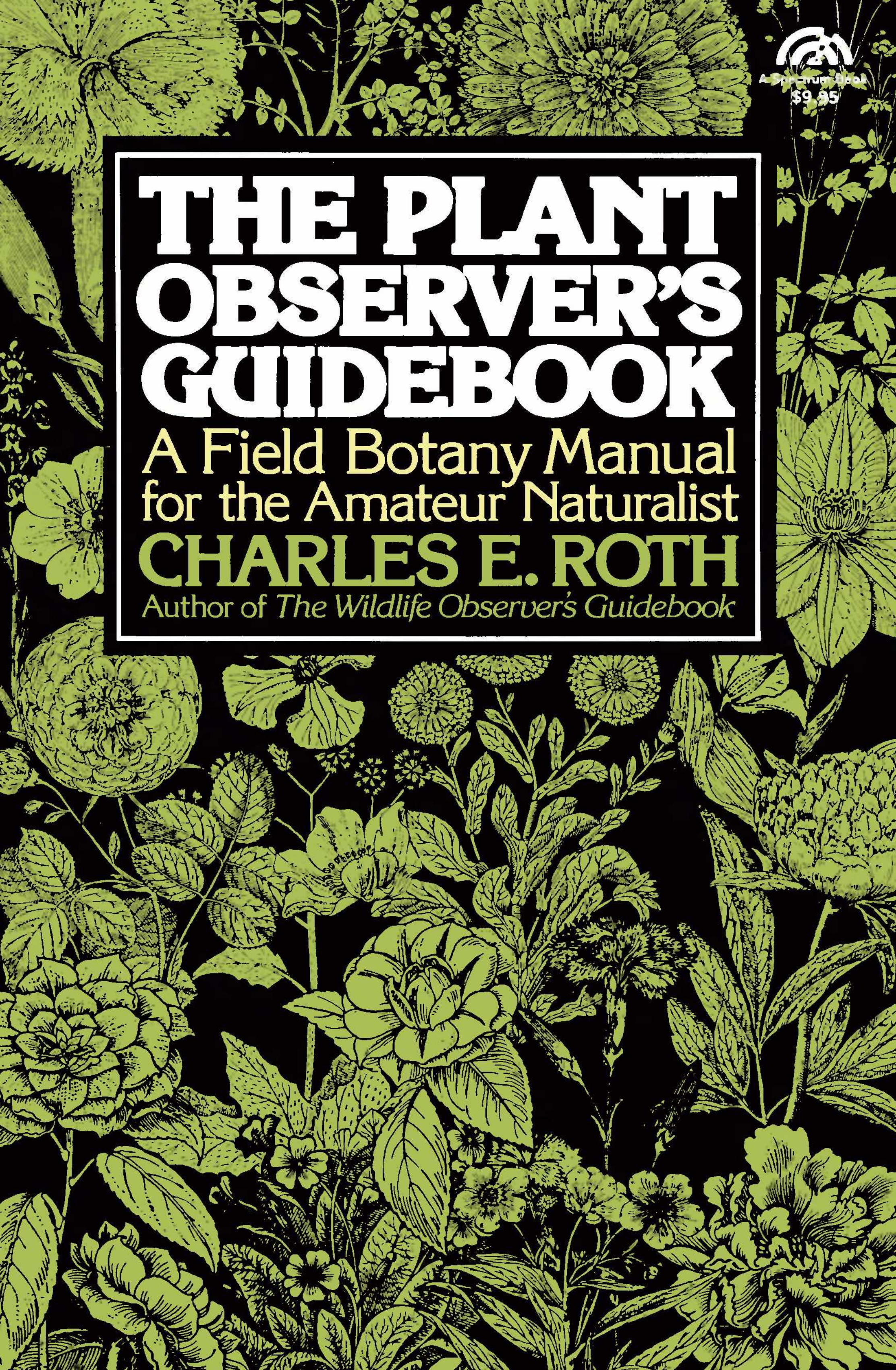

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THE PLANT OBSERVER'S GUIDEBOOK

A Field Botany Manual for the Amateur Naturalist

CHARLES E. ROTH

Author of *The Wildlife Observer's Guidebook*

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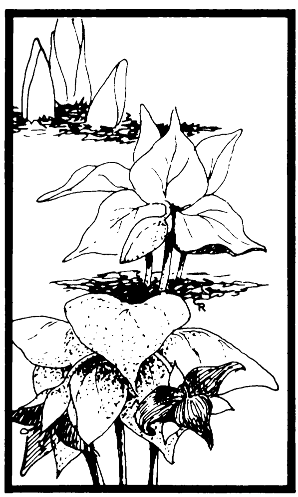

Charles E. Roth

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This volume is dedicated
to the provocative teaching
of Leonard J. Bradley,
Wendell C. Camp,
and
May Thielgaard Watt
with the sincere hope
that it may
stimulate others
as they did me.

CONTENTS

FOREWORD

Future historians will look back on the twentieth century as a period of rapid, tumultuous change in our civilization: an age characterized by explosive population growth and humanity's voracious consumption of Earth's natural resources, when a whirlwind of technological progress seemed to obscure humanity's view of its own connection to the natural world. Perhaps history will also show this to be the dawn of an era when civilized people rediscovered themselves as an integral part of the earth, when the severity of widespread habitat destruction jolted people into a renewed appreciation for the natural world.

Even now, we have yet to fully accept the plant kingdom as the foundation upon which all animal life depends: that we are a part of this intricate, fragile system, and what affects it also affects the quality of our lives and even our ability to survive. The air we breathe, the houses we live in, our meals and medications are largely derived from plant life. The potential economic and medical value of plants can hardly be imagined.

The natural world of plant life is important to humanity in ways that are often immeasurable and abstract. The human spirit is nourished by the constancy and beauty of plants throughout the seasons. The tranquility of crystal, glittering streams beneath the canopy of bountiful forests reassures us. We derive an inner peace by revering our connectedness with our natural environment. Native Americans were acutely aware of this as evidenced by the statement of Sioux Chief Standing Bear: "Kinship with all creatures of the earth, sky and water was a real and active principle. . . . The Indian knew that man's heart away from nature becomes hard; that lack of respect for living, growing things soon led to a lack of respect for humans too."

It is precisely this understanding which must become common knowledge if we are fully to appreciate and conserve the natural world. Chuck Roth effectively conveys his own feelings of curious wonder and appreciation for the cycles and behaviors of plants. His comprehensive and stimulating format guides the reader through the realm of plant studies in a most informative, enjoyable manner. With scientific clarity, the author presents an excellent overview of approaches for observing individuals, communities, relationships and survival strategies of the plant kingdom. For both novice and expert, amateur gardener and ardent botanist, the book provides guidance for observation and investigation. The author's excitement over the prospects of discovery is infectious and motivating; one cannot help but feel an eagerness to observe, experiment, and contribute new information—all essential ingredients for the greater appreciation and conservation of wild plants and ecosystems.

The degree of future conservation concerns ultimately depends upon the quality of the environmental experiences we allow ourselves and our children. It is crucial that as many of us as possible, youths and adults, become directly involved with the world of nature and acquire an ever deeper regard for it. This guide will help all who enter its pages develop the skills necessary to explore and discover the many fascinations of the world of plants which they can then transmit to others around them.

The responsibility we have to ensure our future health and happiness through conservation of natural resources, ecosystems, and wild plant life is virtually awesome. Yet we must accept this challenge with positive commitment. Bringing ourselves closer to the intricacies of plants in the natural world will be a continual source of pleasure and fascination, and our capacity for knowledge and caring will grow like the plants we observe.

DAVID LONGLAND, Horticulturist
New England Wildflower Society

PREFACE

I have a lifelong love affair with living things. When I was a child, my parents suffered through an endless series of my wild gardens and orphaned wildlife. The parade of plant and animal wildlings was eclectic, but my early preference was clearly for animals. As I grew older that preference grew stronger, and I eventually trained as a general biologist with a specialty in zoology and animal behavior.

Thus, in a way, this book is quite presumptuous: a botany book written by a zoologist. Actually, the presumptuousness is not quite as flagrant as might first appear. Years as a camp nature counselor and as an interpretive naturalist brought home the fact that it is not easy to show a group of youngsters or adults the wildlife they hope to see in the wild. In order not to have field trips be a total loss, I learned a great deal of lore about the plants that I knew would be in the areas where we were. At first, plants were primarily a convenient out in an awkward situation. In time both I and the people I had afield discovered that plants were indeed interesting in and of themselves. In time, plants began to absorb increasing amounts of my observation time as well as my interpretive time. They helped my thinking become increasingly ecological.

But it was a child, my own, who eventually led me to see the full fascination of the plant world. From the time he could toddle, plants occupied much of his interest. Where to me they had been interesting things, to him they were friends and companions. He followed their lives and development as ardently as I had pursued those of animals. A re-examination of my own attitudes toward plants indicated that I had held them at a distance largely because of the battles I had had with the formal, and formidable, language of taxonomic botany and impatience with the slow pace of action in plant lives. My son's fascination showed me that what appeared to me to be lack of activity was only the result of poor observation on my part and general lack of patience and persistence. Botanical language was only a "red herring"; it could be mastered, and much of it wasn't even necessary for satisfying exploration.

A new world began to open. All through my youth I had heard about the little green aliens from outer space. I now realized that there were indeed little green aliens, but they were from our local space station—Earth! Furthermore, it wasn't all that difficult to get to know about their needs, preferences, friends and associates, love lives, and other aspects of their private lives if only you set about it in earnest. Several fine teachers, those to whom this book is dedicated, had briefly parted the curtains to this view of the plant world in my collegiate years, but the press of living had pulled the curtains closed for a while longer. It took a child to pull them open for good.

This book is dedicated to the assumption that there are a number of people with the time and inclination to build an intimate acquaintance with that seemingly alien world of plants. For some it will remain an avocation, whereas for others it may be a stepping stone to a career in botany. For both I hope there will be a lifelong devotion to the natural world and continued determination to protect it from those who would destroy its integrity and capacity to generate and support a diversity of living things.

This book has been designed to serve the user over the period of growth from early involvement through increasing seduction by the world of plants to a level of near-professional commitment to field botany. Far more activities and studies are suggested between these covers than any one person could possibly engage in over a lifetime. It is hoped that you will sample judiciously from the smorgasbord of ideas and select your own movable feast. This book is not a volume of facts about plants but a source of tools and strategies for personal investigations into the lives of plants. It should prove to be a reliable and recurring companion and mentor through the years.

Obviously, no book of this sort could be written by a zoologist without the help of many people. The botanical literature is broad, and I have tapped it in many places and gratefully acknowledge my indebtedness to those who not only observed but shared their observations through words, photographs, and drawings. They are not individually acknowledged at each point, but the Further Readings and Bibliography sections of the book urge you to pursue their thinking directly from the sources. Dr. Richard B. Fischer helped by providing access to the Cornell University Library, and I am indebted to the New England Wildflower Society and the Massachusetts Audubon Society for access to their libraries. Massachusetts Audubon's Sue Moody was particularly helpful in tracking down many details.

For encouragement to pursue this project I must thank Dr. Norton Nickerson of Tufts University and my editor, Mary Kennan. For their patient reading of an unfolding manuscript, to keep me botanically on track, I am particularly indebted to Dr. John Brainerd, and also to Dr. Robert Zaremba, Bruce Lund, and C. Douglas Roth. Bruce Sorrie of the Massachusetts Heritage Program gave helpful advice on plant conservation. Errors that remain in the text, however, are solely my responsibility. I wish also to thank the three teachers to whom this book is dedicated along with several other people who, unwittingly, have strongly influenced my interest in the lives of plants—Dr. William Niering, Dr. William J. Jahoda, Frances Sherburne Musgrave, and Albert Bussewitz. The lovely illustrations by Mary Sage Shakespeare, a colleague of many years, speak for themselves and do much to add a simple visual dignity and grace to the volume.

Scientists don't immerse themselves in particulars only for the grandiose (or self-serving) reason that such studies may lead to important generalities. We do it for fun. The pure joy of discovery transcends import. And we do it for adventure and for expansion. . . . Any good field project provides unending stimulation so long as little puzzles remain as intensely absorbing, fascinating and frustrating as big questions. Fieldwork is not like the one hundred-thousandth essay on Shakespeare's sonnets; it always resents something truly new, not a gloss on previous commentaries.

STEPHEN JAY GOULD
"Opus 100"
Natural History, April 1983

THE PLANT OBSERVER'S GUIDEBOOK

CHAPTER 1

THE JOY OF PLANT WATCHING

From the dimmest emergence of the conscious human mind in prehistoric times, there has been an awareness of plants. Members of the simplest of human cultures have probed the plant life about them and discovered food, medicine, fiber, tools, and also sometimes incurred irritation or even death from plant poisons. As civilizations emerged, they did so borne by an agricultural revolution made possible by subtle observation and manipulation of wild plants over long periods of time. These growing civilizations added new insights to the lore of plant manipulation.

Plants are perceived by people quite differently than are animals. More similar to people, animals are often looked upon as somehow more alive, more deserving of human caring, whereas plants are considered as things, alive yes, but less animate, to be used as basic resources or to provide aesthetic pleasures at home or as landscape features.

Today, many people are interested in plants for gardens and home decorations, but far fewer are acquainted with the daily lives of our wild plant neighbors. Many who do have a nodding acquaintance with wildings generally know only those with conspicuous flowers or the common trees. At that, their knowledge is generally confined to the name and general habitat where the plant may be found.

There is much, much more to be known about the plants around us. Their lives are as complex as those of animals, although their lifeways are different and their activities often proceed at a far slower pace. It is not surprising that in our culture, with its penchant for a stepped-up pace of life, plants are perceived as rather static and boring. On the other hand, many people seek to slow down their pace, at least occasionally, and getting to know plant life on a more intimate and detailed basis provides one way to get into a more relaxed frame of mind. Indeed, learning to know more about our plant neighbors can become a source of great joy.

Plants are born, grow, mature, reproduce, grow old, and die. They compete with one another for living space and other basic resources. They have developed diverse strategies for reproducing their kind and expanding their numbers into new sites. In many cases they have coevolved with animal species to achieve survival. Beautiful as our plant neighbors are, their many adaptations to life on this planet provide an additional source of delight for those of us who gain the skills needed for exploring their lives. Using such skills, we can discover that plants are not mere objects but real beings.

This book has been designed to share some of the skills and techniques of field botanists to help you expand your familiarity with the lives of plants. Field botany can be an entrancing hobby leading you beyond the sheer fascination of learning new things about familiar objects to the uncovering of information that may contribute to knowledge. Over the years botanists and horticulturists have added extensively to our general knowledge of plants, yet details of the lives of many plant species remain vague or unrecorded. Your observations may add new chapters to the understanding of many species. Some of this information might even contribute to activities that help assure the continued survival of some threatened species.

Many people are aware that a number of animal species are threatened with extinction. Fewer realize that even more plant species are similarly threatened as the human race, increasing in numbers, alters landscapes to meet its perceived needs or desires, thus destroying plant habitats. We have only the sparsest knowledge of the specific needs for growth and reproduction of most of the threatened species. Lacking such knowledge, the chances of preserving any such species as viable wild populations become highly limited. Amateur plant watchers, discovering ever more about the life histories and habitat requirements of a wide range of species, increase the chances of more species surviving well into the future. Such survival is desirable because of plants' inherent right to pursue evolution and survival here on Earth and their potential to contribute to human comfort and survival.

This book focuses on how you can discover facts about plants living untended in the wild. You will be helped to become familiar with both individuals and sample populations of species so you can gain a fuller picture of the basic life cycles and survival strategies of species. You will also be encouraged to explore the specifics of the habitat in which a species thrives; seek out the factors that seem critical to both survival and good living; and learn about other species it regularly associates with, and how accidental or obligatory such associations are.

One of the advantages of studying plants, as opposed to pursuing most animals, is that they don't run away from you. Unless it has been consumed or died, you can return again and again to the same site and find the plant you have been watching. Therefore, you can ramble about your community making plant acquaintances and then return over and over to visit them, thus deepening your friendship and enriching your knowledge and understanding of them.

Unfortunately, field study is not sufficient to unravel the many intricacies of a plant's life. There is need to follow up on the observations with field experiments and laboratory studies. Good field observations generate hypotheses to be explored by experiments. In the chapters ahead we will suggest only the simpler experiments that can be undertaken with readily available equipment. The rest are the province of professionals or dedicated amateurs with unusual access to more sophisticated equipment.

From the first time you begin to look up the name of a plant that has intrigued you, you will encounter in the guidebooks the language of the botanist. As with any specialized field, botany has developed its own specialized terms that tend to bewilder and even put off the uninitiated. The value of that special terminology is that it has specificity of meaning. Unfortunately, because of being rooted in the ancient languages of Latin and classical Greek, this special vocabulary tends to leave the average person today more than a little frustrated. The more involved you get in observing plants, the more you will also want to read the works of others, thus raising your level of enjoyment as you acquire the language of botany. This book makes a bridge between everyday English and botanese. Botanical definitions are offered in the context of the sentence and will usually be followed by the botanical term in italics and/or parentheses. Thereafter the botanical term may be used.

There is much to be said for observing plants for sheer aesthetic enjoyment—their colors, forms, patterns, and scents. It is fervently hoped that in becoming more deeply involved with plants you will never lose your capacity for such enjoyment by having it blunted by an overly zealous commitment to "scientific objectivity." On the other hand, aesthetic appreciation of plants can be enriched through a deeper intellectual understanding of plants' lifeways. Throughout this book, we are interested in plant watching, which means learning to "see" the plant throughout its life cycle and developing perceptual skills that make an individual species stand out from the more or less uniformly colored and heavily patterned background. Equipped with such skills, you will experience continuous amazement.

PLANT SPOTTING TECHNIQUES

In one sense, spotting plants is easy since they are all around us, even in the heart of most cities. We quickly detect many flowers because their form and color create sharp contrasts with the rest of the plant and the general background. Indeed, survival of many plant species depends upon their flowers being readily seen by those species of animals that are essential to pollination.

For plants without conspicuous flowers, or even for flowering species outside their flowering season, the situation is quite different. The plants tend to become submerged into a more or less common ground of green, yellow, or brown, depending on their location or the season. Spotting a particular species in such settings takes practice and experience.

Science seems to indicate that we have an almost limitless capacity for storing all the visual images to which we are exposed and for recognizing most of them if we see them again. However, in order to be able to call up their appearance to our conscious mind for verbal communication, we have to have given conscious word labels to those visual images. In other words, in order to recall visual images and communicate them to others we must have associated those images with appropriate language, because visual and language memories normally operate in different hemispheres of our brain.

What does this have to do with ability to observe plants in the field? We all tend to see according to what we know or believe. It's not just light, color, shape, texture, lines, patterns, similarities, contrasts, and movement that form the language of vision and that registers on our retina; it is what our brain makes of this information and how it is stored in terms of our own personal verbal language. Theoretical physicist Albert Einstein is reputed to have said that you cannot make an observation unless you have a theory to bring to bear on what you are looking at. What our mind tends to focus on from among the multiplicity of visual stimuli that arrives there is guided by our accumulated experiences, stored information, private interest, and entrenched beliefs. This all boils down to the need to prepare yourself to see certain plants before you go afield.

The idea is to prepare yourself so that particular plants can get your attention. Philosopher William James wrote: "Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness, are of the essence. It implies withdrawal from some things in order to deal effectively with others."

A few years back a friend of mine was working with an inner-city community group. One of its projects was to plant flowers at various sites. The participants had poor knowledge of gardening and consequently little of what they planted survived. There was inadequate understanding that the plants had to be tended: essentially they were planted and abandoned. But in front of the community center one hardy plant endured and offered up a cluster of bright flowers. On a return visit to the community center, my friend immediately spotted the flowers and commented on them when she went inside. To her surprise, no one else had "seen" the blooms. They had to be taken outside and shown. They didn't expect the plants to survive and grow. For them, there was no expectation of a flower there. It was not part of their consciousness; therefore, it did not get their attention; to them it simply had not existed.

Similarly, many people take drives in the country and perceive the countryside and the tree-lined road only as a tunnel of green flanked by green mats speckled with colored dots. I suspect that I was once much the same, but today it takes a strong effort for me to register just a tunnel of green, for I see oaks, ashes, maples, and much, much more. The colored dots in the fields are dandelions, mustards, and asters. Each has its distinctive shapes, patterns, and tones, and I have learned to discriminate them instantaneously. I have never lost my appreciation of the abstract colors and patterns they present, but that appreciation is enriched by a deeper understanding of the plants that create them. Other field botanists have enjoyed similar experiences.

To become aware of the plant species' presence around you, it pays to become familiar with their distinctive patterns and shapes, and often their particular hues. Several years ago, on moving into a new house, I noticed a rather coarse "weed" growing in the fence row. It was a plant I had never "seen" before. Tall, with hollow, jointed stems and large, heart-shaped leaves, it had a thin, papery covering at each joint along the stem. A few minutes with an identification manual revealed that it was a species known as Japanese knotweed or giant polygonum. I was excited to have found this interesting new plant on my property. Even though the guidebook said it was common, I concluded that it must be rare in the area, for surely I would have spotted it before. Much to my chagrin, in succeeding weeks as I visited many old and new haunts I found the species everywhere. It was common, but for me it had never before emerged from the background into my perception.

Emanating from such experiences and the studies of visual recall is a strategy for making certain that species pop out of the background. Spend time carefully studying botanical illustrations—either good drawings or photographs—and memorizing the distinctive patterns, shapes, and colors of a plant. Also, from the text, become familiar with the habitat preferences of a species so that you will know where to begin looking for it. Prepared with this information, you may be surprised at how readily you are able to spot the real plants. As you become more familiar with a species, its characteristic hues and changes through the season, spotting individuals or clusters of the species will become even easier. After all, seeing is a transaction between the object and the viewer.

The foregoing strategy reverses the usual use of identification guides whereby you find a plant and then try to determine its identity from the keys and pictures. This strategy presupposes that you are searching for a certain species. A major weakness is that good pictorial references for many species are not readily available. Some people can create a visual image of the plant from technical botanical verbal descriptions, but few acquire that skill. It is akin to the skill some have of actually hearing music in their minds when reading the notes of a musical score, a product of years of close familiarity with the discipline.

Another approach to spotting plants, equally dependent upon mental set and background information, involves developing strong familiarity with specific sites or habitats. Become thoroughly acquainted with the shapes, patterns, and hues of the predominant plants that grow in these places. Then scan the sites for items that contrast with the normal, familiar background. As your eyes move around the area, your mind will tend to edit out the familiar but respond to the unfamiliar. You can then focus on a detail that may well reveal itself as a species of interest.

With practice, you can sharpen this trainable skill both by field work and by the following indoor activity that can be either exercise or game. Make a collection of cut paper shapes or a large collection of coins or buttons. Spread most of them out on a table and familiarize yourself with the patterns they form. Then, while you are turned away from the table, have a partner slip an odd shape somewhere onto the table. Then have the partner give a signal and time how long it takes after you turn around to spot the new object. As a game, you and your partner can reverse roles. Compete with yourself or your companion to reduce the time needed to spot the new object. You can build the skill and challenge by making the added items more and more similar to the other shapes and colors on the table.

When you take your improved skill into the field, expect to progress the same way you did in the game—that is, from the most obvious differences to those much more subtle. You will find that your developing skill will be useful not only in spotting new species but also in noting changes within familiar species. You will spot seasonal changes, and you may even learn to spot genetic variants among common species.

Certain groups of plants—grasses, goldenrods, asters, mosses, and a number of others—are often bypassed by people as being too difficult to explore. This is unfortunate, since these groups include many interesting species. In each of these groups there are a number of distinctive species that are quite easy to distinguish from the rest. Become familiar with at least these more readily identifiable ones and don't be disturbed that you don't yet distinguish all their relatives. As you become familiar with the easy ones, you will become more aware of the group characteristics and some of the once-difficult-to-separate species will become more distinguishable. Your growing skill in subtle discrimination of characteristics will make recognition easier. Proceed gradually and before long you will find that the group is much less confusing than you were once led to believe. To be sure, there will be some real puzzlers, but chances are they are confusing to the professional experts as well. Often as not, that is because the genetic status of the species is not clear.

As with all skill development, learning to spot plant species in the field takes practice and persistence. Almost always there is a period of frustration, a time when it seems as though you will never learn. Then all at once there comes a breakthrough and things begin to come into focus. After a little more honing of the skill, you begin to wonder how you ever could have been so blind. Elation comes as you realize how much more there is to this beautiful planet than you had ever previously imagined. This may even be followed by a certain missionary zeal as you try to help others make a similar discovery for themselves. Clearly there is a touch of that behind the writing of this book!

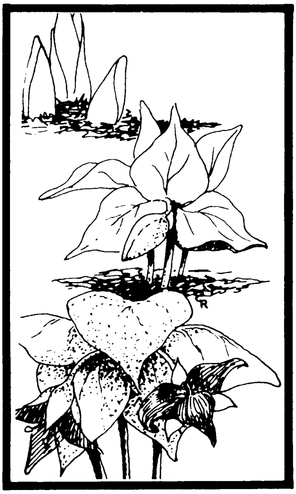
Once you start watching plants, what are you really watching for? For enjoyment, of course, but also to learn more out of curiosity about the life of a fellow traveler on this solar-orbiting space station. Since our focus for this volume is not the laboratory with its electron microscopes and other gadgetry for probing the inner workings of plants, our attention here is on the whole integrated plant organism and its relationship to the physical and biological environment in which it grows.

WHAT THIS BOOK HELPS YOU DO

This book will encourage you to gather life history information, which is only partially known for most species. The tendency among scientists and laypeople alike has been to examine thoroughly a few species in each plant group while gathering only spotty information about their kin. As part of life history investigations, this book can help you explore natural phenomena that recur periodically as seasons change—for example, blossoming, fruiting, and leaf unfurling. *Phenology* is the science of seasonal changes in plants and animals.

Another major area of exploration is searching for environmental tolerances, requirements, and responses of plants or plant species. This branch of ecology, *autecology,* focuses on an individual organism or species as its major unit of concern. This book includes material on how to go about determining other plant species with which a given species is likely to be regularly associated. Indeed, sometimes you will want to study the plant communities themselves as a unit. *Synecology* is the branch of ecology devoted to such synthesis of organisms sharing habitats.

Investigation of all of these aspects of a plant's lifeway are interrelated and of equal importance even though they have not been equally well studied. When taking a broad look at the many plants of an area, we speak of them as *vegetation.* Pressures of time and the large size of many units of vegetation have led to techniques for studying vegetation directly without concern for the nature of the species that compose it. Such studies are based on the size and shape of the plants, whether they are evergreen or deciduous, softly herbaceous or hard and woody, and on various other characteristics comprising life forms. Description of vegetation is a convenient shorthand way of making rather superficial analysis to deduce the botanical character of a region, but it leaves a great deal of exploration for the amateur or professional field botanist. Many conclusions based on plant communities as study units are suspect because of the limited information that exists about the ecological needs of the component species. Plant ecologist Henry Oosting noted in his now classic work, *The Study of Plant Communities*: "Just as the study of vegetation must remain more or less superficial without a solid knowledge of the flora, so will interpretations and explanations be limited by the amount of autecological information available about the species and their environments. Physiological-ecological investigations in the field and under natural conditions constantly modify synecological conclusions that have been made deductively, or they suggest new interpretations and investigations." The amateur field botanist can make contributions to just such studies and from them derive a hobby filled with joy and satisfaction.



CHAPTER 2

ASSEMBLING LIFE HISTORIES

Beautiful flowers or striking foliage usually call attention to a particular plant, but seldom do we have an accurate perception of the whole plant at any given time in its life. Although plants are all around us, in many ways they remain little green alien creatures. Since they don't move about like most animals, communicate in the way animals do, or normally respond quickly to environmental stimuli, people tend to think of them as almost inanimate objects.

However, plants are living things. They develop from tiny embryos into fragile young, mature over time, reproduce, and eventually die. The overall pattern of their life histories is much the same as an animal's, although the details differ significantly.

To become intimately familiar with plants, either as species or as distinctive components of local vegetation, you must understand at least the broad outline of each species' life history. The pattern of their lives determines what they are going to affect and how they will be affected by other species.

Although plants may superficially appear quite simple, their life-ways are often remarkably complex. Over the millennia they have often coevolved intricate relationships with animal species as well as with other plants. Some species have been studied extensively and their life histories are well detailed, but for the majority of species life history information is quite fragmentary; certain stages have been carefully chronicled while others remain virtually unstudied.

Assembling information necessary to creating a full portrait of a species is something that we amateur field botanists can devote ourselves to throughout a lifetime. There will always be something new to discover

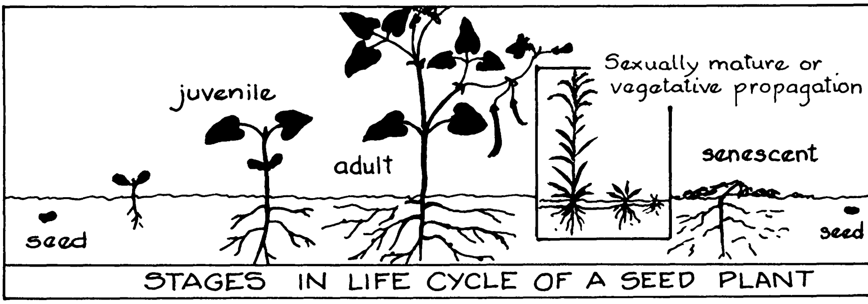


Figure 2.1

and many opportunities to see at firsthand aspects of a species' activities. It is extremely doubtful that a complete life history has yet been written about any species; indeed, it is unlikely that one can ever be written. Conditions change readily and plants respond to them, often causing localized alterations in the basic life history pattern of a species.

The challenge of life is seldom easy for any species. Even though most plants manufacture their own food (we say they are *autotrophic,* literally "self-feeding"), they still must get the basic raw materials from the surrounding environment. They must get enough water and minerals to replace what is lost in the day-to-day living process, and they must avoid excessive heat from the sun. They have to face competition from the leaves, stems, and roots of other species and must cope with the appetites of a broad spectrum of animal species. Local weather may alter the environment of the species for better or worse. Over time, plants have met these and other challenges in quite distinctive ways.

BIG PATTERNS OF LIFEWAYS

There are many ways in which one might classify the life patterns of plants. For the purpose of thinking in terms of plant life histories, we will focus here on three major patterns of longevity for plants known as annuals, biennials, and perennials. These patterns involve the average time it takes for the plant to go through a cycle from germination to reproduction and senescence.

Annuals complete their life cycle in one growing season, surviving to the next growing season only as dormant seed. This pattern of activity is very successful in colonizing frequently disturbed soils. Annuals generally have relatively rapid growth rates and regenerate almost entirely by seed.

Biennials usually complete their life cycle in two growing seasons. Their first year is devoted to *vegetative growth* (roots, stems, and leaves), usually producing a rosette of leaves that grows close to the ground.

Photosynthates, products of photosynthesis, are stored in the root systems over winter. During the following growing season most of the growth is concentrated on reproductive structures—namely flowers, fruits, seeds, and their supporting stems. After that, the plant will die. Biennials tend to do best in disturbed areas and are often found associated with annuals. Biennials, however, can survive bad times more effectively than annuals and may occasionally extend the vegetative stage for another year or so until they have stored up enough photosynthates to invest in a reproductive season. However, once they reproduce, their life is over.

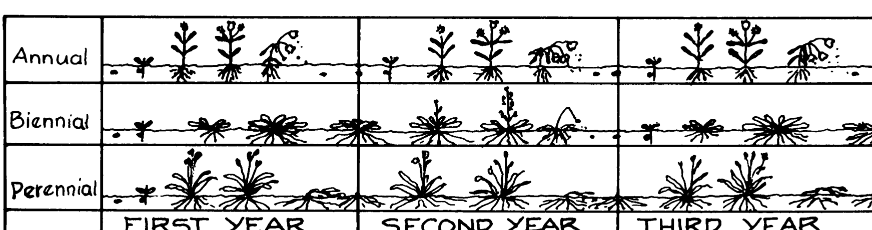
Perennials have an indefinite life span, from three years to centuries. They may take several years to reach reproductive maturity and then produce seeds or spores regularly or intermittently for the rest of their lives. Because of their persistence, many perennials have the opportunity to become well established on a site and eventually to become dominant species in the local vegetation. This may take years and many setbacks, but their ability to store photosynthates in good years and draw upon them in bad ones increases their likelihood of surviving adverse conditions and exploiting favorable ones.

Each of the various patterns of life history conveys advantages and drawbacks for surviving under a given set of conditions. As the field botanist becomes interested in the various strategies for survival in different habitats, the need to be intimately acquainted with the specific lifestyles of the various species that make up the vegetation in any given habitat becomes increasingly important. It is amazing how little is known about the details of the lives of most of our plants, even the most common ones. The amateur has a broad opportunity to add to the general knowledge of almost any species. It is fun getting to know local species in detail and assembling over time an increasingly detailed revelation of their lives.

ASPECTS OF A PORTRAIT

In the following sections we will examine various aspects of the life history of typical plants and look at questions to be explored and ways to go about that exploration. What we will deal with does not apply uni-

Figure 2.2



formly to all groups of plants, for there is too much diversity among these creatures. In Appendix A you will find a working outline for a plant life history with several subsections for special groups such as fungi. This will help you organize your observations over the years. Also, you will find additional discussion of life history finepoints and study techniques in Chapter 8.

SEEDS AND SPORES

Seeds and spores are a good beginning point in the exploration of plant life histories. For most plants they are the primary devices for spanning the generations, surviving difficult times in the environment, reaching new sites to increase populations, and providing some mixing of genetic material that may preadapt a species to subtle environmental changes. However, plants also have a variety of ways of propagating vegetatively.

Spores are limited to the nonflowering plants; seeds to the flowering ones. Spores differ from seeds in that they lack a preformed embryo. Most spores are minute, and the sporophyte plants produce them in prodigious numbers. Study of spores by amateurs is very difficult, requiring access to a microscope and often use of laboratory culturing techniques to get them to germinate under observable conditions.

There are, however, some things regarding spores to be noted by the plant observer. These center around the structures where the spores are generated and the ways in which the spores are dispersed. By far, the most common method of dispersal is by wind, but there are some species of nonflowering plants that depend upon rain splash to scatter the spores—for example, many mosses and bird's-nest fungi. There are also aquatic fungi that depend upon water to disperse their spores. Others have a propulsion mechanism to shoot out the spores. On discovering the history of a particular species, carefully note the method of spore dispersal; it may reveal how individuals of the species get a start in life. A few fungi, like those of Dutch elm disease, *Ceratocystis ulmi*, even depend upon wood-boring insects to inadvertently carry their spores from one infected tree to another.

Study of spore scattering may take some persistent detective work and exploration with a strong hand lens or pocket microscope. Some of the mechanisms among the fungi are fascinating. For example, a common fungus on horse dung is *Pilobolus.* Its spore-holding structure, *sporangium,* sits up on a stalk atop an egg-shaped device called the *vesicle.* The vesicle and its fluids act as a lens that focuses light and creates heat in the same way a magnifying glass does. The heat causes the fluids to expand rapidly, finally forcibly ejecting the sporangium and flinging it onto the surrounding vegetation where its gluelike coating makes it stick.

From the vegetation the sporangium will be ingested by grazing

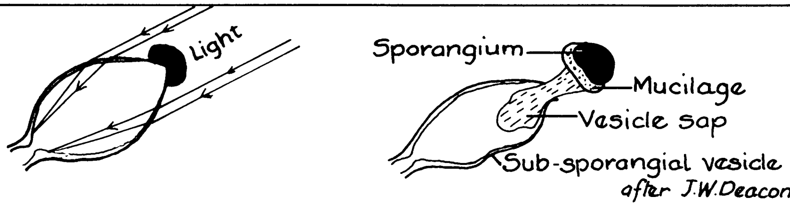


Figure 2.3

animals and eventually will come to rest in their lower intestines. There, it will germinate to grow and eventually will return to the outside world in a dung pellet, where the cycle can begin anew. There are other fungi that have variations of this cannonlike scheme.

All spores are quite small by our standards, but everything is relative and actual spore size gives some clue to the parent plant's habits. Small spores, approximately four microns in diameter, are typical of soil fungi in that they will stay aloft in air currents to settle out on calm spells and find their way down among the soil particles. However, some species grow on the leaves of plants and they must land on them at normal wind speeds; their spores tend to range between eight and fifteen microns. The larger the spores, the less distance they are likely to travel and the shorter the period of time they are likely to remain airborne. It is also worth noting that larger spores have more food reserves than smaller ones and thus more energy for getting a plant established at a new site.

Among the liverworts, spores seldom take long trips but tend to settle relatively near the parent plants. Some of their near cousins, the mosses, have more complex means of spore dispersal that may result in strong ejection of the spores into the atmosphere where air currents may distribute them over considerable distances.

Horsetail (*Equisetum*) spores are interesting in that they have long, coiled flaps called *elaters.* These make up the special part of the spore wall. When the spore dries out, the elaters uncoil to create "sails" that help the spores ride the wind. When the spores land in a moist spot, the elaters coil up again and the spores germinate.

Most fern spores, which are wind-disseminated, tend to be borne in clusters of sporangia called *sori.* Sometimes the sori appear on the undersides of ordinary leaves (*fronds*), while in other species they are located on special stalks or modified fronds. The arrangement of sori often helps to identify species.

Among most spore-bearing plants there is only one type of spore and such species is referred to as *homosporous.* But among *heterosporous* groups, such as the selaginella and some ferns, there are two different-sized spores. The larger ones develop into female plants; the smaller into males.

SEEDS

For most people, seeds are much more familiar than the spores of the nonflowering plants and, by and large, they are much easier to explore than spores because of their comparatively greater size. Seeds differ from spores in that they contain preformed, embryonic plants. In addition, they generally contain significant amounts of stored food that give the embryo a boost in its initial growth.

Seeds vary in size from the dustlike species of many orchids to the somewhat larger than softball-sized coconuts. There is diversity of form as well, much of which is adapted to methods of seed dispersal. There are seeds with floats, wings, parachutes, and grappling hooks. Some are wrapped in edible packages (fruits) that will either be eaten by animals with the seeds passing unharmed through their alimentary tract to be deposited in the accompanying bed of fertilizer, or whose attractive coating itself decays to form fertilizer.

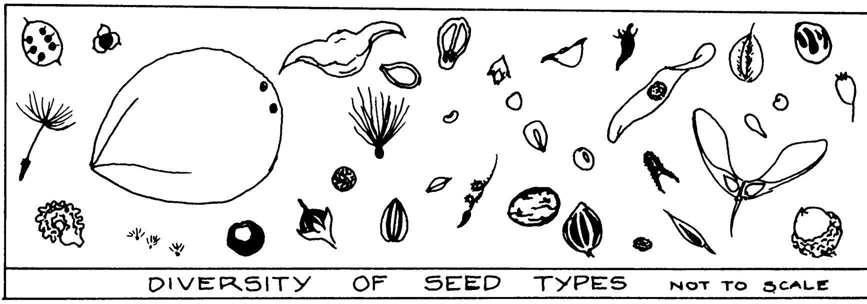


Figure 2.4

There is much to be learned about the seeds of any given species. Because seeds are a major device for permitting a plant species to reproduce its kind and thus expand its occupation of appropriate habitat, they deserve some close attention. As plant communities undergo change, the capacity of a seed to locate a suitable germination site and get its embryo established and growing may be the deciding factor in determining the type of vegetation that will develop next.

DEVELOP A SEED COLLECTION

A good beginning activity for field botanists is to collect envelopes of ripe seeds from as many as possible of the local plants in the areas being explored. Be sure to label each envelope or paper bag carefully with location, date of collection, and species. When the seeds are well dried so they will not become moldy, they can be kept neatly in labeled, transparent, glass or plastic vials arranged in trays or shallow boxes. If a particular plant of a given species seems unusual in flower, color, form, or other characteristic, be sure to keep its seeds separate; you may want to try to grow some later.

The seed collection will be useful for a variety of things. First of all, by studying the seeds you will be able to recognize the species even when you find it some distance from the parent plant. Or you can compare an unknown seed with your labeled collection to help identify it. Second, you can set up experiments with the seeds to determine how long it takes a given species to germinate and also to learn if there are any special conditions that must be met if a given species is to germinate.

You can also try germinating some of the seeds from a given batch over a period of successive years to determine roughly how many years seeds of that species remain viable. For some species it is only a year or two; for a few species, like lotus plants, it can be over a thousand years. The germination characteristics and viability of seeds over time are of considerable import to a species' strategy for survival.

FIELD OBSERVATIONS REGARDING SEEDS

Watch and time the following items in the field. Mark individual plants with little tags to which you can reference your field notes (see Chapter 4).

What is the average time from fertilization of flowering to ripening and dispersal of its seeds? If you can, match this information with data on temperature and rainfall. In some cases you may determine that the average ripening time varies from season to season, depending on environmental conditions. In other species the ripening time may be quite constant from season to season, because it is determined by internal biological rhythms. With such plants, seed size may vary due to environmental conditions during the internally fixed development time.

What devices does a seed have for its dispersal? Make photos or drawings of the seed and its special adaptations for dispersal. Every species has its own special forms, but there are some common themes. For example, maple trees all have the winged (*samara*) form of dispersal, but each species has wings of different length, width, and angle. Thus, each has different aerodynamic qualities that cause it to disperse slightly differently. You can have fun watching the seeds of different maples dispersing and noting their varying abilities to get away from the parent trees.

There are also many variations on the hook theme, which permits certain seeds to catch on animal fur or human clothing and travel to a new area where the animal cleans the seed from its fur. One inventor spent years studying the burdock seed and its crochet-hook barbs. From his studies came the invention of hook-and-loop-type closers.

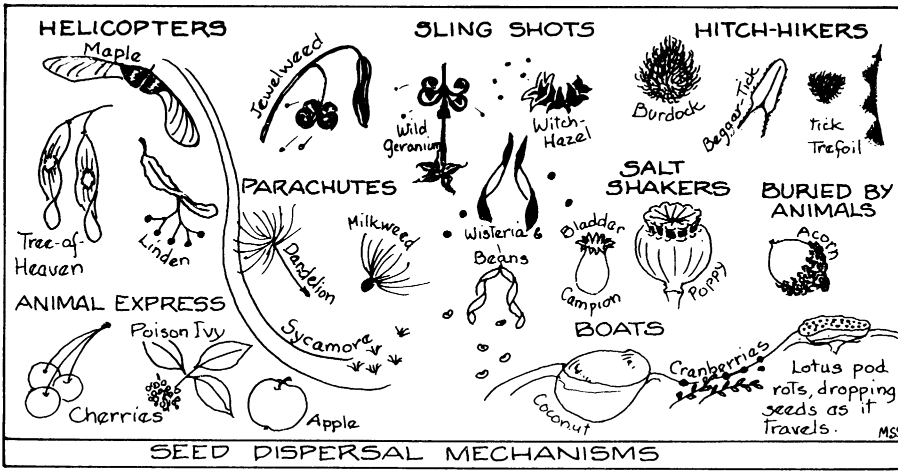


Figure 2.5

Where do seeds from various species end up? One reason for building a good seed collection of species in your area is so you can undertake "scavenger hunts" to see what seeds have made their way to various soil samples. One way is to study the soil sample carefully with a good hand lens and collect as many seeds as possible. Sometimes it helps to put samples through a series of increasingly finer wire mesh, going through the successive screenings for seeds. It's a bit like being an archaeologist sifting a site for human artifacts. The labeled seed collection is a reference for identifying your finds.

The second approach involves putting samples of the soil in trays (flats) and germinating the seeds. The task then is to identify the various seedlings. A discussion of germination methods can be found in the section on seedlings.

Some seeds germinate almost as soon as they land on suitable soil. This should be noted whenever you observe it. Many species, however, must go through a period of dormancy before they can germinate. This dormancy may be only for a brief cold period or may last for decades, even centuries in some species. A variety of things may break the dormancy—the seed coat may become nicked so that water can penetrate; light may finally get to the seed after long periods in the dark; or soil may warm after a prolonged freezing. Each of these things has an influence on the way seeds permit their species to get a start in a new location. In many habitats the soil will be found to hold a fair variety of dormant seeds in what amounts to a seed bank. The bank awaits changes in the environment that will stimulate some of its member species to germinate. The length of the wait and the nature of the changes will determine which components of the seed bank will get their "day in the sun" and thus determine what kind of plant community will next occupy that site.

What enemies does the seed have? For seeds, chance is their best friend and greatest enemy. A plant must produce vast numbers of seeds just to have a very few find suitable germinating conditions. Even fewer will survive long enough to reproduce themselves. In addition to the odds of finding proper conditions, the seeds must face a host of other organisms that want to tap the materials and energy stored in the embryo and its nourishing container. Examine seeds for evidence of insects that may have bored inside to feed or lay eggs. If you find insects or other invertebrates feeding on your seeds, you can send them to scientists at the state university or the county extension service for identification. Note also birds that feed on those seeds and the small and large mammals. Even where the number of seeds per plant is quite large, these enemies can put such a dent in the number of seeds available to germinate that almost no seedlings may get started in a given year.

What is the average seed production per plant in a given location and year? Like animals, plants have good years and bad. Tag enough specimens of your study species for a representative sample and count the seed production. For species that produce relatively few seeds per plant, such a count is much more feasible than for those that produce thousands of tiny seeds. Nonetheless, the number of seeds in a given year helps establish a clue to that species' reproductive potential and its chances of gaining or retreating as a member of the plant community.

THE SEEDLING OR JUVENILE STAGE

Perhaps the most neglected stage of most plant life histories is the juvenile stage, the time between germination and first flowering or sporulation. It is a difficult time in a plant's life, and mortality is generally quite high.

There are many things to observe about the early development of a plant. How does the embryonic plant emerge from the seed? Does the root emerge first or do the seed leaves? Is there a considerable time lag between appearance of root and seed leaves or do they emerge at about the same time? Such details are generally only visible by sprouting seeds between blotters and glass.

As seedlings emerge from the ground, photograph or sketch them carefully over a period of several weeks. Be sure to note data about when you begin to see particular seedlings. They will often be quite different in appearance from more mature plants and will frequently have distinctive seed leaves, or *cotyledons.* A number will have first leaves quite different in

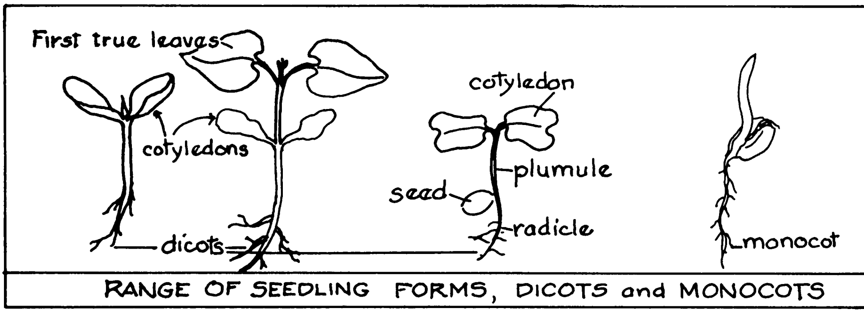


Figure 2.6

form and/or color from more mature ones. Almost no books exist that provide identification keys to seedlings. It is assumed that people either overlook them entirely or can wait until they are mature to identify them.

At first that is what you may have to do. Carefully record the seedlings that interest you and follow their development to mature plants that you can more readily identify. Then in the next growing season you will have the ability to recognize the seedlings by species while they are still small. Being able to recognize seedlings helps determine which plants are trying to establish in an area. It is not unusual for all the seedlings of a particular species to die in an area year after year until some change in the surroundings creates altered conditions that will permit some of the seedlings to become well established and survive. By following the successes of a selected species' seedlings in various habitats, you may learn something of the conditions needed for them to succeed.

In order for seedlings to survive, they generally have to maximize their surface area successfully both above and below ground. This is necessary to tap the most basic resources possible. Shallow-rooted seedlings will spread a network of rootlets but are very vulnerable to drought or competition from the roots of more established plants. Taprooted species will send their roots downward to perhaps more secure sources of moisture and minerals. These seedlings may survive several seasons of having their aerial parts damaged or removed completely. As long as their growth center—just below the ground—remains intact, they may appear to have been destroyed only to reappear again later in the season or in the next one. Some seedlings, particularly of tree species, are remarkably persistent over a period of years before they get a chance to make significant growth.

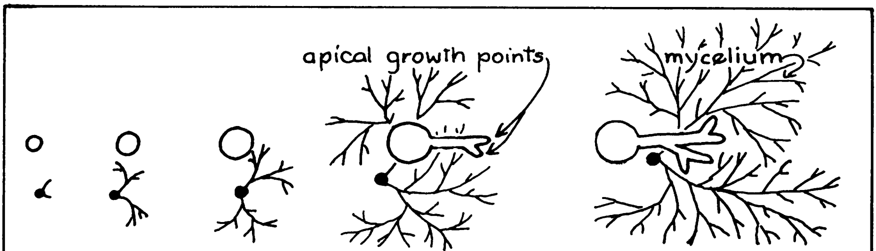
Seedlings are especially vulnerable to predation by a host of organisms. As many as possible of these should be recorded for any species under study. The outer surface of a tender stem has very little deposit of corky material to protect it from the invasion of fungi (the dreaded "damping off" disease of gardeners' seedlings); mechanical injury from the passing of animals; the falling of limbs, and the like. Depending upon the species, however, the biggest threats to survival are usually too much or too little light or too much or too little water. The needs of seedlings may be quite different than the needs of mature plants, and these should be determined. Conditions for successful seedling establishment and growth may be much more critical to a species than its adult preferences. Indeed, the environment of an adult plant may be somewhat misleading in terms of that species' needs. As adults, individual species may be able to tolerate a wide range of conditions while as seedlings their environmental tolerances may be much more critical.

In the field, it is difficult to assess accurately a seedling's specific environmental needs. That must usually be done in the greenhouse or laboratory under carefully controlled conditions with many batches of seedlings. However, field studies of light, pH, moisture, and mineral nutrients around the seedlings will point to parameters to be later confirmed or denied by the controlled studies.

There are a number of other ecologically important matters to be noted by following a seedling's development in the field. *On average, how long after germination do first true leaves appear? How much growth of stem occurs between each new leaf? If the species is herbaceous, is there a particular number of leaves that must develop before the plant matures and produces flowers? Are young leaves significantly different in shape and size from older ones? How old is the seedling before it develops a more fibrous or corky stem covering to add to its protection? Does this coincide with a time when mortality among the seedlings seems to be reduced?*

Although invisible to the unaided eye, fungi also go through a juvenile stage. A spore at germination swells and sends forth a germ tube that develops into hollow, threadlike structures (*hyphae*). Growth is at the tip or *apex* of each cell. After a period of growth, a wall (the septum, plural "septa") forms across the cell. A new growth point may develop at the apex just behind the septum and send forth a branch. This develops a basic pattern in which the hyphal branches grow toward the colony margin away from the original hypha and from each other. The cluster of hyphal threads is called a *mycelium* and is the main body of the fungus.

Figure 2.7



DEVELOPMENT OF SPORE FROM HYPHAE TO MYCELIUM

Branching of the mycelium appears to be a function of the nutrients in which it is growing. If you uncover a mycelium among dead leaves, logs, or other sources of fungal decay and it is relatively unbranched, its base is probably nutrient-poor; if it is heavily branched, it is nutrient-rich. Generally it does not begin to produce fruiting bodies, such as the compact clusters of hyphae that we recognize as mushrooms, unless it is nutrient-rich.

Fungi, now recognized by many biologists as a life kingdom separate from other plants, animals, and microscopic organisms, are still a diverse, complex, and valuable group. There is no way we can do justice to the whole group. Mushrooms, however, are conspicuous organisms in our environment and we focus our discussion on them without meaning to belittle the importance of the yeasts, soil fungi, mycorrhizal fungi, parasitic fungi, and others which are generally microscopic and require special tools and techniques for their study. Most of the fungi we comment upon belong to the club fungi, *Basidiomycotina*, the group that encompasses most of the common mushrooms or toadstools, with spores produced on club-shaped hyphae.

REPRODUCTIVE MATURITY

After an appropriate period of development, each species of plant may reproduce if it is in a proper habitat and fortune smiles. Some species will grow and survive outside their preferred home but never reproduce there although they seem appropriately mature. Annual and biennial species generally go through their growth and development phase, and then flower and shortly thereafter die. However, perennials are more complex in their reproductive patterns. Many utilize both vegetative modes such as runners, stolons, bulbs, and the like, and sexual modes such as flowers, fruits, and seeds. They may reproduce for several years or more entirely by vegetative means and then proceed to flower. They may reproduce regularly by both means. A bad season's stress may trigger greatest flowering. Apparently such species respond to stress by using the sexual mode, which creates offspring of wider genetic variation than vegetative reproduction and provides opportunities for dispersal beyond the area of stress. The astute plant watcher keeps good track of what is happening reproductively with each of the species that catch his or her attention and realizes that what happens in any given year is not necessarily typical of the species.

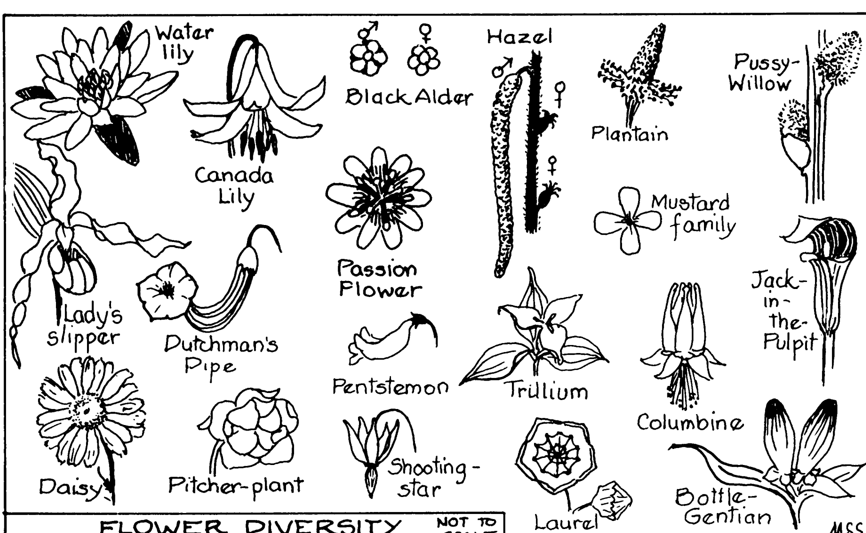
As we suggested, early reproduction of fungi is generally a function of the success of mycelia in gathering adequate nutrients. Mycelia may grow very slowly for several years before gathering enough resources to focus hyphal growth into a typical mushroom fruiting body that will produce spores. The abundance of a given mushroom in your study area, or its apparent lack of abundance, is primarily a result of growing conditions. A species may be present and growing slowly for several seasons before producing fruiting bodies. Although most fungi fruiting bodies are rather ephemeral, some of them, particularly the various shelf fungi, may persist for several years with new spore-producing layers added each year.

THE WORLD OF FLOWERS

For most species, the flowers are their best-known feature. The more colorful or bizarre of form, the greater the likelihood that they have been carefully studied—yet new things are being discovered about flowers all the time. For instance, it has recently been discovered that a number of species that live in arctic climates or flower in the cool of early spring act as miniature solar reflectors that focus the sun's warmth over the center of the flower. Studies with delicate temperature sensors show these spots to be several degrees warmer than the surrounding air. This proves very attractive to local flying insects. The plants profit because the insects that take advantage of the warmth get covered with pollen and thus transfer it from plant to plant. It is a nice example of the phenomenon of coevolution, whereby two very different life forms slowly evolve together for mutual benefit.

We have also discovered rather recently that flowers may appear quite differently to certain insects than they do to us. We do not perceive light energy in the ultraviolet range, but many insects, particularly bees,

Figure 2.8



do. Photographs taken with ultraviolet-sensitive film have revealed that some flowers that seem uniformly colored to us actually have definite patterns to those sensitive to ultraviolet. These patterns often direct an insect's attention to those parts of the flower that will most benefit the insect in its search for food and thus create the highest chance of the plant being pollinated—another indication of coevolution at work. You can check out this phenomenon of ultraviolet patterns for yourself using techniques described on page 68.

There are many aspects of flowering for the plant observer to note. *Does the flower remain open around the clock once it unfolds from the bud, or does it open and close according to a regular time pattern?* Some species are so specific in the timing of their opening and closing that it is possible for gardeners to plant floral clocks with a regular succession of openings and closings throughout the day and to some extent at night. Once you become familiar with the habits of certain species, you can tell roughly what time of day it is by whether these species of the season do or do not have their blossoms open—but don't let cloudy days fool you.

How long does a blossom last? Is its longevity essentially a built-in period of growth or does its demise start soon after pollination? This isn't always easy to determine; you may have to experiment by mechanically preventing pollination, such as by encasing the blooms in mesh bags.

What adaptations does the plant have for either self- or cross-fertilization? The eggs, or *ovules,* in the ovary of a flower can be fertilized by pollen from the stamens of any flower of the same species, including the ones in the very flower in which they are located. Indeed, many species self-pollinate regularly, while others go to elaborate lengths to assure that pollen from different flowers or different plants of the same species accomplish the fertilization. This may mean that pollen grains in a given flower mature at a different rate from its ovules; that some flowers produce only pollen or only ovules; or that male and female flowers may occur on separate plants.

As you find flowers in bloom, carefully note the presence or absence of stamens; and if stamens are present, check them and note when pollen grains appear and how long they are present. Pollen grains are often bizarre when seen close up. Check them with a 10× magnifier, or a microscope, and sketch or photograph the pollen grains. Pollen grains that don't land on a pistil may survive intact for hundreds of centuries if they land on an acid bog. Scientists have been able to determine the abundance of some species over time by separating pollen from cores of peat extracted from such bogs. The science of determining changing plant communities of the distant past using the pollen record of bogs is called *palynology.*

When does the flower produce odor or nectar, if it does? Many flowers generate scents or liquid nectars that attract certain species of insects. In their visits the insects either collect pollen deliberately or accidentally pick it up on their bodies and carry it to other flowers, thus enhancing the chances of the species' pollination. Some produce the odor or nectar on a fairly constant basis, while others produce it only at certain times of the day. Generally, species that depend upon wind pollination lack either odor or nectar and produce much more pollen than do insect-pollinated plants.

The odors that some flowers produce are not sweet-smelling but are more like the foul odors of carrion. Examples include skunk cabbage, carrion flower, and stinkhorn mushrooms. Such species tend to depend more on species of flies for their pollination than on the bees and butterflies we usually associate with that task. There are also many other insect groups that may get involved in pollination. Note the kinds you see visiting the blossoms and identify them if you can. If they are unfamiliar, collect one or two voucher specimens and preserve them. They can be sent to the department of entomology at a state university for identification. Be sure to have good data for each specimen (date, location, plants associated with it, collector's name). Normally, the university people will want to keep the specimens. If you have questions about preparing the specimens, refer to a good field guide to insects at your local library, or, even better, buy one for continuing use. Watching insects can be one of the great joys of observing plant lifeways.

What is the flowering period? Flowering is affected by a variety of environmental factors, but for most temperate-zone species the main stimulating factors are fairly constant, such as changing length of day or night. In more extreme environments, such as deserts, the process may be triggered by a sudden influx of moisture. For the plant observer it is more to the point to first record a species' flowering sequence over a period of years and then try to determine whether it is primarily attuned to recurring climatic constants or to more changeable local weather conditions. To get good information about flowering times, you will want to gather data from several study plots (see Chapter 7). Note when the first blossom opens, when half the plants in the study areas are in bloom, and when the last blossom opens. If you are really eager, you may also want to add data on when one-quarter and then three-quarters of the blooms are open. This data can then be plotted on a calendar to create a flowering chart for the area's species in any given year. Such information might look like Figure 2.9.

Recordkeeping of the timing of various events in a plant's life history (like flowering), and the linking of such events to factors of weather, climate, and soils is called *phenology*. Ecologist Paul Shepard writes that "Phenology, like taxonomy, in contrast to the more trendy forms of nature study in behavior or ecology, does not have a lively press. But it is what the mature naturalist finally comes to. It is not that these topics are

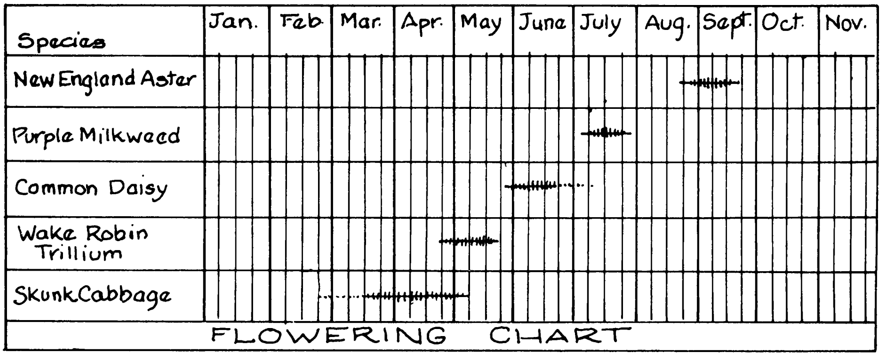


Figure 2.9

actually less dynamic than the more dramatic aspects of nature, but that their liveliness depends on a deeper understanding and a more refined sense of mystery."

Collecting phenological records is clearly within the realm of the amateur plant observer. There has been a tendency for amateurs to go for the "first and last" records, such as the first bluebird of spring and the last rose of summer. But much more valuable is information on when the majority of a species is involved in a given activity. First and last records may set the outer limits of a species' particular activity pattern, but they generally are records of the exceptions rather than the rule. Their major value may be in suggesting the limits of present adaptability to prevailing conditions.

What is the average number of blossoms per plant? Gathering such information will require some patience at counting or the recruitment of some friends to help. In many cases you will have to take some standard samples and deal with the number of flowers in the sample. This figure will vary considerably from year to year and location to location. It's important to have good information on rainfall, temperature, soil conditions, and changing exposure to light or shade to correlate with your plant's blossoming data.

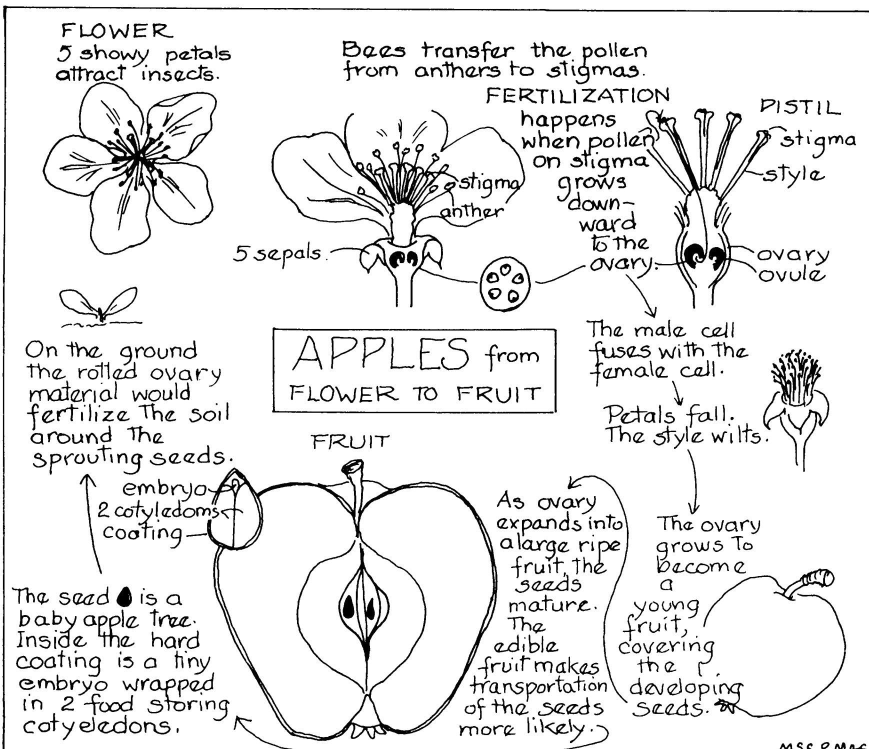
In some cases, you may also want to note the percentage of blossoms that go unfertilized. There may be a good bloom, but pollinator populations may be down for a variety of reasons so that few seeds will actually be produced. It is even possible for a year of relatively poor blossom numbers to end up with a higher set of seed because pollination is high. The plant observer should keep constantly alert for such events. The information helps determine the reproductive efficiency of the plants, and this information may be crucial when trying to determine conservation strategies for plants that are becoming threatened or endangered.

What factors injure the flower buds and cause them to self-destruct? Flower buds are often more sensitive to various environmental insults than is the plant as a whole. Frost, drought, drying out from wind, mechanical damage from wind, passing animals, or the onslaught of certain insects—all can prevent flower buds from doing their job. Such injuries should be noted for the species you are studying. What specific temperatures are deadly? What relative humidity conditions are lethal to the bud? Such things will be most noticeable with species at the edges of their normal range of distribution. The frequency of occurrence of such conditions over a span of years may say a great deal about the likelihood of whether a species will become well established in an area or die out.

What is the sequence of loss of flower parts as the fertilized flower transforms into the fruit? The transformation from flower to fruit is a fascinating one that few people ever observe very closely. Various parts of the flower will be shed in sequence to become part of the "organic rain" that settles on the ground. Petals, sepals, and stamens tend to be lost, and other parts may be absorbed by the expanding ovary with its developing seeds. Familiarize yourself with the various flower parts and then carefully record the fate of each as the transformation occurs (see Figure 2.10).

What is the sequence of opening of individual blossoms in a cluster? Some clusters have all blossoms open at the same time, others open sequentially from the tip down to the base, and still others open just the reverse. A

Figure 2.10



few, like teasel, begin opening at the middle of the cluster and work both ways. For many species you may find that just as there is a definite mathematical sequencing to the blossom and leaf arrangements, so too is there an orderly sequence of blossom opening. Keep track also of how long it takes for a whole cluster to go through its bloom cycle.

FRUITS

It is very difficult to separate flowering from development of fruit since it is a continuous development of some of the same flower parts. Botanically, a fruit is the mature ovary of the plant along with its included seeds, and occasionally with neighboring flower parts incorporated (as in strawberries and pineapples). Although conifers bear cones that are not technically fruits, we include consideration of them here for convenience.

How long does it take for the ovary to develop from the flower to a mature state for seed dispersal? It is interesting to keep a photographic or sketched record of the development of various fruits. Keep track of any insects or fungi that invade the developing fruits, for they are often responsible for preventing a large percentage of ovaries from developing into mature fruits. It is good to establish a sample of marked ovaries and determine what percent of them reach maturity in any given year. It gives another piece of information for determining reproductive success in a given year.

What is the method of seed release from the fruit? In some species the outer husk of the fruit dries and splits, releasing the seeds; in others, there is an increase in water intake that stretches the covering until the slightest touch will force it to burst open and expel the seeds, as with the various species of touch-me-not (*Impatiens*). Other species depend upon the feeding activities of animals to free the seeds. Some species have coverings that decay to create a nutrient-rich bed for the now-exposed seed or seeds. Pine cones usually must dry out so that the cone scales extend to release the winged seeds, with a few species requiring the heat of fire to bring about the slow opening of the cone scales.

What is the average number of seeds per fruit and what is the average number of fruits per plant? The number of seeds per fruit is normally fairly constant and genetically determined, but the number of fruits per plant will depend on a number of factors relative to a particular growing season. It is an indication of the plant's reproductive potential in a given year.

VEGETATIVE REPRODUCTION

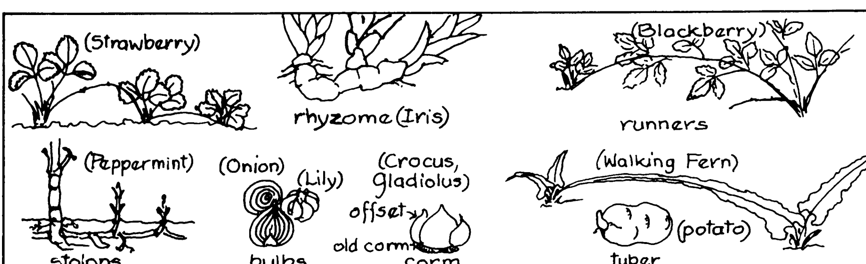
Flowers are only one way in which a plant may reproduce itself. They are the sexual mode that provides for a genetic diversity in the offspring, thus allowing for some adaptation to slightly altered environments. Flowers create *disseminules* that help new individuals move some distance from the parent plants. But many species also have various ways of reproducing asexually by vegetative reproduction of roots, stems, or leaves. These offspring have the same genetic makeup as their parents. This is quite satisfactory as long as living conditions remain within the same range that the parent plants needed. Such vegetative offspring of the same genetic makeup are often known as *clones*.

In many kinds of vegetative reproduction, the new plant remains attached to the parent for indefinite periods of time, so it is often difficult to determine whether we are dealing with an individual plant or many. Whole hillsides of aspen trees (*Populus*) may be interconnected clones from one tree that arrived as a seed. You may also have seen symmetrical clumps of sumac along roadsides that are high in the center and taper to the edges. These too are clonal clumps. The tallest individuals in the center are the oldest and the increasingly shorter individuals represent progressively younger individuals. It is highly likely that they are all interconnected below the ground.

In developing a full account of a plant's life history, you should record any types of vegetative reproduction. Most of them are below-ground activities, but there are a variety of above-ground structures that should be noted. Strawberries, for example, send out runners (stolons) that eventually touch ground, send down roots, and develop a new stem, leaves, and other appropriate structures; many roses, raspberries, viburnums, and other plants will root if a stem tip bends over and touches the ground; some ferns produce little bulblets on the leaves that drop off and grow; some species, like Kalanchoe, form little plants along the leaf margins that will drop off and grow; and some ferns, such as walking fern, form new plants when the extended leaf tip reaches ground. Many aquatic plants reproduce vegetatively; the tiny duckweeds (*Lemna*) that tend to cover our waterways in summer like green confetti are true flowering plants yet they seldom bloom, reproducing instead almost entirely by budding off from the existing leaves.

Plants with both vegetative and sexual reproduction have increased

Figure 2.11



VEGETATIVE REPRODUCTION — STRATEGY SAMPLER their options and thus their chances of expanding their populations through a wide range of conditions. Where it is hard for seedlings to get established, vegetative offspring, partially subsidized by their connection to the parent for a substantial period of time, allow the plant to expand into new, unexploited territory. Seeds are the high-risk adventurers, vegetative offspring the conservative stay-at-homes.

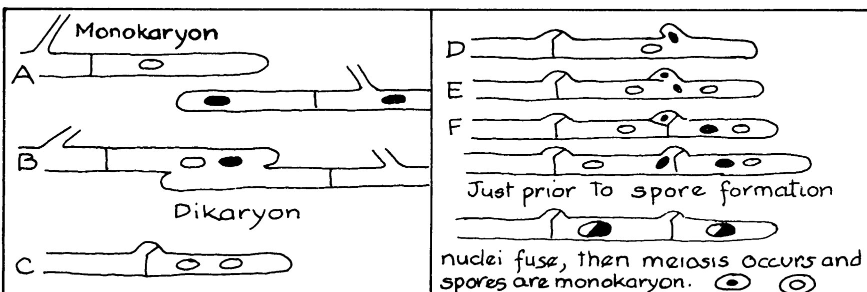
MUSHROOM REPRODUCTION

Because the study of reproduction in many kinds of fungi usually requires careful investigation under laboratory conditions and with a microscope, the average plant watcher will confine his or her observations to the so-called mushrooms, toadstools, and shelf fungi.

The early stages of sexual reproduction can be observed only under a microscope, but they are described here to give a general idea of the process. The hyphae, the individual threads that make up the mycelium of the fungus, normally contain cells with one nucleus which has only half the full complement of chromosomes. The Greek word for "nucleus" is *karyon* and the word for "one" is *mono*. Thus, these mycelia composed of hyphae with one nucleus are referred to as *monokaryotic*. When two monokaryons of different genetic heritage come together, their hyphae may fuse and the resulting hypha will grow into a mycelium in which each cell has two (*di*) nuclei (*karyons*). That type of mycelium is referred to as *dikaryotic*. It is dikaryotic mycelia that will form a fruiting body which we know as a mushroom but which the botanist refers to as a *basidiocarp*. Within this fruiting body, cells are formed in which the two nuclei fuse and the genetic material mixes. These cells, the *basidia*, go through *meiosis*, a cell division process in which the resulting cell has only half the original number of chromosomes. These cells are the spores which, if they grow, will start the whole process anew.

What can be seen without the microscope is the development of the

Figure 2.12



DIAGRAMATIC PROGRESSION OF FUNGUS FROM MONOKARYOTIC TO DIKARYOTIC TO MONOKARYOTIC SPORES.

fruiting bodies; it is at this stage that you can make the easiest field observations of this group of plants. Normally the first clue the sharp-eyed observer gets of an incipient mushroom is a bulge in the leaf litter or soil surface, or a buttonlike mass in a crack in tree bark. You will want to observe the object regularly at intervals of only an hour, or at least every couple of hours, for the mushrooms often develop in a very rapid growth spurt.

Gilled mushrooms start as a ball shape, and if you open one you will see that the rest of the mushroom is folded up inside like a furled umbrella. In the center there is the stem (*stipe*), folded down around the stipe is the cap (*pileus*), and on the underside of the cap are the gills (*lamellae*) along which the spores will form. The whole thing will be enclosed in an outer skin or peel. As the mushroom grows and ruptures the skin, some skin may remain attached to the stipe as a veil around it. Some club fungi, instead of having gills, have innumerable spore-bearing pores on the underside of the cap.

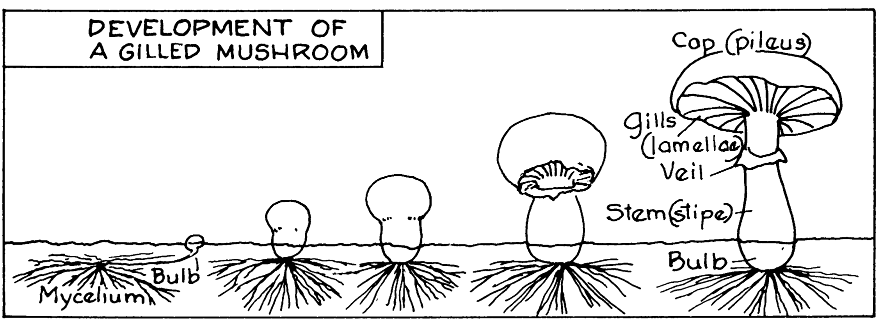


Figure 2.13

How long does it take on average for the button to reach its maximum height and open up the cap? How does the shape of the cap change during the existence of the fruiting body? How long is it after the cap opens before the gills begin shedding spores? You can put blue construction paper under the mushroom and cover it with a jar to prevent drafts from blowing away spores. Notice the colors of the spores; they are an aid to identification of the species.

Over how long a period does the mushroom continue to shed spores? Does most of the growth of the fruiting body take place during the day or the night? By regularly changing the paper under the cap, you can also determine whether the spores are released regularly around the clock or if there are active shedding periods interspersed with quiescence within a 24-hour cycle. Perhaps light is a less important factor than temperature and/or humidity. Be sure to take temperature and humidity readings each time you check for spores to compare development and activity of the fruiting body with all these factors and determine which ones show the highest correlation with the plant's activity.

For a given species, determine when the fruiting bodies first appear and over how long a period they can be found in an area. Keep track of temperature, rainfall, and humidity during that period and contrast it with other times of the year when no fruiting bodies appear. This will help determine the conditions that are optimum for fruiting by a given species.

Mushrooms are fed upon by a host of other living things, including snails, slugs, and a wide variety of insects, birds, and mammals. Record as many as possible of the creatures that feed upon, or within, your study species. This may involve getting specialists at universities or museums to identify specimens for you. Bacteria and other species of fungi may also attack a particular mushroom.

For those who seek the unusual, of particular interest are some of the fungi that produce cold light (*bioluminescence*). The chemicals that produce the light appear to be waste products of the plant's metabolism. The jack-o'-lantern mushroom, or false chanterelle (*Omphalotus olearius*), found around the roots of oaks and other deciduous trees if visited at night will appear to be giving off an eerie green light from its gills. There are other fungi whose hyphae grow similarly. This material, called *fox-fire* by the inhabitants of Appalachia, grows in dead wood and a walk at night in damp woods may lead you to a glowing stump or log.

The stinkhorns are another intriguing group of mushrooms. These rather bizarre, phallic-shaped mushrooms give off the scent of carrion which attracts a variety of flies and other insects that eat off the green slimy outer covering of the mushroom cap and thus release the spores. The spores then cling to the insects and are dispersed by them.

Other unusual mushrooms are the puffballs and earthstars. Puffball spores, which remain enclosed in the peel until they are ripe, depend upon external pressure on the covering itself (such as from an animal's foot) to make an opening and force out the spores. Keep track of the conditions that bring this about. The earthstars (*Geasters*) are like little puffballs set on a star-shaped saucer. *What happens if the star saucer is moist? If it is dry? How are the spores expelled from the earthstar?*

The various shelf or bracket fungi have a somewhat different type of fruiting body. Instead of gills to produce the spores, they have a mass of tubes that appear on the underside of the cap as pores. There is also a group of ground-dwelling mushrooms, the boletes, that likewise have pores instead of gills. Shelf fungi may grow on living or dead trees. Those on living trees generally arrived as spores at the site where a limb was broken or some other injury to the tree occurred. Shelf fungi may severely shorten the life of the tree. Some shelf fungi fruiting bodies last only one season and decay, but many persist year after year to add a new layer of active spore-bearing tissue. This normally creates visible annual rings by which you can roughly determine the age of the fruiting body and count back to the year when it first appeared on the tree. Some giant shelf fungi have been estimated to have been fruiting on a given tree for more than eighty years. Unfortunately, today there are few trees around large enough and old enough to support such a fungus for that long.

OTHER SPORE-PRODUCING NONFLOWERING PLANTS

Mosses, liverworts, club mosses, horsetails, and ferns also produce fruiting bodies that generate spores. Keep watch on each species in your area and note when these fruiting bodies first appear; how long it takes for mature spores to appear; how the spores are released; and what happens to the used fruiting bodies. Be sure to note the weather conditions and microclimate where the plants are located in order to be able to correlate plant activity with environmental conditions. With many of the ferns, the observer has to be very alert and systematic as the fruiting bodies, sori, form on the undersides of the fronds. Other ferns bear their sori on separate fruiting fronds; note when these appear and what ultimately happens to them.

PATTERNS OF GROWTH

The genetic heritage of a species builds into its development certain basic patterns such as leaf shape, size, growth habit, fruiting time, and other such structural and behavioral adaptations. Expression of the genetic heritage will often be altered by local environmental factors. Indeed, if the environmental factors are consistent enough, they may favor some genetic alterations that give rise to slight variations in the local population. These variations are not great enough to warrant new species status but are enough to recognize it properly as a local variety (*ecotype*). Familiarity with a species in one geographical area is no guarantee that the same species will respond or develop in the same way elsewhere, but that is part of the challenge of plant observing.

We can think of most flowering plants as leading dual lives—one above ground, the other below. As a seed first sprouts, a growing point sends a radicle downward to start developing the root system; an adjacent growing point sends the plumule upward to develop the stem, leaves, and later flowers and fruits. The developing plant attempts constantly to increase contact with the environment in order to take in a larger and larger share of the raw materials it needs for living—namely air, water, and mineral nutrients. These raw materials in turn allow the plant to increase its size and environmental contact up to the limits imposed by its current genetic constitution and any constraints imposed by the environment.

Certain parts of many plants, aside from the fruiting bodies, seem almost to have separate lives of their own. With most animal species we usually think of death as coming to the whole organism at once. With plants this is true of annuals and biennials, but with the perennials it is different. Leaves, and often stems, die annually, but underground parts, specialized stems, and roots live on indefinitely and send up new sprouts each year. Many of these species are very long lived but do eventually seem to lose vigor and die. On the other hand, there are those that live for centuries and appear immortal. It is mind-boggling to realize that in some of the remaining wetlands of a place like Plymouth, Massachusetts, there are humble skunk cabbage plants alive today that were probably poking up their mottled hoods when the Pilgrims arrived and for many years before.

As a young stem grows upward, you will be able to note small bumps that are the precursors of leaves. In time their cells will differentiate into the different types that make up a typical leaf. As the leaves form and the stem continues to grow at the tip, new bumps will form at the angle (axil) between the leaf and the stem. Those bumps will become *axillary buds* that may develop into branches, flowers, new leaves, or a combination thereof. Because the growing tip is the apex, or top, of the stem, it should not be surprising that buds that form there are called *apical*, or terminal, *buds*.

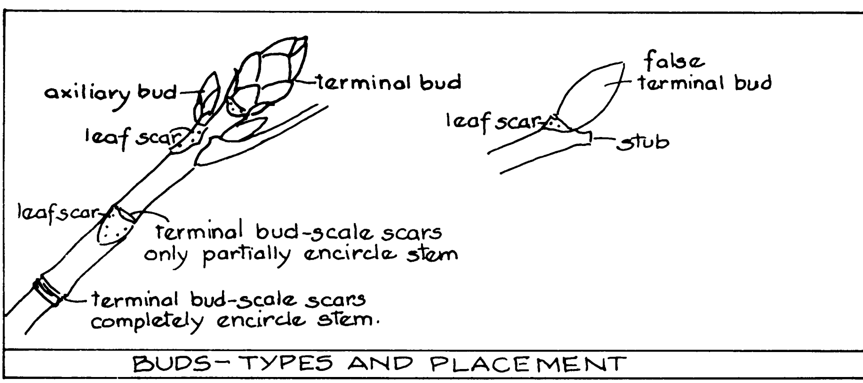


Figure 2.14

As you observe a developing plant, keep track of the number of leaves and buds that appear on the stem. Eventually the plant will stop growing upward. *Is there a reasonably consistent number of leaves on any given stem at the time it stops upward growth?* For some species this will be the case, in others not. Does there appear to be a relationship between the number of leaves on a plant and its environmental conditions; or, under unfavorable conditions, does the plant stick to a basic number of leaves but reflect the conditions in smaller leaf size and less robust stems? Does the plant have to have reached a particular development of stems and leaves before it produces flower buds? You may find that the differences you discover show correlation with annual, biennial, or perennial life-styles.

In the study area, how long does it take a shoot or sapling of a species to reach average maximum height? This will be much easier to determine in annuals and biennials than in woody perennials such as redwood and sequoias, which may continue upward growth for centuries.

What factors seem most to affect rate of growth and/or premature cessation of growth? If you compare rates of growth of annual plants, you may find that they vary from year to year in ways you can correlate with information on temperature, rainfall, mineral depletion, and other environmental factors. Seen in the context of communities of plants, these growth factors can be very important. For example, sideways growth of tree branches eventually creates a forest canopy and blocks light from smaller plants below. For some species there is an ongoing race to gain a permanent place in the sun. Differential rates of growth, based on adaptations to different factors, can determine which individuals and species will survive and how an area will change in the composition of its vegetation.

In other ways the relative rate of growth affects the success of individuals and species. The greater the growth, either in spreading leaf crown, root system, or wandering tillers, the more environmental surface there is and the more photosynthesis can be achieved. This means more photosynthates can be produced to be used either to increase reproduction or survive adverse conditions.

Make careful note of the growth habit of the species in question and of how this may change, if at all, as the plant matures. One of the first things to note is the pattern of leaf arrangement, or *phyllotaxis*, on the stem. There are a variety of patterns that are species-typical. The leaves are arranged on a stem so that exposure to light is good. Different patterns may coexist in the same habitat, so it is not a question of a particular pattern being more ideal than another in any given locale.

Phyllotaxis is usually recorded as a fraction. Choose a leaf on a stem and then count the number of leaves upward until you come to the leaf directly above the one with which you began. This number will be the lower figure in your fractional notation. You will have spiraled around the stem one or more times during the counting process. Record the number of times you circumnavigated the stem and use it as the upper figure in the fraction. Thus, on a sugar maple, with its opposite leaves, you will go up two leaves to get to the one directly above your starting point and will have gone once around the stem—a one-half phyllotaxy. There are other plants with two-thirds phyllotaxy and three-fifths phyllotaxy. There are other patterns as well, but they are less common.

Mathematicians have noted that all the patterns fall into a distinctive mathematical series described by Fibonnacci. In that series each succeeding fraction is composed by adding the numerators and denominators of the previous two fractions in the series (i.e., $1/2$, $2/3$, $3/5$, $5/8$, $8/13$, . . .). Scientists have yet to determine how or why this mathematical precision is built into the development of a plant. However, in recording information for a portrait of any given species, you should record its phyllotaxy.

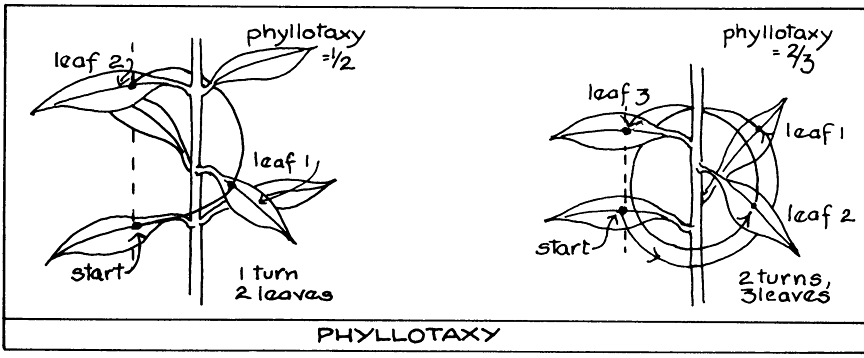


Figure 2.15

Noting phyllotaxy will indirectly lead to observations on growth habit. For some nonwoody (*herbaceous*) plants, the shoot grows only apically and any lateral growth is due to different sizes of leaves. In others, the stem grows to a height and is topped with an apical crown of leaves. Flowers are generally borne on a separate flower stalk. Many herbaceous plants show very specific patterns of branching that begin, of course, from buds formed in the leaf axils or at an apex. Much of the form or growth habit of a plant is determined by the angle at which branches diverge from the stem and the distance between branches. The angle can be determined by the use of a simple protractor. Take a number of readings, average them, and note that the angles of the branches nearest the stem or trunk may differ considerably from those nearer the tips of the branches.

Another factor that affects shape and growth habit is the shade-tolerance of individual leaves. If they cannot tolerate shade, lower leaves and subsequently branches may die and get broken off, thus altering the plant's shape. Because of this, individuals growing close together may have a very different, narrower growth habit from individuals of the same species growing widespreading, by themselves, in the open. Other adverse conditions, such as the drying effect of winds on mountain-top dwellers and salty winds along coasts, may cause changes in growth habit.

There is a wide diversity to growth patterns. There are those whose stems are not upright at all but run along the surface of the ground, with some species even putting down roots at various points along the stem. Such stems are runners, or stolons, and are typical of such species as strawberries. Then there are climbing stems that twist around nearby uprights on the way up or attach to them using coiling tendrils or suckers. There are species that send up multiple shoots from a common growth point, creating shrubby or bush forms; and there are the grasses which add new growth at their bases or near joints part way up their stems rather than at the tip. Many aquatic species have radically different leaves underwater from those in the air. These various growth habits, aside from their intrinsic interest, represent strategies for survival and various adaptations for securing resources for life from different environments. Artists as well as scientists revel in the diversity of plant forms.

Botanists recognize true stems by their microscopic anatomy and, using that knowledge, have discovered that a number of underground structures that might offhandedly appear to be roots are actually modified stems. *Rhizomes* are a common example. Found on such plants as bracken fern, Solomon's seal, cattails, waterlilies, and flags, rhizomes have many buds. In *monopodial rhizomes* the terminal bud extends the rhizome horizontally from year to year, while side buds grow up to form the aboveground leaves and fruiting bodies. Other species have *sympodial rhizomes* in which the terminal bud sends up the leafy shoot of the current year and a side bud develops a new section of rhizome that will produce a new terminal bud. Bracken has monopodial rhizomes; Solomon's seal sympodial ones.

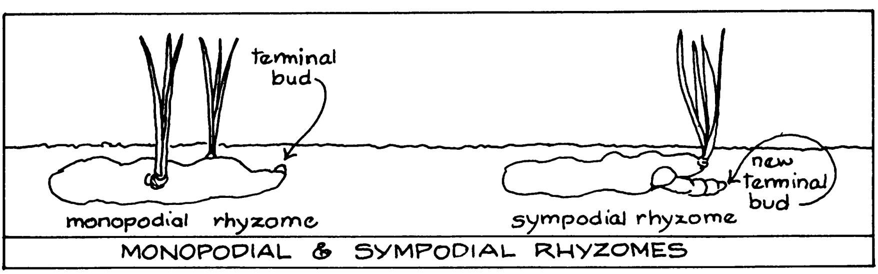


Figure 2.16

Some underground stems form enlargements called *tubers* that are highly adapted for food storage. The common potato is a good example of a tuber. Tubers are also found on such wild plants as groundnut and arrowhead. *Corms* are short, thickened underground stems. Leaves and flower stalks emerge from the top of the corm; roots below. The food from the leaves is sent below ground to form a new corm just above the old one. You might think that corms would eventually get closer and closer to the surface as the years pass, but contractile action of the roots keeps pulling the new corms down into the ground to an appropriate level. A number of spring wildflowers like Dutchman's breeches, squirrel corn, and spring beauty have corms.

Particularly in arid regions where the surface of leaves may provide too much water loss for survival, there are plants in which the whole process of photosynthesis goes on in the stem. The leaves, if they exist, are ephemeral or modified into protective devices such as thorns. In such cases, as with cacti and euphorbias, the stem tends to be thick, succulent, and green.

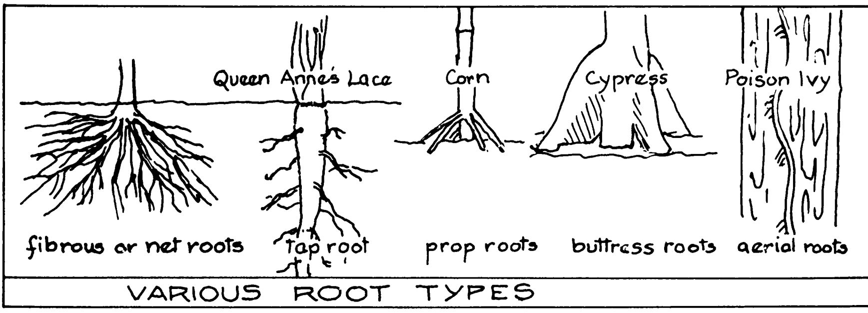
THE ROOT OF THE MATTER

Recall that the plumule that grew upward from the expanding seed developed into stem and leaves, and that there also was a radicle that grew downward. It becomes the primary root that will develop into the root system of the plant. The root system is overlooked by most observers because it is hidden from view; however, become familiar with it for it plays a critical role in the life of vascular plants and is often a key to long-term survival in harsh environments.

Roots have diverse functions. They may provide general or specialized support, absorb water and nutrients, store food manufactured in the leaves, or a combination of these functions. The determined plant observer will take time to examine how a plant's root system is distributed in space. *How far down do the roots penetrate? How far out do they spread? How far down does a root go before side roots, if any, branch out?* Two different species may appear to be occupying very similar above-ground space but actually may be occupying quite different underground space. For example, in a lawn the grass has shallow, spreading roots while the dandelion has a deep taproot that reaches down to depths of four to eight inches. During dry periods, the grass quickly exhausts the near-surface moisture but the dandelion has access to deeper soil moisture and can remain active longer.

Developing an accurate picture of a root system involves far more

Figure 2.17



work than just pulling a plant from the ground and looking at its roots. For some shallower-rooted species, it can involve digging a trench in one plane and photographing or sketching the roots as they are uncovered. A firefighter's back pump and spray mister can be used to jet-wash soil from around the roots. In some cases the plant can be dug out in a large ball of soil. Then you will have to carefully rinse the soil away to reveal the root system.

In prairie and desert soils, or in the case of some trees, the root penetration is so deep that only determination and mechanized digging equipment will permit a thorough mapping of the root system. For some trees the occasional blowdown or erosion along a stream bank will give a fortuitous glimpse of the root system.

If a plant species grows in a variety of habitats, check the pattern of the root growth in each. You may discover somewhat different patterns adapting the roots to the conditions.

When checking on root systems, use your hand lens and see if the finer roots are covered with a whitish fungal growth. This most likely would be one of the species of mycorrhizal fungi that aid the root to get water and minerals from the soil in exchange for some of the photosynthates stored in the root.

You can also note some of the ways roots respond to the underground world. *What do they do when they encounter a rock or root of an adjacent plant? Can you find places where roots rubbing together have grafted together? Where the roots have developed corky bark, how far along the root system does the bark extend?*

Not all roots develop below ground. In some species *adventitious roots* develop at nodes along the stem. Most frequently these adventitious roots are needed primarily for support. Those who have grown corn are familiar with such prop roots at the base of the stalk. In the tropics the screw pine (*Pandanus*) tree is a good example of a plant with prop roots as are the various species of mangrove. Other species may develop aerial roots that grow downward from the crown of the plant, such as the banyan tree. In Hawaii the ohia trees are often buried in volcanic ash, and in such cases they may develop clusters of aerial roots in the crown to take moisture from the clouds that regularly engulf them. The seemingly ubiquitous poison ivy is known for the adventitious roots along its stem which probe dark crevices in bark and help the stem become a climbing vine under certain conditions. When the leaves have fallen, this pattern of adventitious roots lets those "in the know" recognize it from similar climbers such as woodbine.

There are tree species in which there is thickening and vertical extension of tissue from the base of the stem out along the roots to form buttresses. These buttress roots appear to give the tree greater support from the forces of the wind. The "knees" on cypress trees are another strange root formation. These are upward extensions from the roots that grow above the surface of the swampy waters in which the cypress trees live. The function of these "knees" is not completely clear, but it has long been assumed that they help the roots breathe.

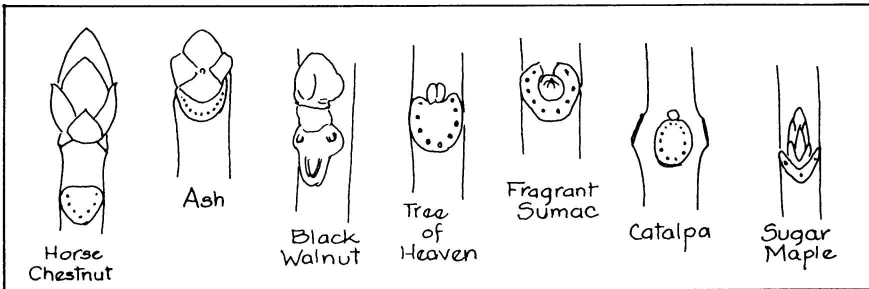
Competition for root space is strong. Where intake of water and nutrients is the primary root function, the plant extends its roots as rapidly as possible to maximize its control of the local resources in the soil. Dominance by the roots of one species may quite successfully prevent the establishment of the young of another species, or even the young of its own species. The roots of some species exude chemicals that deter the growth of other plants.

Just as the above-ground portions of a tree have their enemies, so do the roots. Check them for insects such as the larvae of beetles and cicadas, nematode worms, and others. Heavy infestations may effectively prune the roots and limit the size of the stems and leaves they can support.

THE LIMITS TO LIFE

With most higher animals, we perceive decline and death to occur to the whole organism at once. This is only an illusion, because different organs tend to age at different rates and death of all the body cells actually occurs over a period of hours. Differential aging of the various parts is generally more apparent with plants, particularly perennials. The plant observer gathering life history material will note the time when different flower parts first appear and when they are shed. He or she will note when individual leaves first appear and how long they live before they yellow, shrivel, and drop off the plant. As track is kept of a number of leaves on a plant, some indication may be found as to whether the life span of a leaf seems to be guided by some internal clock or by a fate that is primarily environmentally determined. This is more of an issue in tropical and subtropical plants, as well as among evergreen species in temperate climates.

In temperate climates the perennial deciduous species build up a corky layer at the base of their leaves that seals off the tubular plumbing systems of the plant (the *xylem* and *phloem* tissues), effectively sealing the doom of the leaf for that season. That corky layer is known as the cutting-off or *abcission layer* and it creates a distinctive scar when the leaves fall. The chemicals trapped in the withering leaf undergo a variety of changes that provide the sequence of colors of the dying foliage. Since the percentages of these chemicals and their mix tends to vary with the species, it is not surprising that the colors do as well. A careful observer will be able to identify many species of trees and shrubs at a distance by the subtle differences in the fall foliage colors: the bronzy-purple hue of white ash; the deep red or yellow of red maple; the orangy red and yellow of sugar maple; or the yellow of birch and aspen.



EXAMPLES OF LEAF SCARS

Figure 2.18

If there is annual or seasonal die-back of parts of a plant, keep track of the normal amount. Is it just the most recent succulent growth? The leaves only? The stem back to the ground? Or back to the transition zone between stem and root, wherever that may be? The grasses and other plants of prairies and marshes also have their distinctive colors as they die back to their roots.

Do not neglect what is happening underground. Often underground parts also regularly die back, leaving only a tuber or apical growth bud to regenerate new life. If you carefully map the location of some plants year after year, you may get the impression that a plant is slowly marching away from the point where you first spotted it. Indeed it may be, as the previous year's growth dies away and the next year's plant emerges at its tip or side.

You will want to keep track of the life span of the various species you are studying. For the annuals and biennials this is generally easy, but don't take these categories for granted. Biennials growing in poor habitats may live in the rosette stage for more than one year. They keep accumulating food in their roots until they have a sufficient supply to generate a flowering and fruiting stalk. For annuals and biennials, the flowering/fruiting process is usually the death knell for the plant. Having expended most of its accumulated photosynthates once the fruits are made, the plant loses vigor, becomes senescent, and dies.

With perennial species, determining the life span is less simple. Some are virtually immortal; many, although long-lived, begin to show a gradual loss of vigor and die. It is hard to think of small plants living so long. I have a red trillium (*Trillium erectum*), or wake robin, that I collected from the wild as a youngster over thirty years ago. It has been transplanted to two different homes, and yet it continues to thrive. There is no way of knowing how old it was when collected, and it will probably outlive me.

You will also want to keep track of the mortality factors affecting mature plants. Frequently these may be insects or disease but may also be changing light, temperature, or moisture conditions, or nutritional depletion from the competition from other species. Gathering such information will be a slow process based on many observations and notes taken over an extended time.

As individual plants age you may notice a decline in their rate of growth, amount of growth, and reproductive ability, as indicated by frequency of flowering and amount of flowers produced. Such information helps round out the picture of the life stages of that species.

PLANT BEHAVIOR

Plants may lack the nervous systems of animals and remain relatively stationary throughout their adult lives, but they are nonetheless sentient—that is, they are perceptive of some aspects of their surroundings. The mechanisms for perceiving and responding seem largely to be different from those of most animals, but they do function. The careful and persistent plant observer will note these actions even if their means is not clear.

Many species orient their leaves toward or away from the sun throughout the day. *What is the pattern and time sequence? How is it affected by overcast days?* Use your hand lens to check the donut-shaped cells, the *stomates,* on the underside of a leaf. Is there any correlation between the leaf orientation and whether the stomates generally are open or closed? Many flowers also follow the sun.

What happens to the leaves at night? Some keep their daytime positions, while others take on a new attitude. That new attitude is sometimes referred to as a sleep position.

Stems may also show a definite growth movement toward light and thus affect the growth patterns of the total plant. A plant that gets pushed over may show a sharp bend as the growing point orients toward the light or away from the Earth's gravity. Depending upon the direction of the response, it is referred to as positive (toward) or negative (away). Different parts of the same plant may respond oppositely to the same stimulus. For example, the plumule of many seeds is negatively geotropic, whereas the radicle is positively geotropic.

Most stems are negatively geotropic, growing away from gravity's pull even in darkness. Roots are generally positively geotropic, growing downward toward the earth, but study of root systems shows that this is not universally the case. Many grow underground, parallel to the surface of the soil, apparently reacting more negatively to light than positively to gravitational forces. You will also see geotropism at work in the orientation of the gills and pores of most mushrooms.

If a plant has tendrils or a swinging stem for climbing, be alert for *thigmotropism,* the phenomenon of response to touch. The tendrils grow out and wave about, but if they make contact they quickly begin to spiral about and grasp the object they have touched. In some plants, the tendril may even shrink once the spiral has been completed, thus pulling the plant closer to its newfound support. Such thigmotropic behavior is characteristic of some adventitious roots as well, like those of poison ivy.

The leaflets of mimosa plants show a rapid response to touch by quickly drooping together. The traps of some insect-eating plants also are activated by touch, for example, the Venus'-flytrap, and some soil fungi create loops to snare nematode worms.

Many plants respond to water. It's common to speak of roots following water gradients in the soil as *hydrotropism*, but evidence for such is very slim and shaky. Some trees, however, like elms, willows, and poplars, have a propensity for finding cracks in water pipes and entering them with their roots. On the other hand, rapid changes in internal water pressure, or *turgor*, account for the mechanism of a number of plant movements—such as the opening and closing of the breathing pores (*stomates*) and the sleep movements of leaves. Some grasses, such as beach grass, have grooved leaves with cells that may lose water and shrink during drought. This results in the leaf curling into a tube to help prevent further water loss through transpiration.

On a different time scale, the plant observer should be alert for evidence of coevolution, the adaptation of plants to interactions with animals. Sometimes this evidence is relatively simple to find, such as the development of protective thorns and spines or the production of toxic chemicals as defensive weapons against excessive predation. In other cases it is much more complex and involves modifications for pollination by specific animal groups or even species, such as bats, butterflies and moths, and bees. There are also defense mechanisms whereby certain insects such as ants or wasps are attracted and accommodated with the benefit to them that these mechanisms, thorns and the like, provide effective deterrent action against browsing creatures. Such complex coevolutionary developments are more common in tropical and subtropical regions. The development of partnership between mycorrhizal fungi and some plant roots is yet another example of coevolutionary behavior. The relationships develop and generally become refined as they increase benefit to the participants, resulting in some survival advantages over others of their kind.

What you will want to note is what other species regularly attempt to interact with a plant in a *co-action*, and how the plant responds to the attention—i.e., by chemical or mechanical repellants, attractants, or toleration. Note also what adaptations the animals have for responding positively to the attractants or for circumventing the repellants.

We have implied that there are two major categories of plant behavior: (1) responsive, as in the case of tropisms, and (2) adaptive, as in the case of protective and attractant devices. Another form of adaptive behavior to note is the mechanisms for expanding the populations of the species. These mechanisms are discussed in the section on reproduction, but the alert observer will be looking at not only the simple mechanism but at how that mechanism creates a strategy for perpetuating and expanding the population of a species as well as how the individual plant reproduces. We will discuss the nature of various strategies and their investigation more fully in Chapter 6.

GENERAL INFORMATION

There are a number of odds and ends to be noted about a plant to round out its life history and compose a more complete description of the species. Some are related to individuals of the species, others to the local population of the species and the other species with which it associates.

Resistance to environmental stress. Plants face a variety of stresses from the physical and biological environment. Determine and note such things as resistance to drought, flooding, burial in sand or mud, intense cold, frost, water-table fluctuations, salinity (from road salting as well as coastal or arid-land salinity), fires, ice, grazing, trampling, and similar phenomena. Don't forget the impact of human activities such as logging, tilling, herbiciding, and many others.

Population Data. *What is the average number of individuals per unit area for the species in your region? Does any particular age class dominate your area of study? Is there a good range of age and/or of size class that indicates a stable population or does the population seem to be increasing or declining?* For methods of determining such information you will want to explore Chapter 7.

Species Associates. *What other species are usually present in the same general area as this species? Are there some that are always present? Are there species that tend to appear when populations of the study species begin to decline?* Chapter 6 helps you explore such relationships more fully.

Variability. A major effect of sexual reproduction is to produce variability. Much of the variability will never be expressed in a mature plant; the genetic alteration is nonadaptive at the moment. It seems to be a very wasteful lifestyle, yet if conditions change slightly there is a chance that one of the variants may be suited to the change and will survive to pass along its uniqueness to the following generations. In addition, a number of variations are produced and survive because they are not maladaptive—that is, they do not seriously affect the plant in any negative way. These we search for among a population of plants. Some species seem quite plastic and produce a large number of subtle variants; others show a small degree of variation. These latter species will probably be most vulnerable to environmental alterations by humans or nature. Populations developed vegetatively, in particular, show low variability and thus a high degree of vulnerability to environmental changes.

Habitat Preferences. Once a plant sprouts from its seed coat and sends down its radicle, it is locked into a site. It can't decide it doesn't like it there and get up and move elsewhere. Either the habitat is right and the young plant becomes established and thrives, or it dies. Depending upon the degree of suitability of the site, the death can come swiftly or linger over a period of time as the too-limited resources are gradually exhausted or competition for them becomes excessive.

You will want to note many things about the sites where a species is growing successfully and also about those where it grows with obvious lack of vigor. *What are the characteristics of the soil, its texture, nutrients, depth, erodability, and the like? What is the pH of the soil? What are its water-holding characteristics? What kind of microclimate exists where the species grows—that is, what is the surrounding vegetation, slope, exposure, altitude, or other factors affecting insolation, wind, heat and moisture? What are the general stresses of the habitat, such as recurring flooding, persistent wind, periodic fire, or erosive forces?* Gathering aspects of such information is explored more fully in Chapter 5.

FOR EVERYTHING THERE IS A SEASON

In building an account of a species, we want to build a chronology of the events in the plant's life, particularly the recurring seasonal events such as appearance of seedlings, first leaves, flowers, shedding of pollen, ripening of fruit, and dropping of leaves. We may be able to correlate such events with environmental conditions such as day length, rainfall patterns, and temperature averages. The science of such seasonal events is known as phenology. It is a particularly rewarding activity for the dedicated amateur plant observer. The beginning phenologist usually notes only the big, obvious events such as the date the first blossom of a species occurs, but once hooked he or she begins to elaborate more fully, noting not only first and lasts but when the bulk of the local population is blooming and records of other events.

With each species be sure to keep a record of what months some part of the plant is observable above ground and note the gross changes to be expected. For example, many weeds are visible all winter if you can recognize the forms of their dried stalks, rosettes of basal leaves, and/or seedpods. Such materials look quite different, however, from the more vibrant living stems and leaves—different but still beautiful.

Date	Species	Event
		tips of leaves first appear above ground
		folded leaves completely out of ground
		leaves completely unfurled
		flower buds appear above leaves
		first flower opens
PHENOLOGICAL RECORD FORM		

Figure 2.19

Phenological records can be kept in charts such as those illustrated in Figure 2.19 or on regular calendars from year to year. Reflecting on several years' data may indicate whether certain recurring events are more under the control of some form of internal clock or are more variable and responsive to weather conditions. More detail of procedures for keeping phenological records is presented in Chapter 4.

SUMMARY

In this chapter we have suggested many of the questions to be asked about a plant species if you truly want to know it. Most of these questions can be answered about the species by patient and persistent observation. Some answers will be found reasonably quickly; others will emerge only after many years and an occasional bit of luck. Plant observing is an activity for a lifetime, actually several lifetimes. No matter where you are or what the season of the year, there are plant observations to be made. For the avid plant observer, time seldom weighs heavy on the mind. And of course there are many more questions than have been set forth here that might be asked. As you become more deeply involved, these will come to you and you will seek their answers.

FURTHER READING

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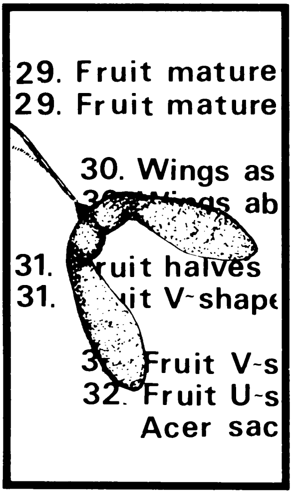

CHAPTER 3

THE KEY TO IDENTIFICATION

You don't have to know the technical name of a plant to make extended observations on its life history, but chances are that the more familiar you become with a particular type of plant the greater will be your desire to know its botanical name used by serious amateurs and professionals. Your initial involvement with field botany may come to focus on developing a species inventory of an area of particular interest to you or perhaps you will find significant enjoyment in getting to know the identity of as many different plant species as possible in whatever area of the globe you may find them. Whatever the motivation, tracking down the proper identification of any specimen involves close observation, development of skill in working through various identification "keys," determination, persistence, and appreciation of the complexities of the plant world. It will also take you on a voyage into the esoteric language of botany.

TAXONOMY: AN IMPERFECT ART AND SCIENCE

Over the past several centuries scientists have been examining closely the similarities and differences of various living things on this planet. They have attempted to create systems of categories into which they can logically arrange the variety of life forms. As more and more information has accumulated and been evaluated, the various systems of classification have become increasingly sophisticated. But even the system we use today is only our present approximation of actual relationships and is constantly subject to fine tuning. The rationale behind the current scientific classification, or *taxonomy,* of living things is the alleged evolutionary relationships among the various categories, or *taxa,* of life forms. As we add to our knowledge of each taxon, views often change about the degree of closeness of relationship to other taxa. In spite of our human desires to have neat, fixed sets of pigeonholes into which any given life form can be placed, nature refuses to cooperate fully and we are left with a certain amount of confusion. The taxonomy of plants is no different in this respect than classification of other life forms. All retain a certain amount of fluidity that defies precision.

THE NOTION OF SPECIES

The basic unit of plant and animal classification is the *species.* At first glance it seems to be a clear enough concept; by definition all members of species should be able to interbreed and produce viable offspring that closely resemble their parents. But examination of almost all species shows a range of variation that is open to interpretation as to whether or not it is significant enough to deserve separate identity as one species. Perhaps taxonomists should split it into two or more species or perhaps lump it along with another closely related species.

Be aware of problems in identification and take them in stride as you attempt to hurdle them. Some variant specimens may be strikingly different in appearance from other members of the apparent species. Experiments in laboratories or test plots may show that variants interbreed normally with others of their apparent species even though they seldom get the chance in nature because of geographic isolation. In other cases, plants of a species may show individual variation as a response to local differences in the environment. Such genetic variants or ecological variants sometimes may be classified as *subspecies* or *varieties.* Some hybrids in the wild are the offspring of a cross between two distinct species. Some hybrids are fertile and produce vigorous second-generation offspring while others are partially or fully sterile. Hybrids show characteristics of both original parent species but not all the characteristics of either parent. All such variations present problems in trying to make a firm determination of species affiliation on some specimens. Because of different reproduction strategies, some plant groups are more susceptible to confusing variations than others. For instance, beware of sedges, hawthorns, and hawkweeds!

It is not my intent to confuse or discourage you with this discussion, but rather to help you understand that it is quite reasonable to expect that any given plants you may be trying to identify to species may not fit neatly into one of the preconceived species boxes presented by any of the identification tools we will be discussing here. Even the so-called experts do not agree on just what constitutes the boundaries of the various taxa or how many species the known variations in a group represent. Some classifiers, taxonomists, and considered lumpers—that is, they lump together plants with several "minor differences" into one species. Others are splitters. They give greater weight to those "minor differences" and therefore describe two or more species in the same population. In *Taxonomy of Flowering Plants,* taxonomist C. L. Porter sums it up in slightly more technical language thusly: "It must be apparent that no universal definition of species is likely to be forthcoming even though a definite concept may be formulated for any group of plants. When plants reproduce by purely sexual means, in the usual fashion, the problem is more easily resolved on the basis of sterility barriers and overall morphology and geography. But when plants reproduce asexually, by apomixis or other means, only experience and judgment can bring about a reasonable working system of classification. Perhaps it is reasonable, for practical purposes, to interpret a species as a recognizable and self-perpetuating population that is more or less isolated genetically as well as by its geographic distribution and its environment."

While doing field studies, we do not have to be overly concerned about such professional taxonomic differences except to recognize that they do exist and that our best attempts to come up with a positive species identification may be thwarted. It is usually possible to key a specimen to its larger categories of family and genus without identifying it to species; that initially is enough if you carefully prepare a *voucher specimen* of the plant under study so that at a later date you and the botanical experts can focus on a more precise determination to species. (Instructions for preparing voucher specimens are given in Chapter 4.)

POPULAR GUIDES TO IDENTIFICATION

Over the past half century, botanists and naturalists have devised popular guides to the identification of the more common or conspicuous plant species. These guides tend to recognize an average person's aversion to working his or her way through most technical botanical keys or sorting through the specimens in an herbarium to match a labeled specimen with the unknown one in order to identify it.

In presenting his visual approach to wildflower identification, Roger Tory Peterson, an artist-naturalist, wrote: "Some people, those with orderly minds, are able to use keys in running down their flowers, but many throw up their hands in despair because of the bewildering terminology. . . . However, if one can master them, keys are the proper formal approach to flower identification. But, I am afraid, most of us belong to the picture-matching school, and it is for this audience that our *Field Guide* has been planned."

Today, most people who want to learn to identify wild plants begin with one or more of such popular, visually oriented guides. All of them depend fundamentally on such visual cues as color, shape, and discriminating details of form. In the early part of the twentieth century, artist-naturalist F. Schuyler Mathews developed two of the most successful early visual guides to identification—one for wildflowers, the other for trees and shrubs. More recently, Roger Tory Peterson refined the approach through more carefully delineated line drawings and paintings enhanced by arrows pointing to the most discriminating diagnostic features. His system has been used by other authors in the field guide series he edits, the Peterson Field Guide Series (Houghton-Mifflin), which provides assistance for identification through picture matching of more plant species than any other.

Over the years, field identification guides have also been produced that based their illustrations on color photographs rather than on drawings and paintings. Most of these have not been truly satisfactory in large measure because reproduction of color photographs has been relatively expensive and, to save money, most guides clustered many species on a page with such small photos that identification is difficult. By the 1970s, reproduction of color photography had so improved in cost and quality that one publisher, Alfred A. Knopf, put forth a series of field identification books based entirely on the use of color photos. The Audubon Field Guide Series has guides to wildflowers, trees, and mushrooms, and given its popularity will undoubtedly produce guides to other plant groups.

These visually oriented identification guides have strengths and weaknesses that should be borne in mind by those planning to use them. Their biggest plus is relative ease of use because they depend largely on visual comparison for the first cut at eliminating species unlike the one you wish to identify. As Peterson said, it's mostly picture matching and you do not need to be aware of the subtle shades of meaning of hundreds of descriptive botanical terms.

Most of these guides arrange the species according to the color of their flowers, which is often their most obvious characteristic. But there can be confusion in some species. White trillium blossoms, for instance, change from white to deep pink as they age. You would tend to look up an older bloom in the red category and you usually would not find it there. You would have to know by other criteria that although the specimen's color was different from others growing nearby, it was not a different species. Similarly, you may find an orchid that looks like pink lady-slipper (*Cypripedium acaule*) but has a pure white flower. If you look it up in the section on white blossoms, you probably would not find it, because it is a genetic variety (*Cypripedium acaule* var. *alba*). There are any number of examples of this sort that could be cited but these give some indication of a weakness of this color-based system of sorting out species.

Among the guides, the illustrations vary in their accuracy and method of presenting the most diagnostic features of a species. Photographs, despite their realism, illustrate only one example of a species. Given the variability within any particular species, your unknown specimen may look very much like the guide's photo or it may appear disturbingly different yet still be that species. Drawings, of course, can share this same weakness, but the artist can alter things to present more of the variations of the species within the one drawing and also can carefully change leaf position or make other perspective changes that will better illustrate a diagnostic feature. Thus, many people still feel that, unless photos have been exceedingly carefully selected, an artist's renderings are more useful than photos in identification. There are, of course, some things that are usually more effectively presented by photos than drawings, such as tree bark. Each approach has its advantages and drawbacks.

I find that no one system or series is satisfactory by itself. Normally I use several field guides in making a determination, cross-checking one against another. For one thing, there is no visual guide to all the plant species of a region, and different authors make different determinations about which species they will include in their guides. One field guide to a geographic region may include my unknown specimen while it is absent from another guide to the same region. It seems to be one of the infamous Murphy's Laws that I always look in the latter first!

Pictorial guides use clues to identification that are not necessarily based on the anatomical features that plant taxonomists use to determine the evolutionary relationships of species. Such keys are termed *artificial keys* as opposed to the *natural keys* of technical literature. A major concern of many botanists is that people who learn to identify plants by using the popular artificial keys are not apt to come away with any basic understanding of the fundamental characteristics of the major plant families. To the beginner at plant identification this may seem unimportant, but as you become more deeply involved you will find yourself wanting to identify plants not included in the usual field guides. It is then that the lack of knowledge of plant family characteristics begins to emerge as a distinct handicap that results in spending inordinately more time than necessary in trying to use the technical keys. Among the visual field keys, those in the Houghton-Mifflin series use a symbolic set of clues to the plant families—based on the key characteristics of the families—to help those who desire to gain some basic knowledge of the family characteristics and the genera and species that share them.

ON TO TECHNICAL KEYS

Why is it so important to become familiar with the family characteristics? Sooner or later you will have to turn to technical keys to identify some plant or plants that have stimulated your curiosity. Most of these are in thick tomes that include several thousand species usually arranged according to approved botanical order. The hierarchy of arrangements is as follows:

Phylum
  Class
    Order
      Family
        Genus
          Species

The first three taxa are large categories helpful as a quick start in deciding what part of a kingdom your to-be-identified specimen belongs to.

The family level of the hierarchy is the taxon, where the next very important cut can be made in deciding what species are irrelevant in your search to narrow down the choices to one. You will want then to determine the proper genus within the family in which to search further among the various species to find the one that matches your unknown specimen. Coming to terms with the use of technical keys involves two basic skills, mastering the puzzle-solving structure of a key's format and mastering botanical terminology. Both involve a certain mind set, concentration, and determination.

Although most people today begin with the popular picture-matching guides, there are a few popular field identification guides and simple keys that allow for a reasonable transition to the highly technical keys of such standard references as *Gray's Manual of Botany* and *Britton and Brown's Illustrated Flora.* These include Ricketts' *New Fieldbook of American Wildflowers* and a number of volumes of the Wm. C. Brown Company's Pictured Key Nature Series. These books attempt to simplify the botanical terminology and provide illustrations for some of the terms. Ricketts' book also has many of the characteristics of the picture-matching guides.

WORKING A TECHNICAL KEY

The basic concept of a technical identification key is quite simple. You are given a set of descriptive choices, or leads, in the form of phrases or sentences. Normally there are two such choices forming a couplet. A *dichotomous key* is composed of such couplets but in other kinds of keys there may be more leads. Each lead of the couplet is given the same number and a letter designation. You make an appropriate choice from the leads and follow the line to the right, where you will either find a number that represents the next set of choices you should pursue or the name of the taxon you have been seeking. If the latter, you have completed your quest. The number of choices you will have to pursue before reaching a final determination is highly variable.

Another common form of key frequently used by botanists has an indented format; each successive set of choices is indented further from the left margin of the page, thus obviating the need for numbers. Formats that vary significantly from these two formats are usually explained in a users' note at the beginning of the key.

Observe the following common-sense rules in working specimens through a key:

1. Read through each of the choices or leads very carefully, even if the first statement appears to be the appropriate one. You may find that another lead is even more descriptive of your specimen.
2. If measurements are given in the key, actually measure your specimen. Don't guess.
3. Where technical botanical terms are given, look up the exact meaning if you are uncertain about it. Again, don't guess.
4. Don't base conclusions on an inadequate portion of a specimen. Even on a single plant there will be a certain degree of variability, so if possible use observations of several specimens of the same type to arrive at your determination. Another of Murphy's Laws is that given random choice a beginner tends to choose the most atypical part of a specimen upon which to base determinations!
5. Key makers are, after all, only human, so sometimes choices clear to them are much less clear to others. When you come to an unclear set of choices, follow each lead to see if the information of one of them perhaps relates to your specimen.

Some people get a great deal of pleasure from working specimens through the various choices of a technical key to arrive at a final determination. There is the same kind of challenge as solving a mystery story or finding the solution to a puzzle. Keying often has the added challenge and frustration of running a maze, for there may be blind alleys that lead nowhere or to a false conclusion.

Errors may occur because of imperfect construction of the key itself, but more frequently it is because of pitfalls inherent in unfamiliarity with botanical terminology and failure to follow common-sense rule 3 above. The potential for confusion is highlighted by Peterson's note that "There are at least 60 ways of saying that a plant is not smooth. They range from aculeate, asperous, and bristly to villous, viscid, and wooly." Each has a very specific technical meaning to the botanist and represents a broad range of subtle differences. Despite the implications of their supposed exactitude of meaning, not all botanists use the same term for the same given shade of variation in a plant's structure. Thus, you may have a slightly different impression of a character mentioned in a key than did the person who prepared it. This may well lead you down dead ends and byways in a key which, depending upon your personality, are guaranteed to heighten either your fun or your frustration. Technical keys seem most enjoyable to people with orderly minds and a capacity for using words in a precise and narrowly defined manner. For others, they remain an all-but-unescapable necessary evil.

FACING THE LANGUAGE OF BOTANY

In a modern, living language, words tend to go through historical changes in use and meaning. What may begin as street slang may end up in broad common usage. For example, grass once meant those plants of lawn, hayfield, and high plains; today it is commonly used to refer to the distinctly ungrasslike marijuana and to "bluegrass" music. Such shifts in meaning in a living language make any commonly agreed-upon, precise meaning for words to some degree ephemeral. If such precision were possible, there would be little need to update our standard dictionaries periodically.

On the other hand, science has a strongly felt need for stable, precise meanings for words. To achieve stability, a so-called "dead" language, Latin (augmented with classical Greek), is utilized. Since no modern peoples speak Latin today as a daily language, the meanings of its words and word endings remain reasonably fixed and thus more precise. Actually, the language is not truly dead, for it is modified by the construction of new words by the Vatican and scientists who may Latinize words to use in scientific names to keep it up-to-date with new discoveries and inventions. This use of Latin meets the needs of professional scientists reasonably well but tends to frustrate the amateur who finds him- or herself learning new subject matter by means of a new and strange language.

However, scientific names and technical terms are understood by scientifically oriented people of many languages. Whether the people of a nation know the common, yellow-flowered, dooryard plant as a dandelion, *dent de lion*, or *los dientes del leon*, their botanists will all know it as a member of the genus *Taraxacum*, and most likely as *Taraxacum officinale*. Each species has its binomial name composed of a Latin noun to designate the genus plus a Latin adjective to designate the species. Many people are most frustrated when they face a scientific name because they are baffled by how to pronounce it. They see each term as a potential tongue-tripping embarrassment, throw up their hands, and give up. It is seldom realized how many such technical names are now in everyday usage—for example, chrysanthemum, gladiola, clintonia, trillium, nasturtium, and spirea. Others differ only slightly from the Latin term—violet (*Viola*), lupine (*Lupinus*), rose (*Rosa*).

Interestingly enough, in spite of the rigid rules for writing Latin words, there is no common agreement on proper pronunciation. Language expert Mario Pei suggests the following guidelines to help build your courage in saying the words without feeling foolish.

"LONG" VOWELS	"SHORT" VOWELS
a, like *a* in "father"	*a,* the same sound, but shorter
e, like *a* in "mate"	*e,* like *e* in "met"
i, like *i* in "machine"	*i,* like *i* in "it"
o, like *o* in "no"	*o,* like *aw* in "awful," cut very short
u, like *oo* in "food"	*u,* like *oo* in "good"

DIPHTHONGS

ae like English *eye* or the *i* in life

oe like *oy* in "boy"

au like *ow* in "how"

eu like the *e* of "met" quickly followed by the *oo* of "good" essentially as in the word Europe or useful.

CONSONANTS

v takes a *w* sound in Latin, but we seldom do it today. Classically violet would be pronounced *we-o-let.*

c is pronounced like a *k* except before *i* and *e* when it takes the sound of the modern language you speak.

g is given a hard sound as in "get," again with the exception of when it precedes *i* and *e* and uses the modern language standard.

sc is usually pronounced like modern *sh.*

ti before a vowel is sometimes pronounced *tsee* today.

j is pronounced like the *y* in "you".

Thus, our dandelion's *Taraxacum officinale* can be pronounced approximately as follows: *ta-rocks-ah-coom of-fish-i-nal-e.*

If you are exploring the plant world on your own, taking the effort to cope with botanical language may seem like a lot of work for nothing. But if you start fraternizing with serious amateur or professional botanists, read in botany books, or try to key out uncommon species in the technical keys, you will soon find yourself lost if lacking some familiarity with the language. I still recall vividly my first awakening to this fact. As a college undergraduate with a primarily zoological background, I set forth one bracing fall day with one of my biology professors and his botanist friend on a canoe trip into a local wild area to survey it as a possible acquisition by the Nature Conservancy. Before long I felt as though I had set forth with a couple of Chinese for all of their conservation that I could understand. I knew the common names of the trees, shrubs, and wildflowers we were drifting past, but they communicated only in a rapid-fire string of scientific names that were hastily scribbled down in a notebook. I knew almost none of those scientific names but was embarrassed to admit it, so I spent most of the trip in silence and ignorance, forced to be content absorbing the pervading beauty of the place. I vowed that I would never let myself get caught in such a situation again.

The next day I set about listing all the native trees and shrubs on campus or at least those that I passed on my various daily routes. I then wrote down each plant's scientific name and began memorizing. Each day as I walked to and from class I would greet each species by its proper name—"Good morning, *Thuja canadensis*"; "Good morning, *Ulmus americana*"; "Good morning, *Lyriodendron tulipifera*," and so forth. Soon these names flowed as easily from my tongue as everyday English, and adding scientific names to my vocabulary came much easier as I learned new species.

Acquiring and remembering the technical, descriptive terms of botany also comes more easily when you are using them every day. Some terms are used extensively with one group of plants and hardly at all, if ever, with others. Without regular use, the subtle differences between and among terms quickly fades from memory. For this reason most technical keys have an extensive glossary so that you can look up new terms and refresh your memory on others. *Gray's Manual of Botany* (8th ed.), a major standard reference, lists 1,141 technical terms in its glossary. One difficulty in coping with technical descriptions is that you are often faced with a string of unfamiliar terms, not just one or two. Thus, you may generate a breeze flipping back and forth between the description and the glossary!

The use of technical terms is not confined to heavily technical books. This is even more reason to become botanically literate as you become more deeply involved with plant watching. As an example of what you might expect, I offer the following quotation from a delightful and informative book on ferns. Written in 1901, *Our Ferns and Their Haunts* by Willard Clute is full of interesting information about the habits and habitats of these graceful plants along with descriptions:

> All the Christmas fern's fronds are produced early in spring. They rise in circular clumps from a stout rootstock and when uncoiling are thickly covered with silky-white scales that make them conspicuous objects in the vernal woods. As the fronds mature, the scales turn brown and many remain upon rachis and stipe, especially the latter, through the seasons. The fronds occasionally reach a height of three feet, and are thick, narrowly lancelolate, acute and once pinnate. The numerous narrow pinnules have finely serrate margins and are arranged alternately on the rachis. Each has a triangular ear on the upper side at base. The fertile fronds are taller than the sterile and differ in having the upper third or half suddenly decreased in size, this part bearing the sporangia. The sori are arranged on the under surface in two or more rows lengthwise of the pinnules with two other short rows on the earlike projections. They are partly formed before the fronds unfurl and ripen early in the year, being among the first of our species in this respect. The sporangia early push out from beneath the peltate indusia and make fruiting pinnules look like little assemblages of tiny brown anthills.

Approach botanical lingo as you would any other new language. Discover which are the most basic terms for whatever group you are working with and memorize them. You may even want to go so far as to make up vocabulary cards with the term on one side and its meaning on the other. In spare moments you can work through these "flash cards" to reinforce your memory of the terms. As you master the basics, you will add some of the less common terms to your collection of flash cards and eventually to your mental repertoire. It generally takes much less time than you originally expected before the once strange and frightening language of botany begins to look much more familiar and friendly. Like many new ventures, mastering the language of botany is best accomplished by taking one step, and one day, at a time and patiently refusing to be cowed by the strange and unfamiliar. Ultimately it is cracking a secret code that opens new avenues of excitement and happiness.

FURTHER READING

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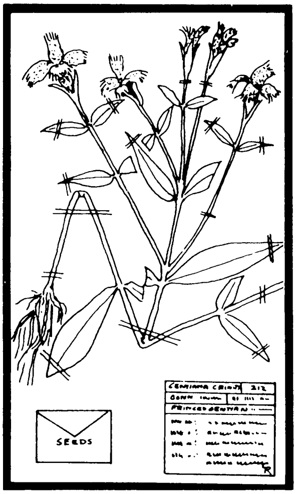


CHAPTER 4

FOR THE RECORD

There is much to be said for quiet walks through field, forest, mountain, meadow, or desert draw to enjoy the various beauties of the vegetation and revitalize the inner spirit. Under such conditions the only record necessary is that etched in the deep recesses of human memory. Detail is unimportant—only the broad impact on the emotions need be recalled, the sense of mood engendered.

However, if you want to go beyond such generalities and for any purpose retrieve details of field observations and experiences hours, days, or years after they have happened, it is important to develop the skills and habits of keeping notes and records. A serious amateur botanist is always accompanied by a companion, a field journal. This is simply a notebook that holds a continuous record of your field excursions and the observations you have made. It is normally a blend of words and sketches but may include pressed leaves or other preserved plant parts.

THE FIELD JOURNAL

A field journal can be a rather informal memory-jogger used to recall pleasant and stimulating observations when you are stuck at home during inclement weather or when for some other reason you can no longer go afield; or it can grow into a more disciplined record of your observations and studies serving as a data base for your longer-term plant studies. It may also be used as a valuable resource for others.

Some basic conventions are useful. Each journal entry should carry its date, a description of the geographical location of the observation site, and general observations on the weather. It is also useful to make note of any others who may have accompanied you on the field excursion. (They may be helpful at a later date in cross-checking some fact from their notes.) After such standard information, enter your observations about the plants of the site; these might include lists of species, notes on growth, phenological information, plant/animal interactions, ecological data, and related matters.

Description of the geographical location is very important if you, or someone else, are to relocate a site years later to determine if certain species are still there. It should therefore be done precisely the initial time you visit a particular site. Record not only the broad indications of town, county, and state, but also present careful road directions and/or geographical coordinates from the appropriate topographical map. Such detail is consumptive of time and space, and we all quickly rebel at writing up a description for each visit to the same site. Instead, assign a number to each site at the time you prepare its first detailed description. This number is used as the site descriptor on each subsequent return along with a parenthetical note as to where the original description occurs in your series of journals (i.e., Locale #46—see Field Journal 3, page 15). This site number can also be attached to the labels of any voucher specimens collected or on soil samples, photographs, or other pertinent materials.

Few people are guilty of taking overly detailed notes. Record as much information as you can at any particular location. Some of the information may seem irrelevant at the moment, but at some later time, as you ponder the data you have gathered, you may discover an apparent correlation that seems important. It is most frustrating to go back through older notes to locate additional supportive data only to find that you didn't bother to record any comparable information at all.

Try to think of the particular plant not by itself but in its context. Describe its habitat, locale, plant and animal associates, altitude, exposure, soil condition, and any other information that might possibly be influencing the plant's growth, health, and well-being. This is a difficult discipline to foster in the field, because there is often so much of interest happening that it seems a shame to "waste time" with extensive notetaking. It normally takes several frustrating searches through one's notes for essential but ultimately nonexistent prior detail to bring about the mental "knuckle-rapping" that fosters better detailed notetaking.

One way to increase detail in the notes is to use a standardized checklist of data to be gathered at each site. These checklists can be mimeographed or photocopied sheets that are carried afield on a clipboard and bound in with the descriptive field notes when completed. Also, take photographs that help give a good overview of the place and its plants. These photos can be augmented by sketch maps of the area indicating major plant communities, rock outcroppings, waterways, and the like. Plant observers have an advantage over wildlife observers because the subjects of their study stay put and cannot flee from view while you are taking notes.

Choice of the best format for a field journal is largely a matter of personal preference. Your style of notetaking is the primary determinant. Those who confine notetaking primarily to words generally prefer some form of lined pages. Spiral-bound notebooks appeal to many because they open flat and are easy to use in the field. However, pages can tear loose easily and data may become lost. Others prefer stitch-bound books such as the journals available in many stationery stores. Because they will not open flat, they are more awkward to use afield, but they are generally of better quality with more durable paper not easily torn from the book. Those, like myself, who like to use many sketches and maps in notetaking prefer the unlined pages and stitch-bound format of artist's sketchbooks. These give good flexibility of style of recording, but they share the inconveniences of stitch-bound journals.

Keep the following points in mind when making your own choice.

1. Because your notes will probably be kept for many years and indeed may pass on to succeeding generations, choose a good quality paper. Acid papers slowly turn yellow and brittle with age; so, when possible, choose rag papers. They are more expensive, but they will stand up to the years much more effectively.

2. Be sure the binding is durable. Stitched bindings and plastic or steel spiral-bound books are usually a good investment. Should you decide to use three-ring spring binders, be sure to reinforce holes in the pages with gummed rings to help prevent loss of good material.

3. Choose a size that fits conveniently into a coat pocket or day pack. A widely used size is 6″ × 9″. I find that is a good size also for carrying in the belt packs designed for field guides. I usually carry one guide and my field journal in such a belt pack.

4. If you don't use a belt pack, make some form of waterproof covering to protect your journal from the vicissitudes of the weather and accidental drops into dew-covered grass, ponds, and the like. You may want to make the cover of vinyl or similar materials, or simply stuff the field journal into a Ziploc bag that can also serve as a spare specimen holder (*vasculum*) on occasion.

5. Almost as important as your choice of field journal is your choice of writing instrument. Its marking material must be waterproof and permanent. There is little more frustrating than seeing good notes dissolve into unintelligible streaks when hit by rain from a sudden squall or retrieved from a visit to a puddle.

Some people take all their notes in pencil because it doesn't run, but soft graphites such as the normal Nos. 2 and 2B are apt to smudge and the points wear down quickly. Harder graphites, such as Nos. 2H and HB, resist smudging and are slower to wear down, but the line they leave is light and harder to read. Most who prefer graphite choose a mechanical holder rather than a wooden pencil and carry plenty of spare leads.

Ballpoint pens can be used if you are certain of their ink's waterproofness; check it carefully. Purists insist that only a good waterproof India ink is appropriate for field notes; they prefer a fountain pen with Higgins Eternal or Higgins Engrossing Ink. My preference is for a Rapidograph or Castell Drawing Pen filled with one of the newer, nonclogging drawing inks. Nonetheless, I always carry a pencil to use in damp or wet weather, or if the pen runs out of ink.

Your field journal is the heart and soul of your records of experiences afield. It is worth investing in the best materials you can afford and taking adequate time for notetaking and filing. Keep your journals on your shelves in numerical order and labeled with the dates each volume includes. This will help you refer quickly back to past observations. Keep notes clear and legible with good reference keys to abbreviations you habitually use; you never know who else may have reason to use your data in the future. If notes are legible only to you, their usefulness will be greatly impaired and, unless you keep a good key to each, you may forget exactly what your abbreviations and symbolic shorthand meant.

SPECIES FILES

Your field journal is a valuable chronological record of your excursions, but it is often difficult to go back to past specific entries containing notes on a particular species upon which you are concentrating. Maintain a second set of records into which species information is transcribed from the field journal.

One method is to record the information on file cards which can be filed by family, genus, and species. Be sure to note the page in the field journals from which each entry is transcribed so you can quickly check the accuracy of a transcription if need be.

Another format uses three-ring notebooks as its basis. This has the advantage that the field notes, plastic storage pages of slides and/or photographic prints taken, along with voucher specimens in plastic sleeves can all be kept together. As you become more deeply involved, you may wish to devote a separate notebook to each family or genus upon which you are concentrating. This method allows the detailed compilation of plant life histories as suggested in Chapter 2. You can buy plastic storage sleeves for slides and prints from most large photo supply stores. Plastic sleeves or mylar sheets to cover and protect voucher specimens can be found in stationery stores or can be ordered from biological supply houses (see Chapter 10). To include voucher specimens in this format will require some modification from conventional herbarium sheet sizes as noted below, but it is generally worthwhile.

COLLECTIONS FOR THE RECORD

Collecting and pressing plants for an herbarium was a primary activity of botanists in past years; indeed, it still is for many. During the age of exploration it was a valuable activity but has more limited value today except under special situations that are primarily within the realm of professional botanists.

However, in many places you may undertake observations of a plant that you cannot readily identify or whose determination by you may be questioned by others. In such situations collect and prepare a *voucher specimen* of the species to include with your records. A voucher specimen is simply a good representative of the plant form upon which you are making detailed observation. Botanists may change their opinion about the appropriate name to assign a given species, subspecies or variety, but as long as you have the voucher specimen among your records all your data can be accredited to the proper taxon at any future time.

Although many identification books concentrate on a few features of the plant such as flowers or leaves, in preparing a voucher specimen you should collect the entire plant of small herbaceous species whenever possible—i.e., leaves, stems, roots, and flowers or fruiting bodies.[1]

The plants can be gathered in the field and assigned a small tag or tape with a field *collection number.* This number is also entered into the field journal as well. Field collection numbers are sequential and begin with your first specimen; they should never be repeated or confusion would reign! However, all specimens of the same species from the same site receive the same number. The tagged specimen should be kept moist until you are ready to press it. This can be done by carrying it in a standard botanical metal vasculum lined with damp newspaper or paper towels or by carrying it in a plastic Ziploc bag. Treat the materials gently to keep damage to a minimum.

Once you return home or to your base camp if you are on an expedition, begin the drying and pressing process. If necessary, larger plants should be folded into an N or M shape so that when dry they will fit onto an herbarium sheet. Standard herbarium sheets are 14″ × 16″, but you may wish to use an 8½″ × 11″ size that fits in a standard three-ring

[1]Here we shall discuss only how to make pressed voucher specimens of herbaceous plants. Specialized specimen preparation such as for lichens, algae, fungi, shrubs, trees, and the like will be detailed in the appropriate section of Chapter 9.

binder. Care should be taken to lay out leaves and flowers carefully so that all possible detail can be readily observed. Prepared plants are placed between folded sheets of newspaper and then sandwiched between two dryers of blotter material, corrugated cardboard, or professional botanical dryers. These in turn are placed between the rigid wooden frame of the plant press, and pressure is applied by tightening straps or wing nuts depending upon the type of press used (see Chapter 10).

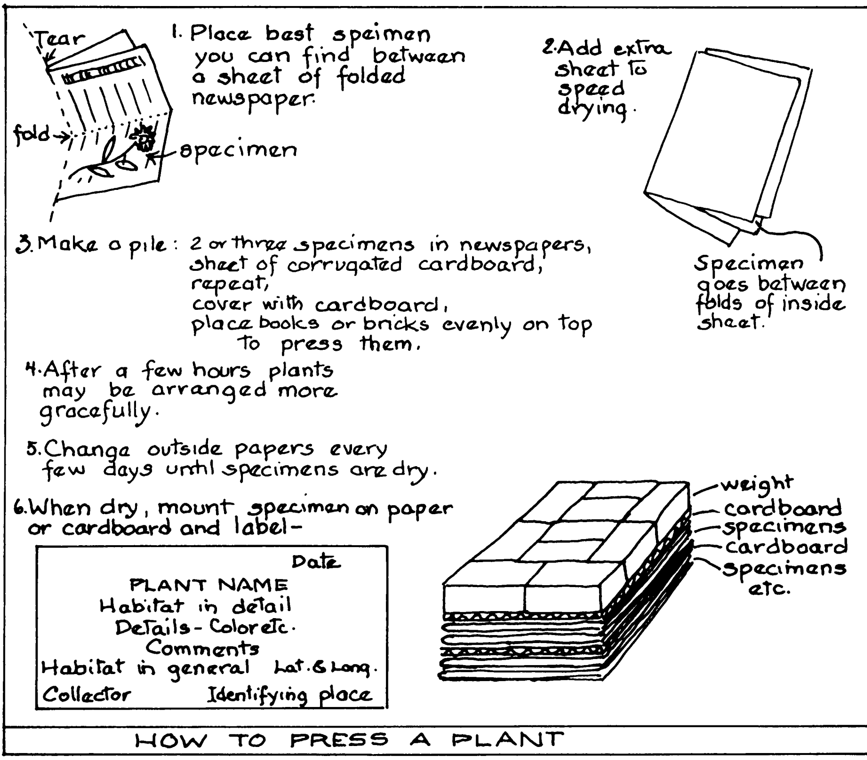


Figure 4.1

Dryers should be changed each day and replaced with fresh ones. Those removed can be placed in the sun or another appropriate place to dry out for reuse. After a week or so in the press, the specimens should be adequately dry for permanent mounting unless they are unusually fleshy and/or succulent. Thick roots, tubers, and rhizomes should be sliced longitudinally to make them thinner while reflecting the original shape and orientation.

Dried and pressed specimens are laid out on the final herbarium sheet and arranged as neatly as possible. Stems can be held in place with strips of transparent tape, but such tape will deteriorate far more rapidly than the plant material and in a matter of only a few years the specimens will come loose from the backing sheet. Some people spread white glue on a sheet of glass and then lay their specimen on the glue. Next, the specimen with its coating of glue is carefully lifted off the glass and laid carefully, glue down, on the herbarium sheet. If you are likely to prepare a number of specimens, apply Archer's solution as your adhesive in simple strips using a plastic catsup dispenser or an oil gun. Archer's solution is an efficient, neat, easily applied adhesive available from some biological supply house (see Chapter 10 for address).

If you use standard herbarium sheets, you will want to keep the finished specimen in an herbarium folder. If you use the 8½" × 11" size, enclose the finished specimen in plastic sleeves.

Whatever its format, an herbarium sheet must have a specimen label; unlabeled specimens are virtually useless scientifically. A label should contain:

Field Collection Number:
Location:
Date:
Collector:
Species Determination:
Determination by:

It takes work to prepare a good botanical specimen for your voucher records or for a formal herbarium. Take the time to do the job the way a craftsperson would. A specimen, properly prepared and stored, is useful for hundreds of years.

RECORDING WITH A CAMERA

Plants are ideal for photography, because there is plenty of time to set up the equipment and take good pictures. The major difficulty is coping with wind. Photographing flowers is a hobby in and of itself, but that is not the objective of the following suggestions. Here we confine our discussion to techniques for building photographic records of plant activity, although the two objectives are not mutually exclusive. There is no reason why a record shot cannot be aesthetically pleasing and artistic; on the other hand, useful record shots do not have to be so.

EQUIPMENT

A serious amateur will prefer to use a 35mm single-lens reflex camera for its versatility. Interchangeability of lenses, along with through-the-lens viewing, permits everything from extreme close-ups to telephoto shots.

And today's advances in through-the-lens light metering permit accurate exposure under a variety of conditions with minimum aggravation.

Although 35mm systems are ideal for such picture taking, you can still do good plant recording with simpler, less expensive cameras if you are willing to do a little ingenious tinkering to ease your work. Parallax is a key problem of taking close-up pictures with other than through-the-lens reflex lenses. This is due to the fact that you are looking through a viewfinder lens that is slightly offset from the picture-taking lens. At a distance this is of little import, but as you get fairly close to the subject the difference between what the two lenses are framing becomes significant.

Parallax can be compensated for by using a view frame. This is simply a wire frame that outlines a fraction more than what the film will actually record at a fixed distance. Such a frame is clipped to the camera so that it protrudes in front the proper distance. You need only include the plant to be photographed in the plane and area of the frame, and then push the shutter release. Normally you will want to use the largest f-stop number (smallest aperture size) possible to get the greatest possible depth of field.

To get close up to a subject using a fixed focus lens, you will need to acquire diopter or portrait lenses that clip on in front of your camera's regular lens. Differing magnifications of such lenses encompass quite different fields of view which must be reflected in the area of the wire view frame that you use with it.

When you use a small aperture to get depth of field, you must have a good natural or artificial light source. If a flash is used in ultra-close-up photography, you generally need to use some form of deflector so that illumination is placed on, not over, the object to be photographed. All this requires careful measurement and maneuvering to create a rigging that is reasonably convenient to use. A knowledgeable hobbyist photographer should be able to give you a hand. A useful reference for determining focal frame size, lighting techniques, and related detail is Kodak Manual N-12, *Close-up Photography and Photomacrography* (1977).

For a number of years, the Kodak people have offered specially modified versions of their simple pocket cameras for use in close-up work. They have been very useful for dentists and the amateur botanist who does not want to get overinvolved in the mechanics of photography, yet wants good close-up photos of the plants or plant parts. The Kodak Pocket Instatech Close-up Camera uses 110-size film, has a sliding aperture for exposure control, and uses Magicubes® for illumination. The Kodak Instatech-X Close-up Camera uses 126-size film that will give 2″ × 2″ slides as well as prints and has the same modifications for close-up work. Both cameras have focal frame attachments. For more information on these useful recording devices, write to: Eastman Kodak Company, Department 740, 343 State Street, Rochester, NY 14650.

The director of a nature center, an old friend of mine, uses such a camera to record every species of plant he finds blooming in his sanctuary. This has provided a record of the plant life over the years without disturbing the plants' life histories in any way. His collection of thousands of slides and prints provides an unparalleled record of the sanctuary flora by someone who detested the complex paraphernalia—the tripods, lenses, flash units and the like—of the ardent photographer, but who wanted good pictures nonetheless.

LENSES

For single-lens reflex cameras with interchangeable lenses, the most practical lens for plant data gathering is probably the 50mm macro lens. This lens permits both normal distance shots and effective close-ups. Some people prefer the 100mm macro because it allows them to take excellent close-up views at a greater distance from the subject than is possible with the 50mm macro.

If the price of a macro lens seems excessive, you have essentially three other choices for close-up work—the bellows extension, extension tubes, and diopter or portrait lenses. Each of these devices has advantages and disadvantages that should be carefully weighed before making a purchase. Talk them over with a knowledgeable photographer and/or read up carefully on the optical properties of these devices in one or more good photography books.

TRIPODS

For clear, sharp photographs a sturdy tripod is an essential piece of equipment. A low camera angle is desirable for photos of most flowers, fungi, lichens, ferns, and the like, but low tripods are often hard to find. Ideally you are looking for a tripod that will let the camera get down to at least 18″ or lower. If you can't find such, you can mount the pivoting head of a tripod on a wide flat board, as shown in Figure 4.2.

Because of the generally low angle desirable for much plant photography, it is helpful either to get a camera with a waist-level viewfinder or, if your camera comes with interchangeable viewfinders, a waist-level model for use with plants. Eye-level viewfinders are not impossible, but they often prove awkward because they force you into uncomfortable squatting or prone positions that may also cause you to mangle surrounding vegetation.

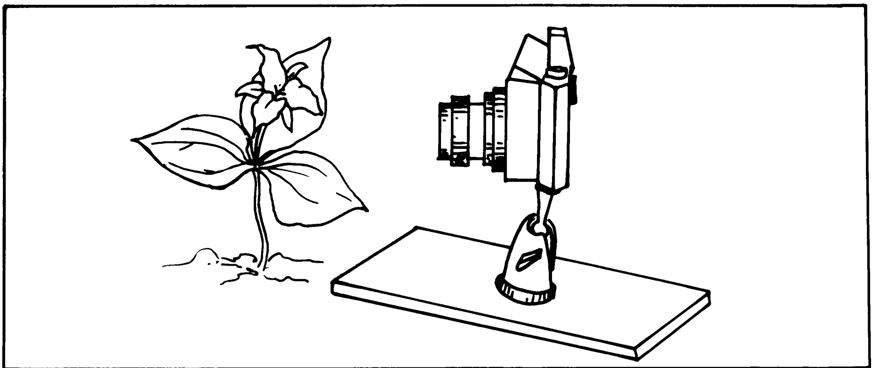


Figure 4.2

FLASH

An electronic flash is desirable or necessary for much plant photography either to supplement low natural light in shaded areas or to allow use of higher shutter speeds that will freeze wind-generated motion. A single flash tends to produce harsh, strong shadows that are not only visually unpleasant but may hide desired detail.

Multiple flash units are recommended, preferably on an extension bar for convenience. They are variously aimed to counter the shadows of each other. Normally, one goes on the camera hot shoe and shoots head on, while another is aimed at 45° from the film plane and a third at 30° from the film plane. Such lighting provides for great depth of field and regular use of low-grain, slow films for the highest degree of sharpness and detail. The extra flash units can be set up on tripods and tripped by relatively inexpensive electric-eye units triggered by the flash on the camera itself. All this means more gadgets to lug into the field and set up. Many people simplify matters and compromise by using a single flash but carry and set up sheets of white cardboard to reflect some of the light into the shadows caused by the flash. It's not as good as multiple flash but better than using the single flash alone.

Wind is the curse of plant photographers, and in some places wind is an almost continuous phenomenon. Some people carry cardboard folded to a V-shape so that it can be set, pointing into the wind, just beyond the camera's field of view. In lighter breezes some photographers wrap green florists' wire around the plant stem to stiffen it and provide wind resistance. For use in very windy areas, some have clear plastic tents built to cover themselves, their equipment, and their subject. Such tactics are most important with natural light if you are using slow-speed film which demands a longer exposure. Under such conditions, motion equals blur. In many cases, use of electronic flash and/or high-speed film will overcome the wind-induced movement.

Picture background is important for both aesthetic and scientific reasons. To emphasize the primary subject, the background should not be distracting. One way to achieve this is by controlling depth of focus. By using a large lens aperture (small f-stop number), depth of field is reduced. You can adjust your focus so that the desired plant or plant part is in sharp focus and everything else is blurred. This produces a crisp-edged flower or other plant part against a pleasing mottled background. If you desire an artificial, plain background, use either a sheet of cardboard or cloth stretched behind the plant at enough distance so that light from the flash does not project a distinct shadow upon it. If you are using a 35mm camera, background sheets 3′ × 4.5′ or 4′ × 6′ are convenient sizes. Sheets of several different colors are desirable to meet different needs and can be rolled in a cardboard mailing tube and slung across your back with a strap like an archer's quiver. For some studies, such as growth rates, you may wish to carry instead a backdrop that has clearly marked grid lines so that you can readily perceive changes in successive photos. When using such grid material, be sure it is consistently set up a fixed distance from the subject so that comparisons are reliable. As a background for black-and-white photography, use a medium gray.

FILTERS

Filters are often desirable on the lenses. It is wise to keep a Skylight filter on your camera at all times when you are using color film, but it is essential when you are filming in shady places so that you avoid an overly bluish cast to the scene. With black-and-white film, use a standard yellow or CC filter. When using these or other filters, be alert to the predominant color of what you will be photographing and remember the rule that a filter lightens objects of its own color. This has a distinct impact on the resulting photo.

UNDERWATER PHOTOGRAPHY

For those who want to record underwater plant life, I recommend the 35mm Nikonos or the Minolta Weathermatic-A, each of which can be used above and below water without an additional waterproof housing. Use of the Minolta Weathermatic-A is limited to depths less than fifteen feet but is within the depth range of much aquatic plant growth and most snorkeling activity. Both these cameras can be used with a close-up focal frame to simplify focusing underwater. You can, of course, get clear plastic underwater housings for your regular camera, but these are quite expensive and make sense only if you plan to do extensive underwater photography. Although most aquatic plants grow where light is relatively strong, an underwater electronic flash is very useful to permit shutter speeds that will freeze the motion caused by tidal surge and underwater currents.

Although it is inappropriate to elaborate on photographic skills and techniques in this book, photography is such an important tool for botanical field studies that it is worth the time of anyone doing such work to read and study photographic fundamentals and develop basic skills in photography. Some helpful references are listed at the end of this chapter.

Two special techniques of particular value to plant observers are time-lapse photography and ultraviolet photography. Time-lapse work requires the use of a movie camera that can be advanced one frame at a time. Instead of passing by the camera lens at the standard rate of sixteen frames a second, film is put through at the rate of perhaps one frame per hour, or whatever rate you determine as appropriate to the subject. However, the developed film will go through the projector at sixteen frames per second, resulting in the illusion of apparently rapid uncoiling of a fiddlehead, opening of a flower, grasping of a tendril, or the like. Ultraviolet photography requires use of special film sensitive to that part of the light spectrum and special lighting technique, but the result is very revealing about flower patterns. Flowers that appear pure white to us may present distinctive patterns in ultraviolet, and many insects, particularly pollinators, are able to see in that spectral range. It is worth photographing flowers with ultraviolet film to determine how they may appear to such creatures.

FIELD SKETCHING

The advantage of photography is that the resulting photograph is a remarkably detailed representation of the original object as it existed at that moment in time. However, it is not always possible, nor even desirable, to take a camera afield, and carefully done field sketches are the next best thing. Indeed, an advantage of sketches is that a plant part can be drawn in a perspective or view that best shows certain key features. This is often not possible with the camera.

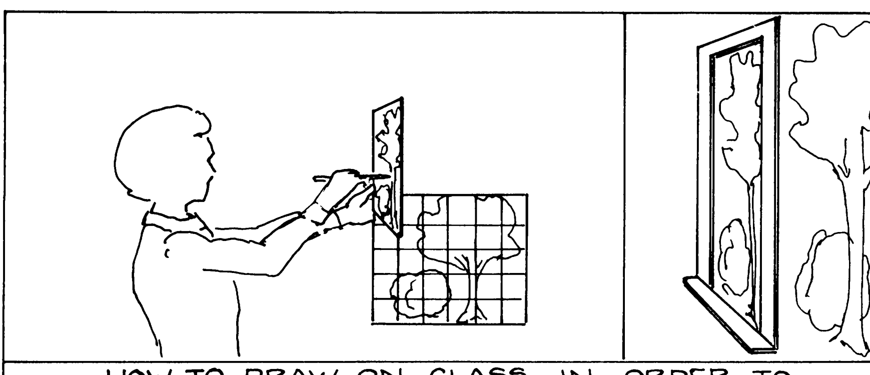
Field sketching also focuses observations, helping the observer see details that might normally have gone unnoticed—exactly how does the leaf attach to the stem; where are buds located; how is the flower placed? Some people are shy about sketching, but they needn't be. Like other skills, it develops only through practice. First and foremost, sketching is dependent upon seeing. Once able to truly see, you learn some conventional ways to represent the illusion of three dimensions on a single plane using lines and shading. Over time, you learn more refinements for building the illusions and become increasingly skillful.

Field sketching allows you to go afield lightly encumbered yet return with detailed notes and records of what you have seen. You will not have to transport extensive equipment to be set up over and over, nor worry about focus, exposure, angle, and the like. You need only open your notebook, observe carefully, and represent those observations in line, shading, and explanatory notes. The relative immobility of plants is a great asset to botanical field sketching and allows you to take adequate time both for observing and checking the accuracy of your representation. If you find an error, you have ample time to erase and redraw. Wildlife sketchers seldom have the luxury of such prolonged observation.

When sketching in the field notebook, artistic rendering is not the primary purpose; more important is the accuracy of particular key features, such as the angle at which leaves emerge from the stem; how the lip of the flower orients to the horizon; the pattern of toothing of the leaves; the pattern of overlap of bud scales; and the like.

If you are having trouble with the accuracy of your freehand sketching, there are a variety of shortcuts you can take which are perfectly acceptable. For example, you can put a leaf under the notebook page and then rub over it with the side of the pencil to get a rubbing that shows details of the leaf edge and veination. Or you may want to carry a pane of glass, its edges covered with mystic tape for safety, and a glass marking pencil. If you are having trouble getting the appropriate outline of a tree and its branching or the precise perspective of a curling leaf, hold the glass pane in front of you at a fixed point and trace the outline of what you are viewing with the grease pencil. To change the size of the drawing, move

Figure 4.3



HOW TO DRAW ON GLASS IN ORDER TO KEEP PERSPECTIVE ACCURATE WITH HINT OF PROPORTIONAL SQUARE METHOD WHICH WILL BE ILLUSTRATED LATER.

the pane closer or further away from the object itself. Afterwards, the drawing on the glass can be traced, freehand copied, or copied via the proportionate square method into your notebook. Wipe off the glass, sharpen the grease pencil, and you are ready for your next venture. This approach is only a crutch, and people usually wean themselves away from it rather quickly.

FIELD MAPS

The location of individual plants, or stations, where a number of plants of a given species can be found is important botanical data. Much data can be recorded on simple but accurate sketch maps in the field. The location of stands of a species, the approximate area of a tract inhabited by several different species, the patterns of seed or seedling dispersal, and the relationship of plant locations to geographical features can be recorded effectively on field maps along with other valuable data.

At a minimum, you need a compass and measuring device along with your notebook to produce such maps. A plane table and alidade system will produce more sophisticated auxiliary maps.

SKETCH, PACE, AND COMPASS MAPS

The simplest type of map is a sketch map representing a particular area and upon which various items are roughly located. Essentially pictures of relationships, such maps are abstract approximations with little attention paid to scale, distances, or geological orientation. They sometimes are useful in presenting a very broad brush picture of a place or situation.

A more accurate depiction of the same area would require compass points and distances. These can be noted by a compass heading from a given point, an arrow to indicate direction, and a distance figure.

You can use a traditional compass rose notation such as NNW or, as I prefer, a Silva system compass with degree readings (azimuth). For reconnaisance work, distance can be determined by your pace. In determining the length of your pace, use a normal easy stride that you can maintain without significant change over a reasonable distance. For more accurate work, you will need a measuring tape.

Data can be entered in your field journal as a list and be converted to a map at a later date. Such data might appear as follows:

From big rock to lone pine, 32° and 89 paces
From lone pine to willow shrub, 60° and 95 paces
From willow shrub to dead pine snag, 190° and 110 paces
From snag to sugar maple, 225° and 80 paces
From sugar maple to big rock, 330° and 90 paces

Given your normal pace, you can convert the data to feet or meters at a later date when the map can be drawn more accurately to some appropriate scale. Within the area circumscribed by your map, you can locate various items by degrees and paces from your landmarks. To pinpoint them exactly, you will want to use two headings and the objects should be located where the two headings intersect—i.e., ladies tresses growing in open grassy area 40° and 85 paces from big rock, 70° and 30 paces from lone pine. Such data can prove very handy when later trying to relocate stations of particular plants.

If you construct your map later, be sure to indicate on it the journal number and observation number where the original data can be located. Add a note in the journal that the finished map exists and where it is filed.

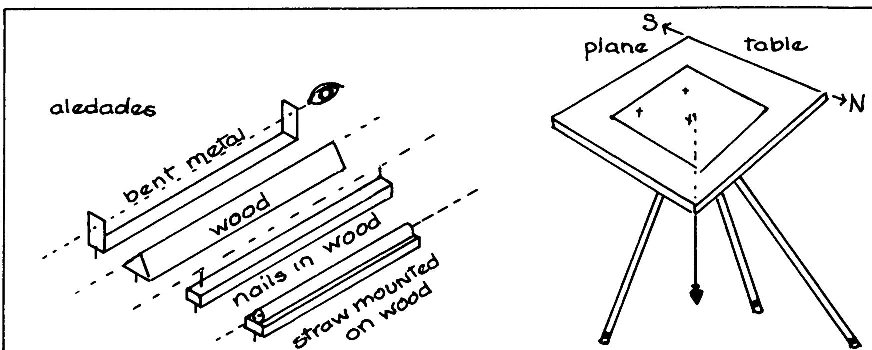
PLANE TABLE MAPPING

Mapping with a plane table normally requires several people and some equipment that must be carried afield and set up. The benefit of doing a plane table map is that it physically develops on the paper as you proceed, and when you are done in the field the completed map lies in front of you. Most of the equipment can be manufactured at home at a modest cost, as described in Chapter 10. At this point, we only describe the process by which you use it.

You need a table roughly three feet square mounted on an adjustable tripod. A plumb bob should descend from the center of the setup so that the table can be set directly over markers in the ground. In addition, you need a straight-edge mounted with sighting devices (an *alidade*) (see Figure 4.4). Other necessary materials are a compass, paper for the map, a pencil, and an eraser.

Your first step is to choose a scale appropriate to the area to be

Figure 4.4



VARIOUS TYPES OF ALEDADES AND A PLANE TABLE SET-UP.

mapped—i.e., 1 in. = 10 ft or 1 in. = 100 ft, and so on. Second, establish a base line about fifty feet long that is precisely measured, with points A and B representing the end points of the base line. Draw the base line to scale on the paper that you have now taped, or tacked, to the plane table. Locate the base line near the center of the paper if you are going to set up in the center of the area to be mapped or to the appropriate edge of the sheet if you are going to work from an edge of the area to be mapped.

You are now ready to begin mapping. Set up the plane table and tripod directly over the stake at point A. Orient the right-hand edge of the table north, making sure the table is level. Stick in the point of the alidade at point A and pivot the alidade until it is lined up with a particular object you wish to record on your map. Trees and rocks or a plant you wish to locate may serve as natural boundary markers. You may wish to have an assistant carry a brightly colored eight-foot-long marker pole and hold it at each sighting point to make sure you are properly lined up. When you are properly aligned, mark the end of the alidade and lightly note the identity of the object upon which you sighted. Repeat this for all the objects you desire. Next, move the whole setup to point B and repeat everything as in point A.

You are now ready to connect the respective points with the marks you made. First, lightly draw the lines from point A to the various objects. Then, when doing the lines from point B to the object, mark only where the straight edge intersects the pencil line from point A, because that point represents the actual position of the object to scale.

You must be very careful in your setup and alignments. With most scales you are likely to use, a very small error in the field results in a large error on the scaled map. Practice making a couple of maps in your backyard or on a local schoolground to get the hang of it before taking the setup afield to map plants.

A somewhat simpler version that does not result in a direct mapping can be undertaken. Again, set up a base line with points A and B. Set up, orient, and level your plane table over the stake. Instead of an alidade, tack down a 360° protractor to the center of the board and orient it so that with 0° to your left and 180° to your right you can sight down two pins placed at these points to point B. Make sure the protractor cannot rotate. Now sight from the center pin along a second pin set to line up with the object to be mapped. Then read and record the angle at the point where you placed the second pin. Repeat this procedure for each object to be mapped. Then set up at point B. Sight back on point A from 180° to 0°. Resight all the objects to be mapped and record the angles. (*Note:* You could do all this with a Silva compass instead of a protractor, but the circle is smaller and thus the margin for error greater.)

Back home you can create a map to scale. Lay out the base line to scale, place a protractor over each point, and mark the angles for the appropriate objects. As with a plane table map, the two lines intersect at the scaled location of the object. This process produces simply a plane table map done in two stages instead of one.

MARKING INDIVIDUALS

As you locate individual plants and plant stations on your maps, you may also want to mark them in the field with tags or markers that will help you relocate them later. A specimen easy to recognize in flower may look quite different at other times or may wither and disappear after flowering. A variety of materials may be used as markers, however all must have similar properties. They must be weather resistant, durable, relatively inexpensive, easy to handle, and easy to mark with an indelible marking. I have found the embossing label devices with their many colors of plastic tape very useful. With them you can punch out any name, number, or other code on a strip and then attach it to a sturdy part of the plant with florists' wire. With annuals, I mark the site using plastic markers that horticulturists stick in their pots to indicate species; the same is done with herbaceous perennials that die down below ground level. These labels can be written on with grease pencil or indelible laundry markers. There is always a certain amount of loss due to the activity of people and animals or machinery trampling, but these methods generally work quite well. If your maps are carefully and accurately prepared, you can easily relocate lost individuals.

For some inconspicuous species in relatively undisturbed places, I may also use a more conspicuous marker such as a pole stuck in the ground with a piece of colorful surveyor's tape tied to it. These are consistently set at a specific distance and direction away from the marked plants so that curiosity seekers do not inadvertently trample on the plants as they investigate the markers.

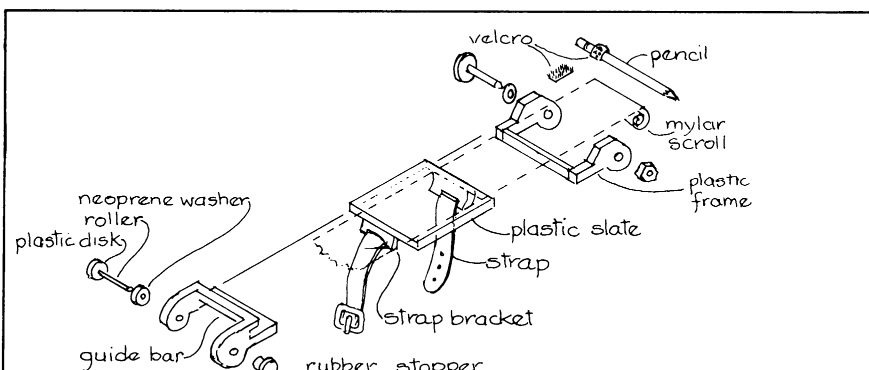
UNDERWATER NOTETAKING

Taking notes underwater presents special problems. It's one thing to don a face mask, snorkel and fins, or SCUBA apparatus to explore beneath the water surface, but quite another to take notes beneath the waves. Traditional notetaking materials are all but useless. Although new underwater phones are available that might permit some dictation into a recording device, they are still prohibitively expensive. However, you can make simple slates of heavy plastic and write on them with grease pencils, but these are primitive and clumsy to use. Somewhat more sophisticated are pads made of sheets of frosted mylar or underwater paper (ASCOT paper, Appleton Papers, Inc., WI 54911) bound with plastic rings or spirals or clipped to an all-plastic clipboard. These pads can be written on with a soft, graphite pencil. Tie your pencil to the pad with nylon monofilament or attach a piece of rubber tubing to the pad with silicone glue and use it to house the unused pencil. Unfortunately, all such pads are nearly as clumsy as the slates and offer resistance in the water. They are most conveniently carried attached to your weight belt or in a net catch-bag.

Personally, I prefer a little device known as a minislate that is worn on your forearm much like a watch. It is essentially a plastic block over which scrolls of frosted mylar can be unrolled. The notes are taken in pencil on the section of mylar exposed on the block. When a section is full, the notes are rolled onto the scroll, at the same time exposing a fresh section of scroll for more notes. In Michael Foster's original model, the pencil is carried in a rubber sleeve; in mine it is held by Velcro with the hooks glued to the slate and the loops glued around the pencil. This device is illustrated in Figure 4.5 in an exploded view so that you can determine how to assemble one for yourself. The plastic used is .25 in. (6.4mm) plexiglass glued with ethylene dichloride. The rollers are attached simply by pushing them tightly into holes of the rubber stoppers that serve as winders. Mylar strips are attached to the rollers with electrical tape. To keep the mylar flat, pass it through a .5mm space between parts K and A. Frosted mylar is available in most art supply stores in sheets which you then cut into appropriate width strips.

Notes taken underwater are not stored directly but are transcribed into the field journal; then the mylar is cleaned for reuse by erasing, or wiping with kitchen cleanser.

Figure 4.5



UNDERWATER MINI-SLATE (after Foster as modified by Roth)

DATA AND THE COMPUTER

With the growing affordability of home computers, more and more amateurs are likely to consider storing their field data in their own computer where it can be retrieved quickly for various forms of analysis. Developing skills to do the necessary programming is well beyond the scope of this book, but there are factors about the data-gathering process that are appropriate to consider here.

The less organized the data is that is entered into the computer, the greater will be the difficulty of retrieving and analyzing it. Unorganized data would require more complex programs and capacities for analysis than the basic home computer can supply. This doesn't mean you can't use your computer, it simply means that you should do very careful advanced planning before entering data into the machine. In fact, that planning should take place even before the data is collected.

In keeping a field journal as an amateur, you generally collect a series of more or less random observations about a variety of interesting things that you come upon in your botanizing rambles. In time, some particular questions about plant life may begin to occupy your mind and focus your observations. It is at this point that the potential of computers may well enter into the picture. You will begin to compile larger and larger amounts of comparable data that you want to analyze for a potential answer to your questions. This is the forte of the computer—arranging, rearranging, and analyzing comparable data toward some predetermined objective. You may want to discover the frequency with which given sets of plant species associate, or perhaps how consistently annual growth rates of particular species match with rainfall, or any of thousands of other objectives.

Different kinds of questions require different sets of data for analysis—that is, they require different *data structure*. Unfortunately, the data structure that is appropriate for one particular set of objectives may be quite inappropriate for others. Thus, you must first establish your questions or objectives to determine the appropriate data structure. From that structure you can design data-collection forms that will speed your data collection by standardizing terms, assuring comparable data from different stations, and providing format for reasonably error-free transfer from field data to computer storage. In designing data structure, considerable thought should be given to ways of accessing data to meet your analytical needs and any application of data needs.

In collecting data for the computer, you will want to violate one of the precepts of field observation—that is, instead of gathering as much data as possible, you will want to limit your data collection only to those data that contribute directly to the objective. You will concentrate on a standardized format for data gathering as suggested above. (*Note:* This does not preclude collecting other observations in your journal.)

There is a certain allure to using modern high-tech computers for handling data, but computers are sophisticated instruments whose effective utilization requires a high degree of sophistication as well. Use them where appropriate, but avoid being seduced by them into following blind alleys or producing pseudo-answers. Helmut Moyseenko, writing on "Limiting Factors of Environmental Data Management," notes:

> It has been our experience that computerized data management is the least satisfactory method of sorting out complex ecological relationships, especially if the systems designers have not put enough intellectual energy into indexing and structuring the data.

The key here is the caveat, and few home computer owners at the moment have the necessary background and skills to design appropriate data structures, particularly for complex ecological problems. This may change in a generation or so as computer literacy in our society becomes more widely based and developed.

SHARING OBSERVATIONS AND DATA

Knowledge gained is not only an individual possession but, where possible, should become part of the aggregate knowledge of humanity. There are several ways this can be done. The simplest is through direct sharing as a participant in botanical and natural history organizations such as clubs and nature centers. Such groups provide opportunities to learn from perhaps more experienced others, and a responsive group who also want to hear of your experiences, discoveries, and hypotheses. In Chapter 9, names and addresses of major botanical groups are cited; in addition, there are many state and local groups throughout the country. You can usually learn about them from staff members of museums, nature centers, and universities. It is worth the inquiry.

As you go about your explorations, you will probably assemble a respectable collection of herbarium specimens, photographs, and field notes. It is farsighted to talk to officials at museums, herbariums, state natural heritage programs, or universities about potential arrangements for accessioning your material when you die. Any such arrangements should also be discussed with your loved ones so they know how the materials should be dealt with. Such preplanning will assure that the data continues to contribute to our overall knowledge and that both institution and family are aware of the extent and value of "that silly hobby."

In the process of exploring the plant world, you may well uncover some significant information that should be shared widely with other plant enthusiasts. This can be presented in articles in popular or technical journals. For many, preparing an article for publication is a highly intimidating prospect, yet it need not be so if you proceed methodically. First, become familiar with the publications most likely to publish your article. A request to the various editors will usually get you a set of author's guidelines designed to aid both you and the editor. These guidelines help establish the perimeters within which to prepare your article for that particular publication.

If your chosen publication is a popular magazine, your skill in writing with a captivating style that holds the reader's attention will be quite important, as will your ability to explain things clearly with a minimum of technical language. Professional journals are not particularly interested in your flair with words. They seek simple, clear, direct prose that states your position, backs it with defensible data, and summarizes your conclusions. Technical language is desirable here because it tends to be most precise and concise for the usual readership.

It is advisable to recruit a professional botanist to coauthor and advise you, at least on your first few technical articles. Most professional journals have a peer review system for screening articles for publication and your coauthor will help raise your chances of not being rejected. You will not get any financial remuneration for publishing in a professional journal; indeed, as printing costs continue to rise, more and more of them ask the author to pay something toward those costs. Almost certainly you will have to pay for reprints of your article for distribution to friends and colleagues. Still, it's part of the overall experience and fun of your botanical efforts.

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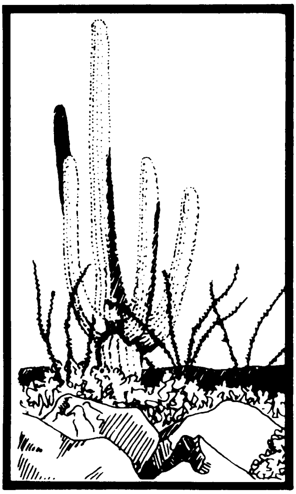


CHAPTER 5

LIVING WITH AN ENVIRONMENT

In large measure animals depend on electrical impulses to transmit messages throughout the organism, but they also have a significant number of chemical messengers. With plants the weighting is reversed; the majority of internal communication is by chemical messengers with only a tiny fraction, in a few species, by electrical impulse. Plants also have broad contact with the air, water, and soil about them and respond intimately to chemicals they encounter there. In a real sense, plants are nature's master chemists. Humans have been profiting from their chemistry from earliest times, finding in plants chemicals for healing and making products like rubber, fibers, and dyes. Of course, plants also make chemicals toxic to other life forms, thus providing the plant a modicum of protection from predators (remember, to a plant herbivores are predators) or a barrier to invasion of their space by other plants. We see the latter particularly among some desert plants such as sagebrush or fungi like *Penicillium*.

To understand fully the many complex interactions between plants and their environment, we would have to delve into the complex arena of plant physiology, which is essentially a laboratory science that involves a long academic background and sophisticated techniques and equipment. That fascinating subject is well beyond the scope of this book. However, clues to problems to be investigated by the plant physiologist often come from the observations of field botanists. A field botanist observes what, when, where, and under what conditions a plant lives and dies; a plant physiologist tries to determine how and perhaps why.

Amateur and professional field botanists need to investigate the physical environment in which a plant is growing, for it is that with which the plant is in most intimate and extensive contact. From it a plant must extract all of the raw materials and nutrients needed for photosynthesis and growth. The quality and nature of the intimate environment will stimulate physical adaptation of the plant or determine its failure to survive. It is not possible to understand the world of a plant unless you understand the kinds of environment it can tolerate and those kinds which it prefers and in which it thrives vigorously.

GETTING ACQUAINTED WITH SOILS

Not all plants require soil, although most true plants and fungi require some substrate to which they attach for all or part of their life cycle. For some the substrate is wood, peat, or tree bark, but for the majority it is soil.

For many people, soil is just so much dirt. Such a view derives from lack of familiarity with this precious commodity that represents the interface of the three great physical spheres of the planet—the lithosphere (the planetary rock), the atmosphere (the gaseous envelope), and the hydrosphere (the areas of liquid and frozen water). Soils are made up of five basic components: rock particles, air, water, living organisms, and organic material. The latter is the product of living organisms and their remains.

As you might imagine, the variation in size and composition of rock particles and organic material, and the changing percentages of air and water, create an immense number of possible mixes that generate quite different soils. The fundamental nature of local soils is a result of the geologic history and current topography of the land. Some soil types remain fairly constant for long periods of time, while others undergo relatively rapid change. Development of soils over time results in identifiable *soil types* somewhat akin to plant and animal species. These different types are recognizable and have been named and mapped. In the United States you can check with your local conservation district and/or the USDA Soil Conservation Service District Office that services it, to find out if the area you are studying has been mapped according to soil types. If it has, you may want to acquire such a map. The Soil Conservation Service also has booklets describing the characteristics of each soil type and listing some of their capabilities for plant growth, at least for agriculturally important plants.

There is much you can learn on your own about the local soils and their characteristics even if you don't have a soils map. Indeed, the scale of many maps is such that one soil type is shown over an area that actually includes a number of small pockets of other soil types too small to map. Because plants may actually be confined to those pockets, it is prudent to do some soil data gathering during your field observation even if you do have the local soils map.

SOIL CHARACTERISTICS

Particle Size. An important way of classifying soils is by the various particle sizes and the percent of each in a standard sample. At each site gather a level measuring cup full of soil and pour it into a pint jar. Fill with water, shake thoroughly, and then set the jar aside and let the particles settle. As the soil settles, it will form stratified layers. The largest particles will be on the bottom and the smallest on top with some bits of clay so small they remain suspended in the water for many hours or even days. Organic material may float at the surface. Be sure to label each sample and key it to the plant observations in your field journal.

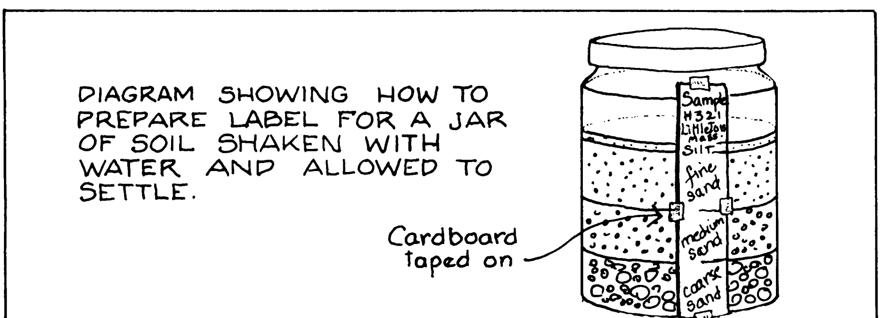
Soil scientists have a specific size-range definition for each of the component particles:

Fine gravel (2mm-1mm)
Coarse sand (1mm–0.5mm)
Medium sand (0.5mm–0.25mm)
Fine sand (0.25mm–0.10mm)
Very fine sand (0.10mm–0.05mm)
Silt (0.05mm–0.002mm)
Clay (below 0.002mm)

Using the technique of a shaken bottle of soil, it is not easy to differentiate the silt and clay; however, after a few hours silt will usually settle out while clay remains suspended.

If you consistently use the same kind of pint jar, you can collect data by taping a strip of paper to the side of the jar before shaking it. Once the settling-out has occurred, carefully mark onto the paper strip the dividing point between each layer. After each layer is labeled, the strip can be removed from the jar and mounted in your journal (see Figure 5.1).

Figure 5.1



By looking at the rough percentages of soil particles, you will be able to classify the soils into three fundamental groups and a variety of subtypes as indicated in the following chart:

SANDY SOILS	LOAMY SOILS	CLAY SOILS
gravelly sands	medium sandy loams	stony clays
coarse sands	stony sandy loams	gravelly clays
medium sands	gravelly sandy loams	sandy clays
fine sands	coarse sandy loams	silty clays
very fine sands	fine sandy loams	clays
loamy sands	very fine sandy loams	
	loams, gravelly loams and stony loams	
	silty loams and stony silt loams	
	silty clay loams	
	clay loams	
	stony clay loams	

Notice that the name of the particle size with the highest percentage provides the last word of the soil type while the first and/or second word modifiers indicate particle sizes mixed in in lesser amounts. A brief description of the major soil groups may help you understand plants' environment.

Sands. A sandy soil has less than twenty percent by weight of silt and clay, is quite porous, and thus has fast drainage. Sand particles are not very cohesive and their soils crumble very easily.

Clays. Soils with thirty percent or more clay particles are classified as clays. These soils may have even more silt than clay, but as long as the requisite amount of clay is present they are still classified as clays. Clay particles, along with being very small, usually carry an electrical charge that helps bind them together, making clay soils extremely sticky and slippery to the touch. The minute particle size and general compactness means that little air or water can circulate in these soils.

Loams. It is more difficult to define loams than sands and clays, because a loam is really a mixture of sand, silt, and clay. This mixture normally results in a soil whose particles cling together well yet also has a good porosity for air and water circulation, making loams a good growing medium for a wide variety of plants. As you would expect, the percent of the various components in the mix changes the character of the loam and its suitability for any particular species.

Gravels. We did not mention gravels as a major soil type, but there are places where the soil is largely composed of gravel, such as in some deserts, piedmont plains, alluvial fans, river bars and deltas, glacial deposits, scree slopes on mountains, and many built environments. There are some specialized plants that do survive, even thrive, in such soils and that may be found almost exclusively in such places.

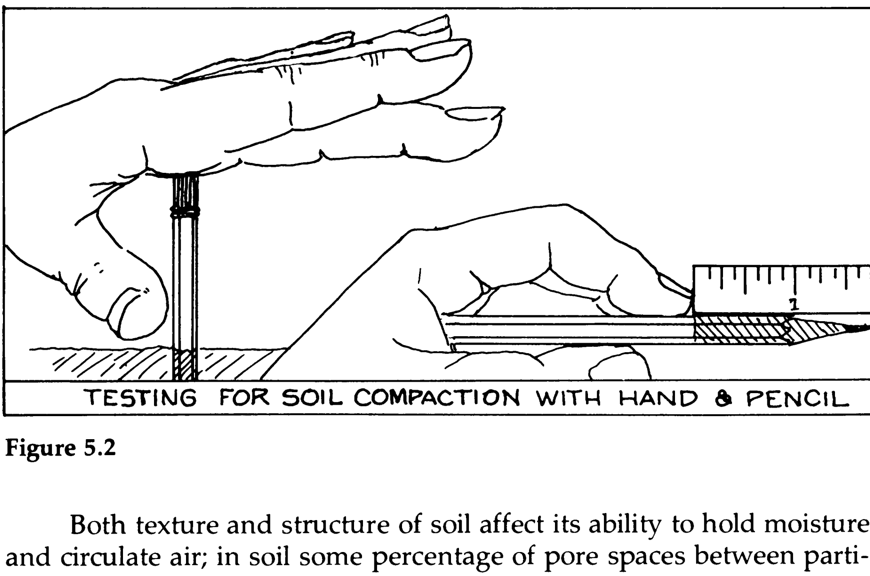
SOIL COMPOSITION AND TEXTURE

A soil is more than just the rock particles in it—it is the total mix with air, water, organisms, and organic material. The various particles bring more than size to the mixture, and their individual properties often change the characteristics of the resulting mix. Because clay particles are quite plastic, when moisture is present they can press together and adhere. If these same particles dry, they shrink together, crack, and store potential energy. When they re-wet, they may give off that potential energy as heat. Clays also absorb water, gases, and soluble salts at a high rate, which makes them valuable in a soil mix for supplying nutrients to plants. Silt has many of the same properties as clay but to a lesser degree. Soils with a high percentage of silts and clays become sticky when wet and form hard clods when dry, resulting in expansion and contraction of these soils. Yet, in smaller quantities, they are an important reason for loams being a good growth medium for many species.

Decayed organic matter is an important part of a soil for many plant species since it is a source of nutrients. It is not surprising that since sands and clays support less life than do loams, they generally have a smaller amount of organic matter. Living plants and their decaying litter affect soil in other ways as well. Water dripping down the plants and percolating through the litter leaches humic acids and other chemicals downward and/or outward. Through complex reactions, these chemicals cause soil particles to form clumps, often referred to as crumbs or aggregates. These vary in size and, because of the spaces (pores) between them, increase the capacity of the soil to hold water and circulate air. Thus, they affect the structure of the soil. Soil structure has a definite impact on root development and, consequently, on plant vigor.

You can get some sense of the texture of soils in places where you are observing plants by passing a soil sample through a series of sieves of decreasing mesh size (see Chapter 10 for details). Examine the coarser particles carefully. Are they solid, or will they crush between your fingers and pass through the mesh? If they do, they are aggregates. What percentage of material at each mesh size is aggregate material? Given the same mix of basic materials, some plants will survive only in a soil of good structure—that is, a good percentage of various size aggregates. This is particularly true in soils that tend to be clayey.

Another factor that affects soil structure is *compaction*, which can be generated from the weight of temporary standing water such as from flooding or from the regular passage of animals or vehicles. Compaction usually occurs in relatively small areas or zones, such as along trails or roadways, and it can modify a soil's normal capacity to support particular species of plants. In some exposed soils, the force of falling raindrops may compact the surface of the soil, preventing insoak of the rain and fostering puddling or runoff of the water. If you see plants distributed in such a way that there are zones where the species is either excluded or where it exists exclusively, check for soil compaction. The simplest way is to take a pencil, place the point in the ground, and put the eraser end against the center of your palm. Press down until it hurts your palm to push farther. Measure how far the pencil penetrates the soil. Repeat at various sites, stopping at the same level of discomfort each time. Compare the amounts of penetration.

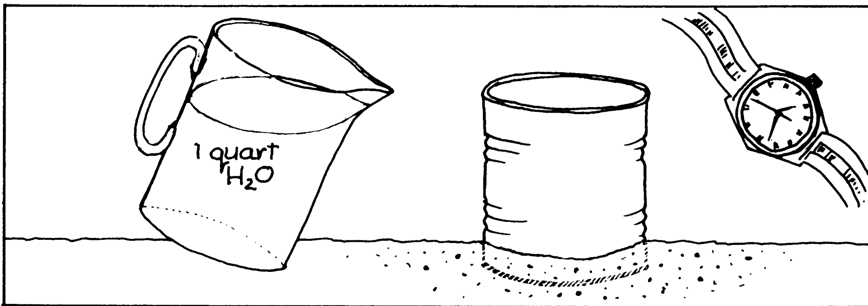


TESTING FOR SOIL COMPACTION WITH HAND & PENCIL

Figure 5.2

Both texture and structure of soil affect its ability to hold moisture and circulate air; in soil some percentage of pore spaces between particles occupied by either air or water is in constant flux. Roots of some species can endure saturated soils while others cannot. It is difficult to get accurate readings of the changing soil moisture in the field, but you can take regular readings with one of the electronic moisture indicators (see Chapter 10) available for use with house plants or you can use the following water absorption method.

For the latter, cut both ends out of a large juice can. Push the can an inch or so into the soil and then pour in a quart of water. Time how long it takes for the full quart to be absorbed below the surface. The method is



SET UP FOR DOING SIMPLE WATER PERCOLATION TEST ON SOIL.

Figure 5.3

crude but provides a rough indication of the water-holding capacity of the soil at that point in time and space.

Some plant species are more efficient than others at tapping water that clings as a thin film to the surface of rock particles. These species may continue to do well in a soil that appears quite dry. There is also dew that condenses on the soil surface at night, sometimes even during dry spells, and which is utilized by some shallow-rooted species.

SOIL DEVELOPMENT

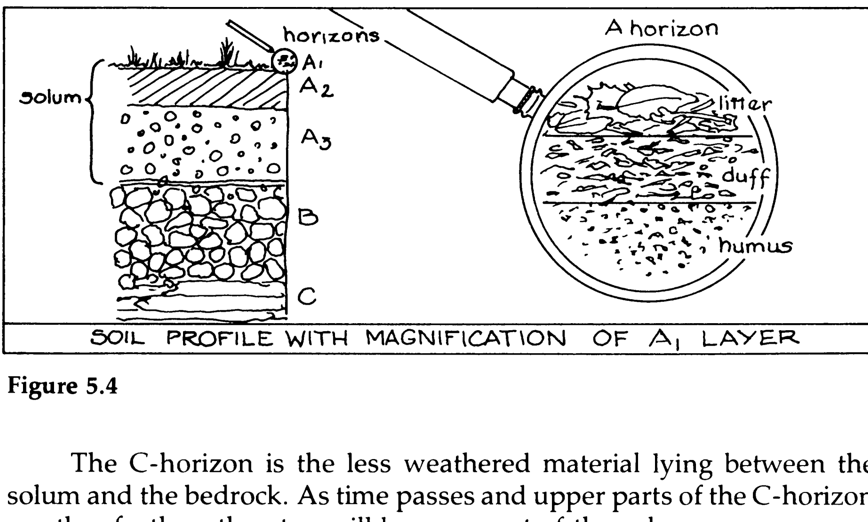
Soils are dynamic and constantly changing, albeit slowly. They evolve from the weathering of bedrock or deposits by wind, water, or glacial ice. In the dry Southwest, many of the soils lie almost directly above the parent rocks, particularly in the flat regions. Soils of the continent's glaciated regions range from fairly thin toppings to deep deposits of glacial till. Slope affects the three-dimensional nature of soils, with materials eroding from steep areas and depositing on flatter ones.

A soil must therefore be considered in three dimensions. In addition to its surface area, it has a depth and a layered structure. This results in a characteristic *soil profile* when a cutaway is dug. Each mature soil type has a characteristic profile that indicates something about the concentration of minerals and the availability of water. Such characteristics affect the activity and location of underground plant parts.

In large measure, the nature of the different layers is caused by the degree of weathering. Soils forming under similar conditions of parent material, topography, rainfall, and biological influence will show similar profiles and probably grow plants of similar requirements. Those soils that are of similar nature and sequences of layers, or *horizons*, can be named and classified in much the same way as plants and animals.

A soil profile usually has three major horizons. These are conventionally designated from the top down as the A-horizon, B-horizon, and C-horizon. If the soil structure warrants it, individual horizons may be subdivided into component layers denoted by a subscript to the major horizon, such as A_1, A_2, and so on.

The A-horizon generally contains the most organic material, and this may be classified by the degree of decay. The top layer, or *litter,* contains plant or animal parts that are virtually intact and recognizable. Beneath that is a layer of material called *duff* that is composed of pieces of litter in only barely recognizable form. Below that is *humus,* a more fully decayed material, generally dark in color, mixed in with the soil. The A-horizon is in contact with rain, and in humid regions chemicals in this layer may be rapidly leached downward to accumulate in the B-horizon. The two horizons are generally recognizable by differences in color. Depending upon the soil type, the leached materials can be such things as iron, aluminum, clay or calcium carbonate, and other salts. Together the A- and B-horizons are developed through the soil-building processes and are collectively known as the *solum.* Most subterranean plant activity occurs in the solum.



SOIL PROFILE WITH MAGNIFICATION OF A_1 LAYER

Figure 5.4

The C-horizon is the less weathered material lying between the solum and the bedrock. As time passes and upper parts of the C-horizon weather further, they too will become part of the solum.

You can collect data on the soil profile near plants you are exploring using a soil auger (see Chapter 10). This device, which resembles an oversize drill bit, allows you to twist up samples of soil to measure the depth and color changes of the various horizons. You may wish to take soil samples from different depths and test them for minerals, pH, and other factors. You may find that conditions at depths where the bulk of a plant's root activity takes place are quite different from those at the surface. Soil samplers that remove a solid core of soil are also available commercially.

The rate at which soils develop is quite variable, but in all cases it is slow by human reckoning. At its fastest, natural soil development usually takes a century or more. Soil development is generally most rapid in cool, humid climates, but rapid development is compromised by poorer quality because the moisture of such climates leaches the A-horizon of its nutrients. Under natural conditions, percolation through fallen leaves makes the soil water acid. This is accentuated by the phenomenon of acid deposition, often popularly called "acid rain." Acid water dissolves out the majority of any calcium carbonate present and deposits aluminum and iron compounds in the B-horizon. This leaching/deposition process is called *podzolization*, and the resulting soils are classified as *podzols*. True podzols have an ashy-gray horizon and the term derives from the Russian *pod*, meaning "under," and *zola*, meaning "ash."

Soils develop very slowly in cool but subhumid climates, and the resulting prairie soils, or *chernozems*, are superior in quality to podzols, at least for many important crops. Chernozems (the Russian word for black soil) concentrate calcium carbonate in the B-horizon, and therefore these soils are distinctly less acid than podzols. This deposition process is known as *calcification*. In subtropical and tropical regions, other soil development processes, *latasolation* and *laterization*, are at work. Soils derived from both processes lack distinct horizons; both decompose and dissipate silicon dioxide from the topsoil and form deposits of iron oxide that give these deep soils a red or yellow color. In areas of heavy rainfall these soils are usually severely leached of plant nutrients. In humid tropical areas, plants must get more of their nutrients from above the ground than below. Most nutrients are incorporated in the growing plants. Cleared of vegetation for any appreciable time, laterites bake rock-hard and exclude new vegetation.

SOIL NUTRIENTS

As a plant observer, you may not want to get deeply involved in chemical analysis of soil, but it is useful to become familiar with basic soil-testing procedures and to keep data on the levels of key nutrients in the habitats of species you are studying. Such information may reveal clues about the apparent state of health and vigor of plants you are observing and may come in handy when you are trying to create optimum conditions for relocating wild plants to a study garden or conservation area.

A simple test to begin with is one for pH. This will measure how basic (alkaline) or acidic the soil is. Testing is accomplished by measuring the free hydrogen ions either with indicator paper that changes color in the presence of specific concentrations of the ions, or with an electronic meter (see Chapter 10).

Various nutrients and their components exist as soluble salts dissolved in soil water. In solution, the compounds dissociate and chemical ions, electrically charged particles, are released. Hydrogen (H) ions have a positive electrical charge; hydroxyl (OH) ions have a negative electrical charge. In a soil solution composed of more H ions than OH ions, the condition is described as being acidic. When the reverse is true, the soil is said to be alkaline. When a balance exists between these two ions, the situation is neutral.

Recorded on a logarithmic scale, pH is defined as the logarithm of the reciprocal of the H ion concentration. It is not essential that you understand its derivation, but you should understand that each unit of change of the scale reflects a tenfold increase or decrease in the degree of acidity or alkalinity; thus, pH 8 is ten times as alkaline as pH 7. Plant species vary greatly in their preferences and tolerances of pH. The chart below indicates some pH values and their interpretation:

pH above 8.0	very alkaline
pH 7.4–8.0	alkaline
pH 6.6–7.3	neutral or nearly so (7.0 is true neutral)
pH 6.0–6.5	slightly acid
pH 5.5–5.9	moderately acid
pH 5.0–5.4	strongly acid
pH 4.3–4.9	very strongly acid
pH below 4.3	extremely acid

While pH is not a direct measurement of any soil nutrients, it does reflect the chemistry of the soil and thus the availability of soil nutrients. In general, the more acid the soil, the greater has been the leaching of the nutrients.

NITROGEN, PHOSPHORUS, AND POTASSIUM

Nitrogen is an important nutrient for most plants. Nitrogen depletion can result in stunted top growth and poor root growth; on the other hand, too much of it will cause retardation of maturation and decreased disease resistance in some species. Nitrogen favors development of leaves.

Phosphorus affects many basic plant functions. Cell division can't take place without it, and it facilitates the conversion of starch to sugars. Seeds do not form without it, and flowering and fruiting depend upon it. Phosphorus will hasten maturation and thus may counter the effects of nitrogen excess.

Potassium affects the general tone and vigor of any plant. It increases resistance to certain diseases and stimulates development of the root system. Essential for the formation of starch and the movement of sugars, potassium also facilitates utilization of carbon dioxide, nitrogen, and the uptake of water; when it is too concentrated, it delays maturation.

You may have noticed that the different nutrients often have contradicting effects on the plant. Thus, we are interested not only in the presence of these nutrients but in their relative abundance, because the suitability of a soil for a particular species depends upon the relative amounts and interplay of these substances and often of others that are less easy to measure.

The above basic three nutrients can be practically measured in a soil by meticulously following the directions in a good soil test kit. Sudbury, Hach, and Lamotte are all reliable manufacturers of such kits (see page 201 for addresses). If you are not performing the field tests, be sure to label each sample carefully and keep them in clean containers that seal tightly to reduce risk of contamination. Unfortunately, extensive soil testing can get to be expensive as you purchase replacement chemicals for the kits. On the other hand, relatively little is known about specific nutrient level preferences of most wild plants, so any measurement you systematically make may be significant to science.

In taking nutrient levels to determine a species' preference, be sure to take readings where the species is not growing as well as where it is to see if differences exist. If, after mapping the distribution of individuals or populations of a species, you suspect some clear patterns of occurrence, run transect lines (Chapter 7) through the pattern and into areas outside the distribution zone. Check nutrient levels and other abiotic factors like temperature, moisture, light intensity, and soil type at a number of points along the transect lines. Map the data for each factor and connect points with the same value. Compare the maps. Does the data create patterns that are similar to the plant distribution map? It may take some statistical analysis, sometimes of a very sophisticated nature, to confirm correlation of a particular degree of a factor with a plant's distribution; however, the simple mapping comparisons often provide a first step toward more detailed research.

The physical environment provides for far more of a plant's needs than just nutrients and other chemicals. Water and energy are other major requirements. The degree to which these environmental factors can be explored by the average amateur depends upon access to, or lack of access to, expensive and sophisticated measuring tools. Nonetheless, a plant observer should pay attention to these environmental factors in a plant's life and record as much data as is practical concerning them.

ENERGY

Two major aspects of environmental energy, heat and light, can be measured relatively easily and with comparatively inexpensive equipment.

In both green plants and fungi, the amount of heat available in air and soil affects a host of plant activities from seed germination to rate of cell division and thus growth. Each plant species tends to have a range of heat tolerance with four critical points and a middle range representing optimal growth. The four critical points are: low temperature, where death occurs; low temperature, where growth stops and dormancy begins; high temperature, where growth stops and dormancy begins; and high temperature that kills. Each species also has a critical time period when temperature must remain within the optimum range; this is the growing season. If weather conditions are unusual and the growing season is significantly shortened in any year, plants may not be able to produce seed. Thus, in some cases, whole populations may be killed outright, altering the distribution pattern of a species in the area.

Because of variations in topography, temperature conditions are seldom constant over extensive areas. Usually there are thousands of miniclimates and microclimates where temperatures are lower or higher than the average for the surrounding environment, resulting in a checkerboard pattern of survival and loss among populations of species in any particular region. Warmblooded animals, which maintain fairly constant body temperatures, are less affected by temperature fluctuations than their coldblooded relatives. Plants are much more like those coldblooded animals; their body temperatures are seldom much cooler or warmer than the surrounding environment. A few notable exceptions have recently been uncovered. Common skunk cabbages push up through freezing soil of the marsh by generating enough heat to exceed that of their surroundings. Thus, the soil immediately around them is thawed. Also, the internal temperature of pine needles in winter has been found to be warmer than the surrounding air by as much as 10° or more.

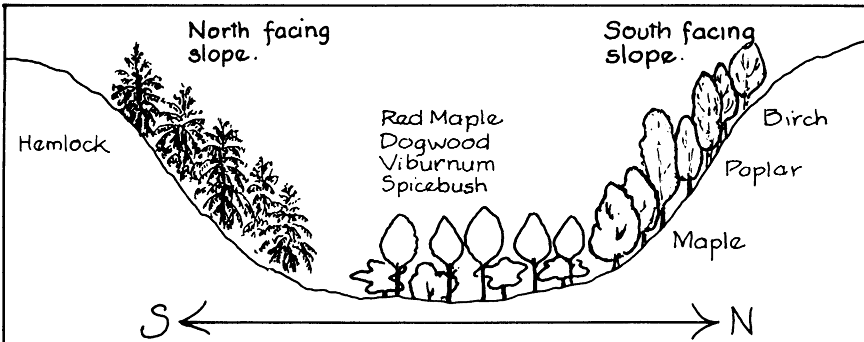
When there is a sudden change in environmental temperature, for a while there will be a marked difference between it and the plant's internal temperature. This is primarily because of the water in the plant which takes longer to heat and cool than does air. This delay factor allows most plants to withstand a brief exposure to lethal temperatures. Thus, many species endure the first isolated frosts of autumn or survive a midday spell of withering heat. Since the sun delivers its most direct rays at midday, it might seem reasonable to expect highest temperatures then, but there is always a time lag as the various materials of air and earth take on solar energy and heat up. Consequently, you can look for highest temperatures around 2:30 P.M. and the coolest just a little before sunrise. These are the times when temperatures are best recorded if you anticipate them to be in the critical ranges. Ecologists use thermographs to provide a continuous recording of temperature, but these are generally too expensive for the average observer. Maximum/minimum thermometers are a little more affordable but are still quite expensive if you are trying to explore a number of stations at the same time. Simple thermometers or thermistors are more practical, but they require more effort on the observer's part (see Chapter 10).

Unfortunately, general temperature information available over the radio, television, or from your home thermometer is of little value in plant observations. Topographical variation affects how the sun's rays strike a particular place and for how long; likewise, the color of soil and vegetation influence how much energy is absorbed and how much is reflected away. These variations, in turn, affect the air and soil temperatures. Temperature varies considerably at different distances from the ground surface. All this adds up to considerable differences among local microclimates, those little pockets of climate in special places. Two species growing only a few feet from one another may dwell in remarkably different microclimates. Thus, the plant observer is well advised to make many and regular temperature readings over several seasons to determine what may be the temperature optimums and limiting extremes for a species.

Where and when possible, you will want to note soil temperatures as well as air temperatures taken primarily at the height of most leaves. Because temperature affects growth rate, and air warms faster than soil, stem and leaf growth may start earlier than root growth. Likewise, because soil remains warmer longer, in temperate climates root growth may continue after stem and leaf activity have greatly slowed down or ceased. Among perennials, this can be important, because the roots give major physical and nutrient support to the next growing season's stem and leaf growth.

Physical topography is not the only factor that affects temperature regimes; vegetation type influences microclimates considerably. Taller, broad-leaved vegetation blocks sunlight from falling directly on the soil, thus slowing down temperature buildup there. It also helps cool air near the ground. Depending upon a species' requirements, these ground and soil temperatures will help determine which seed can sprout and whether resulting seedlings can put on enough growth to become established. Temperature can have a powerful effect on which species survive and which do not at a given station. It has a potent effect on the flora of a region though not necessarily on the vegetation. That is, the types of plants that can survive in an area may be grasses or broad-leaved deciduous plants, and temperature won't change that; what it is likely to affect is which species of grasses or broad-leaved plants will survive and dominate.

In hilly country, it is important to check in which direction the slopes are facing and their altitude. These factors can have a strong impact on temperature and thus on the composition of species that will thrive there. Species growing on a north-facing slope may differ markedly from those growing on a south-facing slope just across the valley or ravine. Such differences of exposure may create isolated pockets (*refugia*) for species normally found in more northerly or southerly regions. Increasing altitude with less dense air results in more rapid heat loss and thus cooler average conditions than those of lower altitude. Average conditions at higher altitudes are usually derived from greater daily extremes, and plants have to have tolerance for such. The microclimate factors strongly affect the distribution of plant species, creating vertical bands of plant communities as altitude increases. Each higher band corresponds to communities of more northern latitudes.



NORTH AND SOUTH FACING SLOPE CONCEPT SHOWING VEGETATIONAL DIFFERENCES.

Figure 5.5

Light is the other energy factor that has strong influence on plants. Certain wavelengths of the radiant energy spectrum we call light are critical for photosynthesis. For optimum growth, the plant must get the proper wavelengths in adequate intensity for a long enough period each day and for a proper number of days each year.

Doing the kind of physical light measurements that precisely define a species' needs is a job for the plant physiologist in his laboratory. That does not mean, however, that the field observer cannot make practical observations about a plant's responses to light. The general effect of light is exerted on plants through changes in its quality, direction, intensity, and duration.

On a clear day the quality of sunlight in the open doesn't vary much in different habitats. There is some seasonal shift, however, due to differences in distance that light must travel through the atmosphere. Thus, in winter more wavelengths in the red than in the blue end of the spectrum reach the earth. However, quality of light is also affected by clouds and fog, and they can effect vegetation in areas where cloud cover or fog banks are present for extended periods of time. Cloud cover, as a percent of sky obscured, should be regularly noted in field journals. Fog, as the percent of the daylight hours it obstructs, should also be recorded.

Light intensity can be measured with photographic light meters that give a reading in foot-candle units. Although light intensity is changing quite constantly and is altered by passing clouds and other atmospheric events, we can get some useful general information. Use light reflected off a piece of white cardboard to secure consistently comparable readings at a site. Holding the meter a constant distance from the cardboard, take one reading in an open, unobstructed area and then take the rest of your readings at various sites in the habitat, such as near a forest floor, at six feet, and at even higher locations if possible. Express each reading as a percentage of the light reading you got out in the open.

If a plant you are studying gets direct light part of the day and shade the rest, keep records of the hours or minutes that the plant gets direct light versus how long it gets filtered light. This light regime may determine whether the plant has a chance to flower or only to grow vegetatively. Many northeast woodland forest floors have healthy-looking blueberry plants that no longer flower and fruit because the closing woodland canopy produces an inadequate light regime. Diffuse light tends to promote development of vegetative structures, while intense light favors development of flowers, fruits, and seeds. Thus, the great flower extravaganzas are in fields, deserts, and tundras rather than in forests. Such floral shows as occur in forests generally appear in deciduous forests in early spring, before the leaf cover appears and shuts off much of the useful wavelengths.

Light intensity has a creative impact on leaf formation, and this is something the alert observer can see. Light affects chloroplasts in leaves and the cells that contain them. *Sponge parenchyma* cells tend to produce leaf growth at right angles to incidental light, thus creating a thin, broad leaf. This results in a leaf with more area to catch light. *Palisade parenchyma* cells, on the other hand, tend to extend the leaf in the direction of the incidental light, thus producing a thicker leaf. Even within a given tree you can see these adaptations. So-called sun leaves at the outer layer of the tree crown tend to be smaller and thicker while leaves inside the crown and on lower branches, shade leaves, will be thinner and broader. Examination with a microscope reveals a different predominance of sponge or palisade layers in those leaves.

It is not surprising that plants of many species of sunny, dry habitats have small leaves with a preponderance of palisade cells, nor that aquatic plants, with submerged leaves that must deal with the reduced intensity of light filtered through water, have predominantly sponge cells in the leaves.

Plant species vary considerably in their tolerances to shade. Light is an important factor in this, but it is linked to interconnected factors of temperature and soil moisture as well. Light's influence is greatest on seedlings. Some species are light-demanding and very intolerant of shade—for example, willows, sumac, bluestem grasses, cottonwood, jack pine, and lodgepole pine. Other species are very tolerant to shade—for instance, beech, sugar maple, basswood, and hemlock. The inherent tolerance of seedlings to shade will have considerable impact on that species' ability to invade and become established in new sites. Some shade-tolerant species, like beech and hemlock, may survive many decades of slow growth and suppression before a new opening in the canopy gives them opportunity for a growth spurt and a dominant place in the vegetation. The degree of shade-tolerance of a species also contributes to membership in the various layers of a woodland. In many kinds of healthy woodland, there will usually be four reasonably distinct vegetation layers: the *herbaceous layer* at the forest floor composed of grasses, other herbs, and assorted nonflowering species such as mosses and ferns; a *shrub layer* of shade-tolerant shrubs; an *understory* of young shade-tolerant trees; and the *canopy* of dominant trees which may or may not be species with shade-tolerant seedlings.

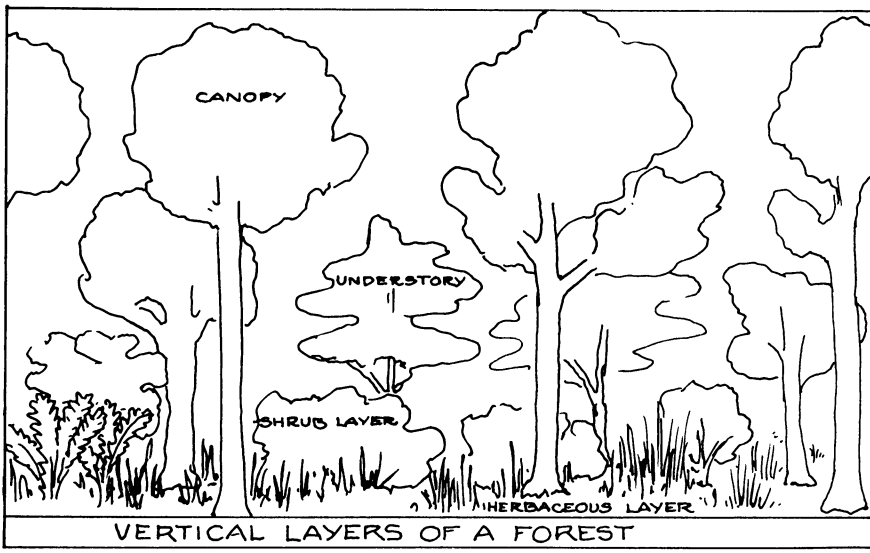


Figure 5.6

The chart below indicates some shade tolerances of common trees in North America:

VERY SHADE-TOLERANT	SHADE-TOLERANT	SHADE-INTOLERANT
Sugar Maple (*Acer saccharinum*)	Elms (*Ulmus*)	Silver Maple (*Acer saccharinum*)
Beech (*Fagus*)	White Oak (*Quercus alba*)	Bur Oak (*Quercus macrocarpa*)
Basswood (*Tilia*)	Red Oak (*Quercus borealis*)	Birch (*Betula*)
Yew (*Taxus*)	Black Oak (*Quercus velutina*)	Poplar (*Populus*)
Hemlock (*Tsuga*)	Ash (*Fraxinum*)	Willow (*Salix*)
Fir (*Abies*)	White Pine (*Pinus strobus*)	Ponderosa Pine (*Pinus ponderosa*)
White Cedar (*Thuja*)	Douglas Fir (*Pseudotsuga taxifolia*)	Larch (*Larix*)
		Lodgepole Pine (*Pinus contorta*)

You can get some idea of the varying shade tolerances of tree species by observing crown density, degree of self-pruning relative to height of growth, and growth of a young stand under the old. In light-demanding species, leaves are concentrated at the outer part of the crown, or the crown is open so all leaves get plenty of light. Shade-tolerant species will have much denser crowns. Shade-intolerant species will self-prune off their limbs high up, even in open habitats. Shade-tolerant species will have leafy branches much closer to the ground and their stems will tend to be thick in proportion to their height. By and large, shade-tolerant species cannot establish themselves in stands of their parents or of other shade-producing species; shade-tolerant species will produce seedlings beneath stands of adults of their species.

MOISTURE

Essentially, all the physiological processes in a plant take place in the presence of water. Water is required for respiration, photosynthesis, and the transport of photosynthates throughout the plant. The plant also transpires quantities of water under most conditions, and water gives considerable support and rigidity to plants. Because of ongoing water loss through transpiration, growing plants must have access to fresh supplies from the environment, primarily from the soil. Water, and minerals dissolved in it, are often taken in through the roots with the aid of cellular extensions called *root hairs,* which increase the absorptive surface. Other plants increase their roots' ability to take in moisture and nutrients by means of a symbiotic relationship with mycorrhizal fungi.

As we remarked earlier in the section on soils, the amount of water in the earth can vary considerably from only a thin film adhering to soil particles to total saturation of all available space between solid particles. Plants have a variety of adaptations for coping with their needs for water and its tendency to be available in amounts either too great or too small. Tolerances to excess or deficiency are highly varied according to species, but they tend to fall into three categories: hydrophytes (from the Greek *hudor* = water and *phyton* = plant); xerophytes (from the Greek *xeros* = dry); and mesophytes (from the Greek *mesos* = middle).

Plants adapted for life submerged in water or floating are called *hydrophytes.* Some hydrophytes are actually amphibious, with parts submerged and parts emerging from the water, such as cattails. The many special adaptations of hydrophytes are more fully explored in Chapter 9. The major adaptations of hydrophytes deal with ways of increasing absorption of carbon dioxide, and neither water loss nor intake mechanisms are emphasized.

Xerophytes, on the other hand, have many adaptations for taking advantage of such little moisture as becomes available and for conserving that moisture against excessive loss through transpiration. *Mesophytes* are less tolerant of moisture content extremes at either end of the continuum.

At their extremes, moisture preferences or tolerances are fairly obvious. But the degree of moisture preferences or tolerance among the apparent mesophytes is much more subtle and should stimulate continuing observation and data gathering by plant watchers. Soil moisture records from a number of plant stations over time will help indicate the range of preferences and the responses of plants to unusual flooding or drought conditions. Flooding presents some unusual situations, so duration of the flooding should be noted. There are species that can endure moderate periods of annual flooding, but even these have distinct limits on how long they can remain inundated and survive. Other species have little or no tolerance for flooding. If you have an opportunity to study a newly flooded area—by a beaver dam, for instance—you will be able to determine some of the tolerance limits. Even plant species that can stand periodic streamside flooding may eventually succumb to prolonged immersion behind a beaver dam.

For nonflooded conditions on most soils, you can gather data with electronic moisture meters available in many gardening and house plant supply stores. These are not the most precise tools available, but they are suitable for rough field observations. Be sure to note the make and model of the instrument you are using for data gathering so its relative reliability can be ascertained later.

INTERPRETING ENVIRONMENTAL INFORMATION

It would be so nice if only we could ascribe particular plant behaviors as responses to a particular environmental factor. In some cases, after long and careful laboratory study, this is possible; but in general the various environmental factors are so interrelated that it is often not possible to separate the factor that is most responsible. Reduced light induces stem elongation, while a shortage of phosphorus will prevent stem elongation. In some situations these two conditions could cancel each other out as far as plant growth is concerned. Increased light intensity usually results in higher temperature. If a plant grows well under these conditions, which one is it responding to—light intensity or heat? Interpreting the relationships between a plant and its environment is seldom easy. It may take sophisticated mathematical analysis. What is clear, however, is that no analysis is possible without data to analyze.

As regularly as possible, plant watchers are urged to gather as much environmental data as they can about the local conditions where the plants they are exploring live. These data may appear to have little meaning at first, but as they accumulate you may begin to see some definite patterns or gain the statistical tools to mine the data for less obvious patterns. Data not collected are like fish that got away. A day may come when you wish you had certain information that you failed, for any of a number of reasons, to collect and note.

Even discovered patterns may raise more questions than they answer. However, the data may well suggest some field or laboratory experiments that can provide more definitive answers. It is partly the puzzles, dilemmas, and frustrations that give stimulation and added joy to the study of the endless diversity of the plant world.

FURTHER READING

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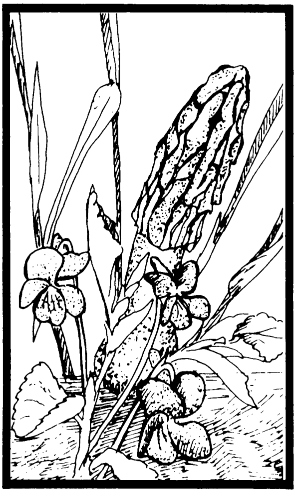

CHAPTER 6

A MATTER OF ASSOCIATES

The alert observer walking about the countryside with an eye to the plants soon begins to notice that the different species are not randomly scattered across the landscape. To be sure, there may be places where many acres seem to be almost totally occupied by a single species, but, even there, closer examination will turn up a variety of other species in less abundance.

Extended observations will most likely reveal that wherever you spot species A, species B, C, and D are likely to be found close by. This may be because their basic needs are very similar, in which case they may be in direct competition for the same space and resources. On the other hand, they may have quite different adaptations that let them utilize different portions of similar habitat or tolerate the stresses one species places on another. Such a mix of species that share space, utilize slightly different resources, and perhaps depend on conditions created by other species such as various degrees of shade, may be thought of as a *plant community*.

Plant ecologist Henry Oosting offered as a working definition of community: "An aggregation of living organisms having mutual relationships among themselves and their environment." Mutual relations in this definition includes both competition between species and individuals and dependence of one species upon another. The challenge to the plant observer is determining the nature and extent of the relationships between plant associates, and thus each associate's place in a designated plant community. We must also continually be aware that a community includes animals and members of other life-kingdoms as well, and that through coevolution these may play critical roles in the functioning of a community. For example, certain insects are critical to completion of particular plant life cycles through pollination, and a number of bacteria species are essential for making available mineral nutrients for various plants. The plant observer is not likely to observe all of these things, yet he or she must remain aware of their presence and importance.

The first challenge to you as an observer of plant communities is to perceive a pattern of association. This involves making thorough lists of the species that inhabit a particular habitat you are studying or that you find within a specified radius of a particular species you are investigating. In doing this, think three-dimensionally, for there are vertical zones of occupancy as well as horizontal ones, and each zone has its own characteristic species that may influence the species in other zones. There will be times when you feel as though you are engaged in a game of three-dimensional tic-tac-toe. However, to the plants, it's not a game, it's life.

First, gather information about which associates grow in a given local community or stand. Later, compare them with what appear to be similar communities. Although there are broad areas of similarity, you probably will discover enough differences to raise serious questions about whether or not they are indeed the same type of community. At that point in your investigation, the tools of statistical analysis will have to be brought to bear on your data. It is beyond the scope of this book to explore the mysteries of statistics, so if you reach that stage seek someone at a local college or university to help you develop the needed statistical tools.

INFORMATION TO SEEK

As you assemble information about plant associates, you will need both quantitative and qualitative data. Quantitatively you need to find out how many of each species are present, their approximate sizes, and some measurement of how much space they occupy. Qualitatively you need to acquire data on how each species is grouped or spaced out within the community, including its place in the vertical as well as horizontal layering. You will want to gather information on how each species develops through critical stages in its life cycle—that is, at what stages in the annual cycle of the community it is prominent. For example, many herbaceous plants of the northeast United States deciduous forest communities flower and die back before the tree canopy leaves out. Even though they might be completely overlooked in a fall study, they are nonetheless part of those plant associations. Each species goes through several distinct periods throughout the year, such as a leafing-out period, a leafless period (for many at least), a flowering period, a fruiting period, and an embryo period. Timing and duration of these periods are part of the phenological records you can gather.

Chapter 7 explores the nature and use of quadrats and transects to gather quantitative information from samples of the various plant associations. In exploring the nature of these quadrats and transects, you will want to gather quantitative data about the following:

Abundance of Each Species. Some people explore their study plots and develop a subjective estimate of whether a species is very abundant, abundant, infrequent, rare, or very rare. Except when you are traveling and lack time for careful accounts, this data is seldom of much value. The problem, of course, is that different observers vary in their perception of just how many must be present to meet a specific category. My "abundant" may be your "very abundant."

It is more informative but requires more effort to establish a number of community sample plots and record the frequency of occurrence of those plots in which the species occurs. You can also note the density of individuals present in the total area sampled. These data will help determine the abundance of the species and its distribution in the community.

Occupance. The space a plant species occupies in a community is a strong indicator of its impact on that community and its relative dominance there. The larger the plants are, the greater access they have to basic resources and the greater the demands they make upon them. Data should be gathered on a species' place and occupancy of each vertical strata present, as well as what is perceived while looking down from above the study plots. Serious plant watchers may also try to get some information on the soil occupancy of the various root systems, because roots are important to a species' role in the community. Plants that dominate a community usually compete successfully at every level of the community.

As indicated in the following chapter, it is fairly easy to measure the crown area of at least the larger plants when working with quadrats. For grasses this is more difficult, but most people simply measure the circumference of a clump. This provides a reasonable measurement but does not adequately indicate the area shaded by the leaves. This shaded area impacts on which smaller plant forms may grow between the clumps or which seedlings of tall herbs can become established there. For some forestry purposes, basal diameter of trees at breast height is used, but the measurement likewise ignores the impact of the crown area on shading and changing microclimates and also on the competitive action of the root systems. This is intended, not to confuse, but only to indicate that certain data, which are relatively easy to gather and do have some uses, must be employed carefully because they could lead to very misleading statements.

When examining vertical zones, map the area of cover at each appropriate height. Then superimpose the cover maps of these various heights one over the other. The combination may reveal causes of patterns on the ground.

Distribution Pattern. This information may best be gathered by mapping but can be entered descriptively in the notes. What this data tells is where plants are located and in what sort of density. What it doesn't tell you is why they are so arranged. Patterns are seldom constant from one place to another, but there are definite tendencies for certain species to be distributed according to specific patterns because of their species-specific reproductive strategy or the distribution patterns of certain environmental factors, such as moisture or nutrients, which are critical to their survival.

Descriptive terms for distribution patterns of a species follow a rough continuum from wide dispersion to high gregariousness and include such terms as: grows singly in small patches (usually refers to individual, seed-generated plants); small or large colonies (usually refers to clonal groups, vegetatively reproduced); large groups (often clusters of patches); mats (extensive cover of small plants, usually bryophytes and other nonflowering groups); pure stands (fairly extensive areas of a single species).

Because it is prone to change, the distribution pattern of a species in a community should be checked with regularity. Change occurs because of alterations in local environmental conditions. Note should be taken of the maturity of the plants and their reproductive state since the distribution pattern of seedlings may vary significantly from that of established plants. Likewise, if a species reproduces by a vegetative strategy, its distributional pattern may also alter once its seedlings become established and vegetatively active.

COMMUNITY—WHO'S A MEMBER?

Even with good data, it is not always easy to determine whether or not the species you find associating with one another actually compose a community. It depends in large measure on careful definition of the characteristics used to verify membership in a particular community. Just as with human communities, some species get along anywhere and can and will mix with any community in which they find themselves. Others confine all their activities to a very limited neighborhood. There are also those who survive in a variety of settings, but can settle in and raise a family only in a particular type of community.

As you begin to look at samples of plant communities of any particular habitat, you need to determine from your notes the frequency with which each species occurs in mixed stands of that habitat. A basic scale for this is: if a species appears in one to twenty percent of the stands, it is rare; twenty-one to forty percent of the stands ranks it as seldom present; forty-one to sixty percent occurrence marks it as often present; sixty-one to eighty percent occurrence labels it mostly present; and eighty-one to one hundred percent labels it constantly present.

But presence of a species in a habitat is not enough to confirm it as a bona fide member of that community. You need to determine over time how it develops in that place. It may frequently be present as seedlings but fail to become established, or it may even get established but fail to do well enough to complete its life cycle and reproduce. *It is the ability to complete its life cycle by reproducing sexually that is most often set as the criterion for true community membership.* There are even species that survive on a site and reproduce vegetatively but never sexually; such are often excluded as true members of that plant community.

As you compare different sets of plant associates to determine whether or not they represent the same, or at least very similar, communities, you will want to compare lists of the species present and also have some idea of these species' presence or absence in other nearby plant communities. Such comparison can be undertaken only after considerable time afield and the acquisition of a reasonably broad knowledge of the life histories of the component species.

For any community under study you will want to determine if a particular species is:

1. a stranger whose presence is essentially accidental
2. present here but also found in many other communities with no apparent preferences
3. a *preferent,* living in a number of communities but showing greatest success in this one
4. a *selective,* found generally in this community but occasionally growing elsewhere
5. an *exclusive,* found only in this type of community.

Not all communities have exclusive species, but for those that do, such species can be considered as *indicator species*—that is, whenever you see the species you can identify the community. Selective and preferent species, along with any indicator species, comprise a community's *characteristic species.* If indicator species are lacking, you may not be sure what community those other plants represent. To resolve the question as to whether two communities are essentially the same or different, you may need to determine a *coefficient of community,* a mathematical expression of the degree of similarity of species lists for the two communities being compared.

To determine the coefficient of community, compare lists of species found in the two communities and note the number of species found on each of the lists. Next, find the total number of species in the combined lists. Divide the first number by the second to determine coefficient of community. Thus:

$$\frac{\text{Number of species common to A and B}}{\text{Total number of species in A and B}} = \text{Coefficient of community}$$

The closer the coefficient approaches one, the greater the similarity and the greater the likelihood that they represent the same community. To refine determination of the degree of similarity between two communities is quite possible, but when you are ready to proceed, it is time to enlist the advice and assistance of a professional botanist or ecologist.

Up to this point you may be aware that we have not named any particular plant communities. That is because there is no commonly agreed-upon classification for them. Some ecologists refer to them according to their outstanding physical features, such as southern or northern bog community; others would use an indicator plant to identify the same communities, such as white cedar bog community or black spruce bog community. Others may classify according to several characteristic genera—i.e., beech-birch-maple forest, oak-hickory forest or, a bit more technically, the *Spartina-Juncus* tidal marsh.

Thus, the name for a community is a judgmental matter of preference. It seems most practical, however, to name communities by the two or three most characteristic genera or species and/or dominant physical characteristics, at least in temperate regions.

Because communities do not exist in a vacuum, ecologists have elaborate classifications for different degrees of community association. These associations are often called communities as well, with such broad headings as wetland communities, desert communities, tall grass prairie communities, deciduous forest communities, coniferous forest communities, and alpine communities. Such units are composed of subunits, and each has common vegetational characteristics. However, they may vary considerably geographically in regard to their flora.

Every community is constantly undergoing change. The very presence and activity of the major species causes changes in the nature of the surroundings. Height relationships change, temperature conditions at various levels are altered, nutrients are added and depleted, space is occupied, and soil structure may be altered. The observant naturalist becomes aware of these changes, for they offer clues to the future of plant associations at that particular site. It is with such studies that knowledge of a species' germination and seedling establishment needs come into play, along with knowledge of vegetative reproduction habits.

In many associations the established plants so alter conditions that their own seeds have difficulty germinating or getting established. On the other hand, these same conditions may be just right for other species that, once established, create totally unsuitable conditions for continued survival of species that preceded them. As this happens and associates of these invading species also appear, the old community will slowly but surely be replaced by a new one. In time this new community will suffer a similar fate.

The *succession* of one community by another will eventually reach a stage at which the physical conditions of the site are relatively stable for that climate. At that time, the species dwelling there are so adapted that their own offspring can become established on the site and fill any vacancies that may occur. Generally it takes well over a century of undisturbed community succession to reach such a state of relative equilibrium. Many ecologists call such a community a *climatic climax community.* Climate, of course, is the long-term average of weather conditions, and it is assumed that this community is the vegetative pattern best adapted to those conditions. Thus it is the climax, or end product, of a sequence of communities.

Other researchers are less sure that this is the case. Within most regions topography makes pockets of alternate climates, and some of these are quite stable over periods of time considered long by human standards. They are clothed by plant communities different from the supposed climax. Similarly, outcrops of certain types of bedrock create soils that support unique vegetation as islands within the supposed climax. The criterion is essentially one of time. The whole Earth is constantly changing, and many of these changes require a time frame outside the general comprehension of most of us. This means that the climate is always changing as well, and so too the vegetation patterns responding to it. Rather than a concept that explains what is happening in the world about us, the concept of climax, then, may be only a shortsighted intellectual convenience to satisfy the human desire to find order in nature.

WATCHING COMMUNITIES CHANGE

A good plant observer records what is actually happening, not what he or she expects to happen. Because nature is full of surprises, much of what has been written in the popular literature and textbooks reflects data from relatively few cases and tends to present them as generalities. Such generalities may or may not hold true for the particular plant community you are investigating, so watch carefully, regularly, and keep careful records of what you observe.

Note what plant strangers begin to appear in your plant community and whether they become established. Many seedlings come and go; the important thing is which species gain a secure roothold. Carefully note where in the community they get their start. Was it in an opening caused by some physical disturbance? Was it in the shade of an already established plant? Then note how the strangers expand their occupancy in the community. Is it by sending out tillers of some type? Is it by saturating the area with seeds? Is it by expanding their crowns and thus light-starving plants beneath them? All of these are strategies different plant species use to reach new sites, become established, and enlarge their occupancy of a site.

As one community is beginning to replace another, keep alert to whether certain of the characteristic species of the new community regularly arrive ahead of various others—that is, are certain species "advance men" for the new community?

As you watch one community replace another, one thing becomes relatively clear: Size is an advantage. At each succeeding stage, the major components of the community are generally those species with the largest life forms—these are the species that become dominant. These large individuals tend to put stress on their smaller neighbors by increasing their own access to the physical resources of the site—water, light, and mineral nutrients—and by reducing access to light, creating increased litter on the surface, and perhaps releasing chemicals toxic to other species.

SURVIVAL STRATEGIES

In recent years some plant ecologists have begun to look at the varying stressful conditions plants have to face and are discovering that there are various strategies that plants have evolved to cope with these situations. Details vary from species to species and determine a species' relative success with the strategy. However, there are commonalities among all species employing each particular basic strategy. These strategies have been well elucidated by the British plant ecologist J. P. Grime, and I owe a great debt to his work for the material in this section. Become alert to the strategies plants in your communities appear to be employing.

Any plant must face a potential of two great challenges: (1) difficulties in gaining access to one or more of the basic resources needed for its life processes, or *stress*; and (2) recovering from physical damage due to predation, hail, fire, trampling, mowing, and the like, or *disturbance.* Since they cannot relocate or avoid these challenges, plants have had to evolve various solutions and incorporate them into their very structure and life history.

Dr. Grime has postulated three major and four secondary types of survival strategies among established plants and five types of regenerative strategies. Plant observers should look for the characteristics of these strategies among the species under study and see what strategies are being used by each of the majority of species involved in the transition from one plant community to another via succession.

Plants utilizing the three primary stages are referred to as *competitors, stress-tolerators,* and *ruderals,* and each is linked to a particular combination of the two challenges of stress and disturbance. Competitors function in situations of both low stress and low disturbance. Stress-tolerators function best in sites where stress may be high but disturbance is low. Ruderals function in situations where stress may be low but disturbance is high. There is no effective adaptation to situations where both stress and disturbance are very high. Such sites remain essentially barren of plant life.

COMPETITORS

When neighboring plants attempt to utilize the same available light, the same particles of mineral nutrient, the same molecules of water, or the same volume of space, they are competing. Competitor species tend to show rapid leaf and root expansion, and lateral spread. They send shoots up rapidly and become tall, have good root storage to provide the energy for the rapid growth, and may have extensive branching rhizomes or tillers to occupy vacant areas rapidly.

Competitors respond to damage, such as defoliation, by speedily sending up new shoots and leaves or by sending out a number of tillers that themselves send up leaves. This is particularly noticeable in competitor grasses used in lawns and pastures. All in all, competitors' adaptations let them take advantage of the resources of their environment at a high rate. In productive, crowded habitats, those plants that can tap the highest amount of the available resources are favored for survival and expansion. Competitors are aggressive in expanding their absorptive surfaces, such as roots and leaves, and flexible in physiologically expending their photosynthates where they will increase absorptive surfaces to tap resources most effectively.

STRESS-TOLERATORS

Stresses—such factors as lack of moisture, mineral depletion, shade, and the like—prevent plants from making plant material. Geared for growth, competitors are exploiters rather than conservers. Their ability to compete is severely curbed under increasing stress, and they fare best in productive habitats.

There are five major kinds of habitats where stress is prevalent—arid areas, arctic-alpine areas, shaded habitats, saline habitats, and nutrient-deficient habitats. Plants that survive in such habitats may have quite different specific adaptations, yet they also share a number of adaptations in common.

Stress-tolerators are slow growers with long-lived organs. Many are evergreen. They may flower infrequently, and they have mechanisms that let them take advantage of temporarily favorable conditions. They have adaptations to conserve their photosynthates rather than rapidly expending them on growth as do competitors and ruderals. Growth among stress-tolerators tends to be intermittent, and they show much less diversity of form within a species.

Stress is not the only hazard stress-tolerators face; because they grow slowly, loss of foliage from plant-eaters can be very dangerous and cause considerable setback from which recovery is slow or nil. Consequently, many stress-tolerators have toxic or unpalatable leaves or protective spines.

RUDERALS

The latin word for rubbish is *rudus*, and thus the plants that grow readily among the rubbish of disturbed areas are called ruderals. The term is applied here to the strategies of plants adapted to areas of low stress but high disturbance—that is, they are adapted to cope with factors of partial or near total destruction that prevent the building of their biomass.

Ruderals are found in such disturbed habitats as beach drift zones, silt deposits from floods, exposed shorelines of ponds and lakes that dry up seasonally, trampled ground where hooved animals or people or their vehicles are abundant, plowed land, desert areas that get a brief rainy season, and smaller disturbed spots such as ant hills, wallows, dusting spots, and similar small, disturbed, bare patches.

Flowering plants adapted to such sites of recurring and intense disturbance generally have an annual or short-lived perennial life cycle. By rapidly completing their life cycle and maximizing seed production, they are able to exploit those environments that can support rapid plant growth only intermittently and for relatively short time spans. Ruderals are short-lived even when they don't face disturbance. For the annual species, death comes to the parent plant right after seed production. Seed ripening is very rapid among ruderals and a flower cluster may contain both blossoms and ripe seeds.

Ruderals tend to respond to stress by converting their growth effort from vegetative growth to flower and seed production. Whereas competitors and stress-tolerators might forego flowering under stress conditions, ruderals strive harder to produce at least a few seeds. Because the environment they thrive in is so unstable, the parent plant is destined for a short life under the best of conditions; therefore, ruderals sacrifice the parent to assure offspring.

This all begins to seem a bit more like armchair ecology than field botany, but it does offer clues as to what plant lifestyles to be alert for. In early successional stages, communities are likely to be composed heavily of ruderal strategists or stress-tolerators, depending upon the conditions. In primary succession situations, where the substrate is bare rock, barren soil, or open water, the first colonists will probably be stress-tolerators. Their tenure is likely to be long, but in time they will moderate the conditions enough for some ruderals to join the community along with some stress-tolerators of less extreme capabilities. Their presence will eventually create conditions that allow invasion by competitor species whose strategies often eliminate quickly the majority of the ruderals and suppress the stress-tolerators. Competitors tend to overexploit certain resources, thus creating new stresses that give newfound advantage to other types of stress-tolerators. Secondary succession, often based on human-initiated disturbance of an area, follows a similar pattern but more usually begins with ruderals.

The major strategies are linked to major habitats, and one does not have to spend much time afield to realize that there is a much broader spectrum of habitat types than three. It should not be unreasonable then to expect that there is a broader spectrum of strategies, probably made up of aspects of the three major ones. Such does indeed seem to be the case.

A species like ragweed (*Ambrosia artemisiifolia*), for example, has a long vegetative phase and puts up tall shoots. Where many ragweed plants are growing close together, the broad spread of their leaves will form something of a dense canopy—characteristics of competitors. Yet the plant comes in on disturbed ground and is an annual that produces many seeds and dies—marks of the ruderals. Dr. Grime calls such species *competitive ruderals*. Competitive ruderals may be annuals, biennials, or perennials. The perennials, like yarrow (*Achillea millefolium*), creeping buttercup (*Ranunculus repens*), or Canada thistle (*Circium arvense*), are adapted to recently, but not newly, disturbed sites. Although they put out many short-lived vegetative shoots and vigorous rhizomes and stolons, they are soon excluded by taller, more consolidated perennial species.

Competitive ruderals generally have a longer period of vegetative growth before flowering than other ruderals and thus develop greater biomass. They also occasionally can exploit environments already occupied by perennial species by doing most of their growth during periods of the year when the impact of the more dominant species is restricted. This strategy seems best adapted to habitats of low stress and where competition is kept moderate because of disturbance.

Stress-tolerant ruderals are found in habitats with a moderate degree of both stress and disturbance. A characteristic of such habitats is that the stresses occur during the growing period of the plants. These are difficult conditions necessitating specialization. Such situations are found in the arctic, on mountaintops, in deserts, and in shallow or sandy soils that dry out quickly. Most such species are small annuals or short-lived perennials that do their growth and flowering in the cool, wet season. Most are of small size, have slow growth rates, and produce seeds that tend to be small and remain dormant over the dry summers. There are also species that survive the dry seasons underground as bulbs, tubers, and rhizomes and do their growing in cool, moist seasons.

These strategies are not limited to flowering plants; many of our mosses and liverworts can also be classified as stress-tolerant ruderals.

There are many species that illustrate a capacity for lateral spreading and are vigorous perennials. They have competitive strategy traits, yet these species have longer life spans for their leaves, lower maximum growth rates, and highest shoot biomass in summer with a marked decline in winter. Such a pattern describes a number of species of grasses, sedges, and rushes which are classified as *stress-tolerant/competitors*. Theirs is a strategy for habitats of moderate productivity or stress and very little disturbance. Many woody plants utilize this strategy, particularly those found in the latter stages of succession where resource depletion increases the levels of stress.

There are also definite trends to the types of changes that occur as a community and its environment change, but these changes are not completely predictable. Dry, *xeric* habitats tend to become moister, more mesic; and wet habitats become drier, more mesic; but these trends can be reversed by any of several environmental events. Habitats that are periodically disturbed do not necessarily generate the same sequence of plant communities each time a succession progresses. Thus, we repeat an earlier admonition: The plant observer must faithfully record what is happening, not what he or she expects should be happening. Nature does what it will do. People try to find patterns and order in that and attempt to predict what will happen under given conditions. Sometimes the order does exist in nature; sometimes it exists only in the minds of humans.

WHO IS DOMINANT?

In any association of plants, a few species are dominant and get the majority of available resources. In general, you can recognize dominants by their greater height, lateral spread, and litter production. Different species will exert different degrees of dominance in different settings. For example, a goldenrod species that is dominant in an old field may lose that dominance as young poplars and dogwoods become established. How does that occur?

The answer lies in the various regenerative strategies that plants employ. Each species has its own variation on the main themes, but there are two major possibilities: through vegetative offspring or by seeds or spores. Some species can use only the latter, a number can use both, and a few, like bamboo, mainly reproduce vegetatively, rarely resorting to seed production. Seed distribution modes have evolved along with germination patterns, and these comprise the various strategies. These strategies apparently have evolved as a means by which juvenile stages in a species' life history can tolerate, or foil, the potentially dominating impact of established plants on a site.

Vegetative expansion by the sending out of persistent tillers, rhizomes, stolons, runners, and the like is a very important strategy that presents a low mortality risk, because the offspring maintain a prolonged attachment to the parent. It is a particularly useful strategy where heavy litter, shade, or other factors make reproduction through establishment of seedlings very difficult. It is also useful where fire and other disturbances cause above-ground setbacks; stored photosynthate below ground can reestablish new growth quickly. However, vegetative strategies are most prevalent in relatively undisturbed habitats.

The other regenerative strategies to be alert for are adapted to exploit disturbances of one sort or another. Their individual uniqueness is shaped by the nature and frequency of disturbances and the environmental settings in which they occur.

Wind Distribution. We often are aware of windblown seeds such as those of dandelions and cottonwoods. Although the seeds are produced in vast numbers, relatively few ever get the opportunity to germinate. The strategy of wind distribution is useful for reaching areas of large-scale and unpredictable disturbance, such as eroded fields, plowed areas, and formerly flooded river terraces. Many devices have evolved to exploit this strategy, ranging from minute size of seeds and spores to complex tufts that catch the breeze to winged extensions that increase lift and drift.

Seasonal Regeneration. Across a wide range of habitats there is a predictable seasonal damage that each year creates bare ground or sparsely vegetated openings. Such openings are the result of seasonal droughts, flooding, grazing and trampling, and the like, and are generally recolonized each year during the season that is most advantageous to the colonizers. In temperate zones, these seasons tend to be either spring or autumn; and each season stimulates its characteristic strategy.

AUTUMNAL REGENERATION

This strategy is most readily used in regions where rainfall is primarily a phenomenon of the cool season, as in Southern California. In such regions a predictable dry season usually precedes the rain, and the dry season tends to kill shallow-rooted species, thus creating openings. The trampling of grazing animals creates further openings.

Seeds of species that will germinate in fall have been lying on the ground through the dry spell and respond quickly to the onset of moist, cool conditions. Seeds of species that use this strategy are able to germinate in light or dark and over a wide range of temperature. The seeds are comparatively large so that they have a good start toward successful establishment and the life cycle can be completed before the next recurring drought. Many grass species use this strategy. There are also some plant species that reproduce by *bulbils* that follow a similar strategy. Bulbils remain dormant over the dry spell and regenerate with the coming of cool, moist autumn weather.

SPRING REGENERATION

In many parts of the north temperate zone, particularly inland on the continents, any plant growth in fall and winter is heavily restricted by low temperature and the action of frost. Consequently, any recurring openings in the vegetation that become available during summer remain unoccupied until spring. Winter itself often adds bare patches through frost heaves and erosion from the melting of early spring snow.

Seeds that are to germinate in spring are adapted to that by a genetically programmed chilling period. If they do not get chilled for a minimum period of time, which varies by species from several days to several months, the seeds will not germinate. Usually the seeds take on water in the fall and then await its chilling period when temperatures must fall between 1 and 2°C. Once the chilling period is completed and temperatures rise somewhere above 10°C, the seeds begin to germinate. The actual temperature needed, which is species-specific, generally causes germination to occur at a time when seedlings will encounter the most favorable conditions that will give them a good opportunity to become established and complete their life cycle.

This strategy is particularly important for woodland plants in which seedlings must become well established before the canopy closes. A number of perennial woodland plants show similar strategy in sending up shoots early from underground storage organs that hold last year's photosynthates. These shoots too will complete most of their life cycle early, storing as many photosynthates as possible for the following year. Seeds of spring regenerators, like those of autumnal regenerators, tend to be relatively large, thus providing enough nutrient for a quick start.

Persistent Seed Banks. If, as a serious plant observer, you sample soil regularly, you will usually find a number of seeds of various species. Comparison with a labeled seed collection, or use of one of the few seed keys, will help identify them. If you sample an area regularly, you may note that the percent of your sample that represents any particular species enlarges and shrinks on a seasonal basis. Some species will show up throughout the year, and some will appear only seasonally for a relatively short period. The assemblage of all these seeds represents a soil's seed bank. Shrubs and perennial herbs are usually heavily represented in a seed bank, as are many ruderal species.

Dormant seeds remain viable for varied periods of time; some only a year or so, others for centuries. To get into the seed bank, seeds must become buried and all must have some mechanism to delay germination after the seeds fall so that they will have a chance to become buried. Most seed-bank seeds are quite small, so they get washed into cracks and crevices in the soil by rain or get buried by the activities of earthworms and other soil animals.

Dormancy of seeds in a seed bank may be set by one of two approaches. The first approach is *enforced dormancy,* in which seeds fall so late in the season that winter temperatures prevent germination. The second is *genetically determined dormancy,* which sets chill requirements or demands an extended incubation period in warm, moist conditions for the embryo to mature. Other innate mechanisms to enforce dormancy include inhibition of germination by light and a heavy, impermeable seed coat which must be mechanically nicked or burned off before it can take on water to germinate.

Once seeds are buried, opposite factors may enforce dormancy, a major one being inhibition of dormancy by darkness. The seeds will then remain in the seed bank until conditions are right for their germination. Such conditions usually result from some disturbance to soil or established vegetation above the seed bank.

Two factors seem to stimulate germination of buried seeds—penetration of light and/or increased daily fluctuations of soil temperature. These can occur due to gaps in the canopy or removal of the litter, or humus, that acts as an insulating blanket over the soil. Fire, windstorms, or other disturbances can bring this about.

I like to think of this response of seed banks as natural photography. When light penetrates through holes in the canopy, or in a clearing made by man, the seed bank responds much as the silver iodide crystals do on photographic film. Increased temperature causes this seed film to develop into a "picture," which is the resultant mosaic of seedlings.

Seedling Banks. In mature forests, seeds of most species germinate a short time after they fall. However, under the conditions they find, their growth after germination is very slow. Most of the seeds are comparatively large, and this undoubtedly helps them survive until their roots and leaves are well established. The seedlings are generally quite hardy and persist over long periods of time. They grow very slowly and suffer many setbacks until some disturbance among the established trees creates an opening and thus an opportunity for rapid growth. The challenge then is for the seedlings to marshal resources and grow upward fast enough to occupy the opening before surrounding trees extend enough laterally to close the opening. James P. Jackson, in his *The Biography of a Tree*, gives an accurate and dramatic view of this regenerative strategy and its challenges.

SUMMARY

Developing familiarity with the processes and strategies of plant communities and with succession provides years of challenging exploration. We have presented here, with a broad brush, overviews of such processes and strategies when they really are often quite subtle, crying for detailed treatment. Nonetheless, the average plant observer can begin to gain familiarity with them, particularly if he or she gains increased understanding of the life histories and phenology of more and more species that comprise various plant communities.

Those observers who find themselves confined close to home may not get a chance to see all the weird and wonderful plant species of faraway places. However, by detailing lives of local plants and their various associates and recording subtle changes in local environments, plant species, and communities that follow, plant watchers have much to stimulate them throughout their lifetimes.

Overall, it should be remembered constantly that plants are reacting to and responding to the immediate environment. The avid plant watcher must be as alert to the nature and changes in that environment as to the plant itself. Plant and environment are so intimately intertwined and interrelated that they become almost as one.

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CHAPTER 7

QUADRATS AND TRANSECTS

Except in extremely arid habitats, a walk almost anywhere reveals a carpet of plant life. One or two species may dominate, but close examination usually turns up a number of less abundant species scattered about. Such pervasiveness of plants in the environment presents a challenge to the observer. How can you focus on individuals? How can individual life cycles be followed and individual plants relocated after periods of seasonal dormancy? How can we possibly determine the changes in populations or associations going on in any given habitat?

The answers lie in finding some devices to focus attention on areas of a size comprehensible to average human perceptions. Different types of observers utilize different techniques for focusing attention. For photographers, it is their viewfinder; for artists, it may be a viewing frame; for plant observers, it is a study plot.

CHOOSING A STUDY AREA

Choice of a study area depends upon several factors: the kinds of plant activity you want to explore; the amount and regularity of the time you can devote to your plant interests; and the distance you can afford to travel to carry on your pursuits. The marvelous thing about plant watching is that there are species to be found virtually anywhere you may find yourself, things to be seen close to home and in far corners of the Earth. Writer, naturalist, and philosopher Henry David Thoreau did much plant watching throughout his life, and most of it was done very close to home.

To emphasize opportunities of close observations of the near-at-hand, he wrote that he had "traveled widely in Concord."

First observations are probably best made of pathside plants along a route you travel regularly. It is easy to find a few specimens upon which to focus. Follow their fates through the various seasons of the year, noting the phases of their lives and trials they must face. Once you find yourself becoming more deeply involved in the events of plant's lives, you will be ready to move from initial casual observation toward a somewhat more studied and systematic approach to viewing these verdant tempters.

It should be possible to find an uncultivated patch near home. In the city it may be a vacant lot or park. For the suburbanite it may be a yard, park, or nature center. In such places you may be able to place some markers to identify individuals of species, or plots of habitat, that you want to follow more closely. Markers must be subtle so as not to attract the attention of mischief makers and vandals—for example, press a golf tee flat into the lawn. We will explore such marking techniques more fully a bit later.

In addition to near-at-hand sites, which are the best for regular observations throughout several seasons, there are many places you may wish to explore more intensively over shorter periods of time, such as during a vacation period. Such places include state and national forests and parks; community conservation lands; wildlife refuges; habitats protected by the Nature Conservancy; botanical reserves; and Audubon sanctuaries and other similar public and private lands where natural communities are given some degree of permanent protection from development. If you plan to observe without disturbing the plant life in any way, you will have little difficulty carrying out your goals; however, if you want to manipulate the plants or their environments, you will need to gather permissions and these may not come without a certain degree of hassle, if at all. The hassling can be grossly annoying, but the officials responsible for land cannot be expected to recognize your good intentions immediately, nor are we always sensitive to officialdom's need not to set difficult precedents when dealing with thousands of users of the land.

GETTING PERMISSION

Getting prior permission to use other people's land may be time-consuming and, on occasion, an annoyance; but it is good manners, good public relations, and good sense. People who make courteous, well-thought-out requests to use land for studying plants are seldom flatly denied. There may be some initial caution and eyebrow-raising, but quiet, courteous persistence will usually win out. Be open and candid about your interests and the kinds of things you might be doing if, in addition to pure observation, field experimentation is part of your intent. Permission granters often end up as new friends and even coworkers.

Private landowners who grant you access to their land are more apt to be flexible than public land managers in allowing you reasonable manipulation of some study sites for field experimentation. However, private lands change hands frequently, and new owners are not necessarily equally gracious about letting you carry on your observations or studies. This can cause problems if you are planning long-term explorations and observations. It is prudent to prepare a write-up of the research and then ask the original owner to inform the new owner about your projects and provide a character reference.

Those in charge of public lands, such as town conservation lands, town forests, parks, nature centers, refuges, sanctuaries, and the like, will also usually grant your requests to establish study sites on their properties, but getting that permission may take considerable time and explanation. Some officials will be very eager to get the kind of information you may generate, since it can help with management development plans or nature interpretation. Others will be very suspicious of your motives, perceive your request as one more thing to worry about, or see your activity as getting in the way of other work they have to do. Requests for making basic observations normally raise fewer bureaucratic warning flags than requests to manipulate the environment for experimental purposes.

It is most prudent to submit to the appropriate officials a written proposal regarding the nature of the field study you want to carry out on their land. This gives them something specific to respond to, and they can negotiate with you on any specifics they may find troubling. It also helps them to help you. Cooperative officials can point out study sites that may be better than ones you had originally discovered or suggest sectors of the property where your explorations can be carried out in greater seclusion from the general public.

Such written proposals from you should suggest the general nature of your study. Is it to record all the species in the area? Detail the life history of a particular species or group of species? Study the plants of a particular type of habitat and its successional patterns? In order to carry out your study, how many study plots will you have to lay out? How will such plots be marked? Will the markers tend to disfigure vegetation or produce safety hazards to other users of the area? Will you merely be observing the plots, or will you be manipulating some of the plots by digging, mulching, burning, applying chemicals, or using other means that might cause concern to other users of the land? Will you expect total exclusion of others from the study site? If so, for how long? How much area will you require for your explorations or studies? What will be done with the information you gather? Be sure to keep a copy of all written submissions.

With such information, a bureaucrat is in a much better position to evaluate your request objectively and respond positively either by directly granting your request or negotiating a satisfactory compromise. Generally the officials want to be cooperative, but they must deal with a spate of rules and regulations that come with their jobs. Anything you can do that clarifies your intent and sets it inside the latitude of their rules will facilitate the granting of your request. Vagueness or flagrant flaunting of a regulation makes the task more difficult. If possible, do your homework; become familiar with as many as possible of the extant rules before drafting your proposal. If the agency you are approaching is a large one, such as most federal agencies, anticipate delay since your request usually gets a review at several bureaucratic levels or by several committees. That's a nuisance but a reality. Patience may gain you access to some very interesting places and species. If yours is the first request for such access for botanical study, expect even longer delay because there will be no precedent upon which the reviewers can base a decision. Start seeking permission well before you plan to begin your field studies.

CHOICES

There are so many species and such a variety of habitats to study, so many interesting problems of survival and adaptation to unravel, that a person could spend many lifetimes studying the plant world and still have new things to explore. Choose a habitat or two that you particularly enjoy—swamps, meadows, deciduous woods, sand dunes, and the like. Focus your attention on the plants that grow therein or choose a family of plants that catches your interest and focus on developing life histories of members of that family. Becoming intimately acquainted with the life cycles and environmental preferences of even a few species can be quite involving and focus you on a relatively few genera or species. On the other hand, some people resist becoming too narrowly focused, choosing instead to know less about more species. For example, they may focus on a particular set of adaptations and search for it in a variety of habitats.

No one approach is right or wrong. It must be adapted to an individual's needs and desires. The only thing certain is that some choices have to be made and that these choices affect the nature of the appropriate study area and ultimately the kinds of study plots or sites within those areas. In the text ahead we will explore different levels of intensity in utilization of basic study plots. These levels of progression range from elementary sampling strategies to gathering quantitative information that has an acceptable degree of scientific validity. All will not be applicable to your present level of involvement. Beyond these elementary methods you enter the realm of the near professional and need to seek the advice of, or apprenticeship under, a professional field botanist.

ESTABLISHING STUDY PLOTS

If your main interests are in following life histories of certain species and keeping phenological records, you will usually need only some well-delineated study plots to which you can return time after time. On the other hand, if you wish to record plant associations and succession you will need to establish those study plots according to the more rigorous sampling procedures discussed later. Even in following life histories and phenological phenomena, be sure to collect data on enough individual species to reflect what is common, not merely what is unique to a few individuals or a very localized population.

In general, the larger the number of individuals you are following and the further apart they are growing, the less likely you are to have the information skewed by anomalies and the more likely that information is to be reliable for the species as a whole.

Choice of plot size depends upon the species you are planning to observe. Normally, small species require smaller plots than larger species and abundant species require smaller plots than rare species. The following can be used as a rule-of-thumb guide to study plot size:

Mosses, liverworts, and lichens	0.1 square meter
Herbaceous plants and tree seedlings	1.0 square meter
Shrubs and saplings up to ten feet tall	10 to 20 square meters
Large trees	100 square meters

You can use yards and other units of our English measuring system instead of meters, but the metric system is the universal system of scientists and your data will be more widely useful to others if you use the metric system in all your explorations.

MARKING PLOTS

Both in the short and long run, you will want to relocate your study plots easily. If you own the study area, it is easier to put in permanent and reasonably conspicuous boundary markers. Lengths of pipe driven into corners of the study plot are good durable markers. These should protrude a few inches from the ground, their height depending upon safety considerations to walkers and machinery. When such a study plot is under active observation, wooden or metal stakes a meter or more long can be set inside the pipes to make plot corners more visible, and string can be tied to these stakes to establish boundary lines.

On property you don't own, it is more likely that aesthetic and/or vandal considerations will make it impractical to install highly visible corner markers. In such cases, it is more feasible to drive one stake down close to ground level. This should be done consistently in the same corner of each study plot, usually the southwest corner.

When you set up the plot the first time, take a compass reading from the southwestern corner to the northwest corner and measure the appropr'ate distance between the markers. Next, measure the appropriate distance to the northeastern marker, which should be located 90°from the line between the two western stakes. With the two side measurements and the compass you can at any time reconstruct any sturdy plot from its single stake and your notes. That base stake should be locatable by distance and azimuth references from permanent landmarks such as distinctive boulders, pathways, or stone walls. A person several decades in the future may want to relocate that study area to see if certain plants or species are still surviving at that particular site and to note such changes as have occurred.

Another type of single stake marking system is useful when you are focusing on one species. That system involves driving a stake in the center of your proposed study plot and conceiving the plot as a large circle. Sight each individual plant you plan to study from the central marker and, using a compass, string, and/or measuring tape, give an azimuth and distance reading from the stake. Again, be sure to get a good locational fix for the base stake from permanent landmark features. It is useful to assign each study plot a Roman numeral designation and each individual plant an arabic numeral. This makes it possible to provide each plant a code name that can be correlated with appropriate data recorded in your notes.

Such central stakes are also useful for setting up *tristat points*, which are points over which a camera tripod is set. Photographs are regularly taken in different directions from these points, with the azimuth being duly noted for each shot. A sequence of photos taken through the seasons and over a span of years provides a most useful record of seasonal and successional changes in the vegetation. Such records are all too few yet are relatively easily gathered by anyone with interest, concern, and dedication. If locations of tristat markers are filed with a local plant society, others can follow up what you started if you move to a new location or become incapacitated in some way.

Rather than using study plots per se, some people merely focus on certain individuals or clumps of plants of a given species that they find along a route they regularly travel. The location of these also should be carefully noted so that they can be checked in other years or by other individuals. This can be done by mapping the route, usually in a sequence of short lengths between permanent landmarks. The numbers on utility poles are useful along roads and transmission lines. Within each of these segments of the route note the distance from the landmark to the plant at right angles to the route of travel. Note whether the plant is to the right or left of the route and roughly estimate its distance from either the center or the edge of the path. (Be sure to indicate which each time.) The accuracy of your measurements will depend upon the species and the terrain. Your normal walking pace is usually a sufficient measuring device, but you may wish to be more accurate for some purposes and utilize a 50- to 100-foot (15- or 30-meter) measuring tape. Taking such measurements is time-consuming and something of a nuisance, but it often proves invaluable in trying to relocate a plant a year or so later after a dormant period.

LESS IS ENOUGH

The ambitious beginner may want to investigate every plant in an area. Even when concentrating on a single species, particularly if it is a common species, it does not take long to realize that ambition must be curbed by reality. Just as you cannot know the details of the lives of all your human neighbors, you cannot know all your plant neighbors either. You have to concentrate on a few species in a few communities, and even then you have to sample the population. And there's the rub. How do you go about determining what is an adequate sample to provide information that is reasonably reliable and valid? You must turn to the science of professional gamblers, the tools of determining the odds that given events will or will not occur—in short, statistics.

It is not within the realm of this book to elaborate on statistics, but it is instructive to look at some basic strategies for sampling the vegetation. Such strategies are not unduly threatening, yet they will increase the value of the information gathered while indulging in the joy of plant exploration. In essence, you will use the same procedures presented in the section on study plots but give the plots fancier names and determine how many such plots to use in a study area and of what size and distribution. It really is not so difficult as might be feared.

USING QUADRATS FOR SAMPLING

When you set about asking and answering quantitative questions such as how many individuals of species are found in a particular plant community, or how much space in a community is occupied by a particular species, or how widely is the species distributed throughout a community, you may find it profitable to sample the study area using a number of standardized study plots known as *quadrats*. These are simply plots of the same size and shape distributed in one of several appropriate patterns through the vegetation. Because of their identical form for any given study, information gathered from quadrats can be compared and used to project information with a significant degree of accuracy about more of the plant life of that community. Of course that information can never be as accurate as when every plant is examined. Nonetheless, it can be quite accurate with a greatly reduced amount of effort.

For many studies, qualitative information is enough. You can determine whether a species is abundant, common, or rare, but usually we need to know just how abundant, how common, and how rare. It is important to set some base-line information to determine what trends are taking place—for instance, which species are increasing, which declining, and at what rate. When the trends indicate a continuing decline, it is often essential to begin work to prevent further decline of a species while it still is more abundant than rare. On the other hand, some species seem always to have been rare, and their numbers today do not indicate any significant decline. Such data are gathered through ongoing studies using quadrat sampling methods. It is very easy to be fooled when making qualitative analysis of the plants around you, for some species stand out because of size, shape, or color. Other species which may be even more abundant are hidden in the surrounding foliage or have less conspicuous size, shape, or color. Quantitative sampling makes the data much more objective.

Although the word derives from the Latin for "squared," quadrats are not necessarily square. They can be rectangular, or even circular. In any given study, the key is that, regardless of choice of shape, all quadrats will be of comparable shape and area. Actual choice of shape depends upon the nature of the vegetation to be explored, while the number and area of quadrats to be used at a particular study area depends upon the number of species in the study area and their density.

Circular plots, or circlats, can be used most effectively in areas of low vegetation such as grasses, bryophytes, lichens, and such. These circlat plots tend to give more valid results than a similar number of square plots in the same area. Circular plots are easy to lay out because you need only a stake, some marker pegs, and a length of cord attached to a ring that will fit loosely over the stake. First determine the area that you must enclose (more on this later), and calculate the proper radius for such a circle. Mark this on your string, measuring from the ring. Slip the ring over the stake that is driven in the center of what is to be your circlat. Then move the taut string around, putting a marker peg in the ground at useful intervals. Pull out the center stake and move to the next place you want a circlat and repeat the process. Or, for more permanent circlats, you can leave the center stake in place, removing the circumferential markers.

For short-term studies in which you are not concerned about relocating the exact site of the quadrat, you can make up portable circlat hoops. Cut lengths of light hose equal to the circumference of your plot. Snugly insert a wooden dowel into one end of the hose and bend the hose into a circle, slipping the dowel into the other end. You can further divide this into pie-shaped sectors by tying strings across the diameter of the hoop. This is particularly useful if you have some friends to help you with counts in the field. Divide your group into teams of as many as you have made sectors in your hoop—usually two or four. Each team member censuses one sector of the hoop quadrat.

Square and rectangular quadrats can be used with vegetation of any height. The square format is the most limited because it is least likely to encompass variety in an area, particularly if there appears to be any sort of environmental gradient in operation. The square format seems most appropriate in highly uniform vegetation where species diversity is limited. This does not mean that square quadrats cannot be used elsewhere, only that the results are apt to be less accurate than if rectangular-shaped plots are employed. With their greater length than width for the same area, they are more likely to detect variations. If a gradient of some sort is perceived, such as moisture, soil texture, or shading, orient the rectangle with its long axis parallel to the gradient.

We now need to explore a basic technique for reasonably determining an appropriate size and number of sampling plots to use in any of your studies. What we seek is a balance between a sample size adequate to provide reliable information and one in which the work is overwhelming and impractical. Particularly for the amateur, we don't want the work to be so great that it ceases to be fun or creates a chore far larger than that to which we can devote available time.

SPECIES / AREA CURVES

In the section on simple study areas, some rough plot sizes for different sizes of vegetation were listed. Those sizes were assembled from some simple averages for that type of vegetation by using a mathematical technique, species/area curves, from data on a variety of habitats. These suggested plot sizes are probably adequate for the initial studies of most serious plant observers. A bit more difficult is determining *how many* such plots are needed for accurate data. Both figures can be determined by minor variants of a species/area curve analysis.

The process involves doing some sampling in the habitat and plotting a graph of the data. The data involved are the number of different species found and either the number of standard plots used or the size of nested quadrats examined (see p. 125). The number of species is plotted on the vertical axis of the graph and the number or size of the quadrat is plotted on the horizontal axis. Each of the data points is then roughly connected by a line to form a distinctive curve (see Figure 7.1).

The curve will normally rise quickly to some point; then further increases in number or size will yield smaller increases in the number of additional species added to the total so that the curve will flatten. This simply means that it takes an increasingly greater amount of effort to get less and less additional information. The question is, When is enough

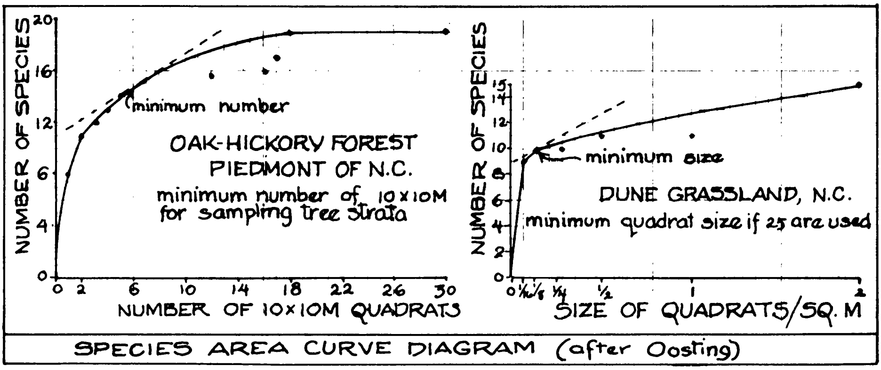


Figure 7.1

enough? After the curve begins to break from its rise, we start to ask how much the information we seek is worth the extra effort to get it. There is no pat answer, but most agree that it is somewhere beyond the break in the curve. A frequent standard has been that point where a ten percent increase in number of plots or area of plots results in an increase in species of no more than ten percent of the total number of species.

Shape of the curves will vary, so determining that point on your graph is not possible simply by eyeballing; you will have to do a little additional drawing on your graph. First locate that point on the graph where ten percent of the number of total species occurs and move over to intersect the point that represents ten percent of the number of plots sampled or area sampled. Mark the point and then draw a line through it and the zero point on the axis. Next draw a line parallel to the one just drawn but such that it is tangent to the species/area curve. Mark the point of tangency. The point directly below it on the horizontal axis will indicate the minimum number of plots, or size of plots, that should be used for reasonably accurate information.

PLACE THE QUADRATS

Once you have determined appropriate size and number of quadrats, there remain the questions of how these should be distributed in the study area so that they most truly represent conditions of the stand as a whole. The need is to avoid personal preconceptions of what is typical of the area thus, perhaps unwittingly, putting a bias to the data. If an area were truly uniform in distribution of plant species, there would be no problem. Each quadrat would equally represent the whole stand. But such does not occur in the real world. Therefore, the study areas are imagined to be divided into a large number of plots, each the size of your quadrats and each representing a segment of the whole. The name of the game is to choose the selection of the plots randomly so that each has an equal chance of being chosen whenever a selection is made. The basic assumption of the statistical analysis is that no valid conclusions can be drawn unless the samples have been taken at random.

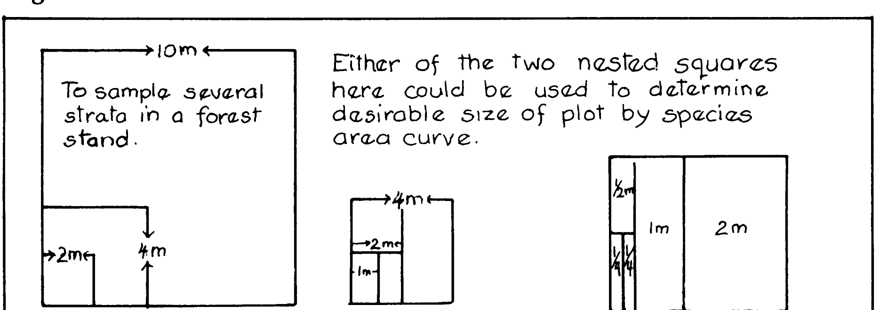
Setting up random selection of plots, free of human error, is not easy. Perhaps the simplest way is to run a grid-line lottery. Map the whole study area and then overlay it with a grid. Number the horizontal lines and letter the vertical lines of the grid. Cut a number of slips of paper, and put a grid line number or letter on each slip. Place all the letters of the vertical grid lines in one container and the horizontal line numbers in another. Shake up the containers thoroughly and then begin your lottery. Draw one slip from each container, and then place a sample plot where the intersecting lines designated by each slip occur. Repeat this process until you have drawn an appropriate number of plot placements.

The resultant distribution of quadrats may appear inappropriate, with some areas heavily sampled and others neglected. Such are the whims of random chance. The fewer the number of quadrats being used, the more likely it is that such skewed distributions will occur. The larger the number of plots, the more the pattern appears to be even-handed.

Statistical analysis is not always of help in studying a given problem, such as how plants are distributed along a particular gradient. In such situations systematic placing of plots is often preferable. To do this simply, mark off a base line of arbitrary length. At uniform intervals along this base line run perpendicular lines. Use a compass to determine direction and pace off equal intervals along each perpendicular and establish the quadrats. Keep to your line and distance. It biases the data to shift the quadrat a bit in some direction to include plants that intrigue you but that would be excluded by sticking to the rule.

If you are carefully sampling a plant community that has several well-defined layers, you may wish to use nested quadrats to deal with each of the different layers. Starting in one corner, build ever larger squares from your smallest area to your largest (see Figure 7.2). Nested

Figure 7.2



NESTED QUADRAT CONCEPT

blocks can also be used in determining quadrat size with a species/area curve. Be sure to keep separately the data for each subblock as well as including it in the data of the larger block (see Figure 7.2).

As you can now see readily, setting up quadrats properly can be rather time-consuming but results gathered using this method are generally good.

LINE TRANSECTS

Another sampling technique can be used to gather much of the same data; it is somewhat more rapid and more objective to use this *line transect* method. It involves running several lines through a plant community and identifying, counting, or measuring all plants that touch, underlie, or overhang the transect line. Transects are particularly useful in open areas such as grasslands, marshes, and shrublands. They are less appropriate in treelands. Useful for exploring environmental gradients, succession, and the zones between two habitats (*ecotones*), line transects are much more practical than quadrats in dense, brushy vegetation. A line transect can be used to calculate species abundance and frequency, although not with quite the same accuracy as with a quadrat. Density per se cannot be calculated by this method, but you can calculate relative density.

In any given study, all the transect lines should be of equal length. For some studies you will want to sample randomly. To do this, mark a stick at one end, take it in your hand, close your eyes, spin about several times, and then toss the stick. Lay out your lines in the direction toward which the stick points, beginning at the marked end of the stick. On the other hand, successional and environmental gradient studies will best be studied using a uniform spacing system that runs parallel to the expected gradient. Sample size normally ranges between twenty-five and thirty transect lines. This demands time, but not as much as a quadrat study.

For sampling such things as frequency, you will want to have your transect line marked in equal intervals. This can be achieved most simply by using a cloth measuring tape as your transect line. But you can also carry cord that has been knotted at equal intervals or marked with paint or ink. A reasonable length for most transects is twenty to thirty meters (100-foot tape). The line will be shorter for some transition areas and longer for others; it depends on the nature of the plant transition zones you are investigating.

BELT TRANSECTS

A belt transect is essentially a line of square quadrats laid end to end. In one sense it is a wide line transect, in another it is an extra-long, rectangular quadrat. The belt transect effectively combines some of the best qualities ot quadrats and transects and compensates for some of the weaknesses of each. Belt transects are most useful in studying subtle abiotic gradients and successional changes.

Belt transects should normally be twenty to thirty times as long as wide. Thus, a one-meter wide strip for studying herbaceous plants would be about thirty meters long, while a 0.1-meter wide strip for studying bryophyte communities would be about three meters long. As a rule, you should lay out enough belt transects to cover ten percent of the study area. Because you would generally use this method when exploring abiotic gradients, you should lay out the belts in a systematic pattern that runs parallel to the apparent direction of gradation.

It is useful to section off the belt into square quadrats for a couple of reasons. First, you can perhaps get helpers to collect data on the separate units and thus reduce the individual workload and increase the sociability of your field work. Second, if the belt is quite long and the gradients quite gradual you can collect data from alternate quadrats. If you do this, be sure to be consistent. If you do it on one belt, you must do the same for all belts in that study.

There are other variants of the quadrat and transect sampling techniques that have special statistical traits appropriate to certain types of studies. However, the ones presented above should serve most needs until you have grown beyond the sophistication of this book. By then you will have discovered professional friends who can guide you through their intricacies.

THE BISECT

Quadrats and transects have a basically two-dimensional bias. Vegetation, however, is three-dimensional. The eager field observer may wish to build a picture of a vertical cross section of a study area. This is known as a *bisect*. Some bisects are prepared showing just the vegetation from the ground to canopy. These are comparatively easy to prepare, but a complete bisect indicates the depth and distribution of the roots and other underground parts. It involves digging a ditch and thus is time-consuming and difficult work.

Preparing a bisect involves drawing the vegetation to scale on graph paper and indicating the proper height and lateral reach of each individual. Use a letter code to indicate the species indicated. When possible, the bisect will also indicate the depth and lateral spread of the roots of the species in the plane of the bisect. Figures 7.3 and 7.4 illustrate bisects of two different kinds of communities.

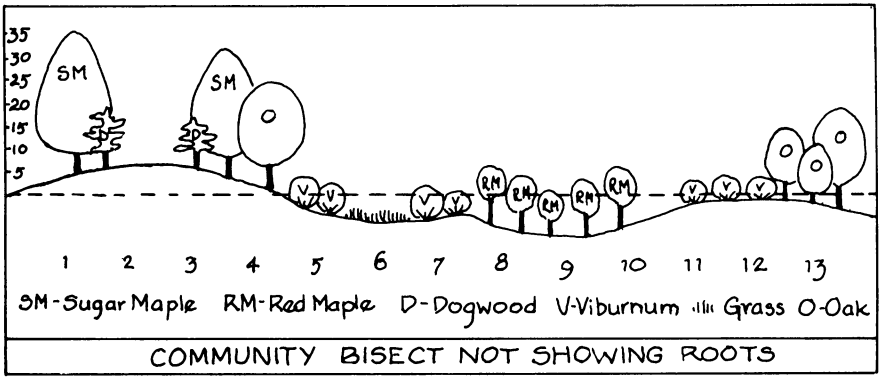


Figure 7.3

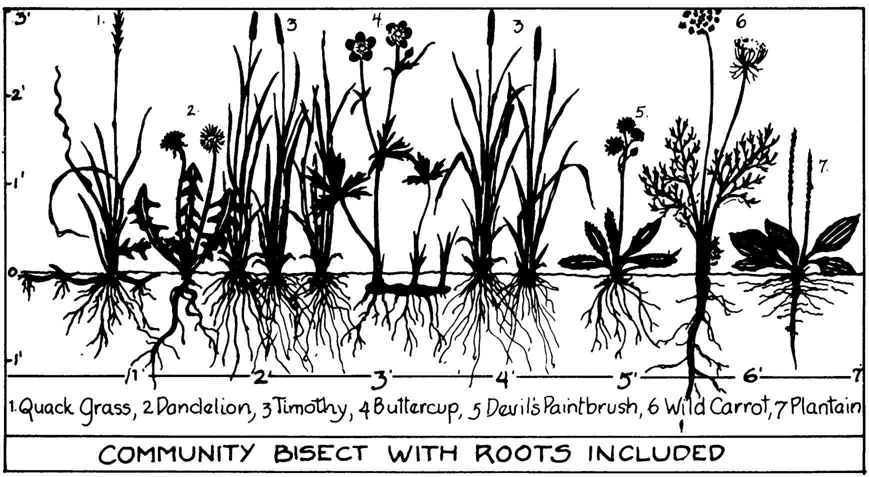


Figure 7.4

WHAT INFORMATION TO GATHER

Now that you know about the mechanics of quadrats and transects, what kind of information should you gather with their aid? Actually, there is a wide variety of information that can be pursued. Depending upon your interests, however, you may want to, or indeed be able to, pursue only a few of them at any given time. Of course, having gone to the effort of setting up a system of quadrats, it makes sense to mine it for as much informational ore as possible.

Species Lists. Among the more basic data are listings of species present in each quadrat or along a transect. This information helps you understand the diversity in the community and provides data for determining an index of similarity between two communities (see page 104).

Frequency measures the percent of the total number of samples that contain representatives of a particular species. It is calculated so:

$$\frac{\text{Number of quadrats in which the species occurs}}{\text{Total number of quadrats}} \times 100 = \text{Frequency}$$

What does it mean "to be present" in a quadrat? Some people count only plants rooted within the plot; others count a species present if its shoots or leaves enter the quadrat. Whichever method you follow should be duly entered into your notes as either "rooted frequency" or "shoot frequency." Frequency provides clues to the importance of a species in its community. The higher the frequency, the greater its importance. Of even greater use in determining a particular species' importance is *relative frequency*—that is, comparison of a species' frequency to total frequency of all species present. Calculate thus:

$$\frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100 = \text{Relative frequency}$$

Abundance. Although often stated in qualitative terms such as rare or common, abundance can be stated more quantitatively by comparing the number of individuals of a species with the total number of individuals of all species. This is usually stated as a percentage and is calculated thusly:

$$\frac{\text{Number of the given species}}{\text{Total number of all plants}} \times 100 = \text{Abundance}$$

A high abundance figure does not necessarily reflect a high importance for the species in the community since larger species, whose shade strongly influences the community, may be far less abundant than smaller species that carpet the ground.

Density. Density is of more importance than abundance for determining the significance of a species in the community. It is a measure of the number of individuals of a particular species per unit of area. Thus, we need to count all the plants of a particular species from all the quadrats; this number is then divided by the total area of all the quadrats:

$$\frac{\text{Number of plants of a species}}{\text{Total area sampled}} = \text{Density}$$

For example, if I sample twenty 1-meter quadrats and count a total of 250 plants of Canada mayflower, I can say that on average the density of this plant is 12.5 plants for each square meter of the study area.

Cover. Frequency and density of a species are important, but equally important is how much space the plants occupy (*cover*). It is very difficult to plot plants' three-dimensional space occupancy but much easier to collect data on the area they cover as perceived from directly above. This is important because cover affects shading, which strongly influences the number and types of species that can grow beneath it. Collecting data on cover involves mapping each quadrat for the area covered by each plant; the area of the leaf crown for herbaceous and woody plants; the diameter of the root crown for grasses and ferns (with some arching species it will extend beyond the root crown); and, for bryophytes, the area of the plant cluster.

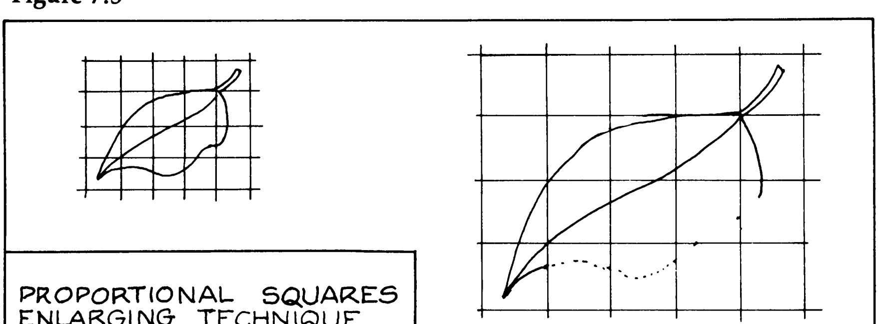
A method used to record cover accurately involves laying a grid over the quadrat that represents squares on a sheet of graph paper. The observer then fills in the portion of each square on the graph paper that represents the corresponding square on the quadrat grid (see Figure 7.5). This is the same technique some artists use to enlarge or reduce drawings. Use a letter code inside each crown area to indicate the species.

Once you have crown outlines and an overlay grid, add up the number of grid squares enclosed by a species. If half or less of a grid square is covered, ignore it; if more than half a grid square is covered, include it in your count. Multiply the resulting number by the area of an individual grid square to get the total area occupied by a species. Divide that by the total area of the quadrat. Thus:

$$\frac{\text{Area covered by specific species}}{\text{Area of quadrat}} \times 100 = \text{Percent cover}$$

Cover information is useful because it gives a good indication of the dominance of each species in the community. Actually the area of the

Figure 7.5



quadrat may not always be the most useful divisor for the formula because the whole area may not be totally covered with vegetation, particularly in unproductive environments. More appropriate is the total cover by all species. This gives as a result a measure of *relative cover.*

Importance Value. To get an indication of the importance of a particular species in a community, sum up the three values of relative frequency, relative density, and relative cover.

Abiotic Data. Data on such abiotic factors as temperature, light, soil texture, and soil structure should be gathered for each plot. It can later be correlated with plant information.

Zoological Data. In some studies you will also want to collect data on the animal life present in the quadrats, particularly those species that feed on the plants or are important in their pollination or dispersal.

WHAT CAN YOU LEARN?

Setting up formal study plots such as quadrats, transects, circlats, and bisects takes considerable effort. It is certainly much easier to ramble through glade and wood enjoying the beauty of many species or the thrill of discovery of the occasional station of a rare species. If, however, you are truly curious, you will want to understand what is happening in the life history of particular species or what goes on in a plant community over a period of time. When compelled by such curiosity, you will find joy and excitement in the work of setting up the formal study plots and examining them intently.

Study plots help focus your purely qualitative observations. You get some very interesting information from them regarding species' life histories and phenology. Using the various vegetative sampling techniques, you can gather information that:

1. allows comparison of two or more plant communities
2. reveals changes occurring within a community over time
3. permits correlation of variation in vegetation with variations in zoological and abiotic factors

Your next step is to get help with basic statistical techniques to manipulate data properly so that they will reveal the degree of comparison or correlation and the degree of significance of the calculations. Some data can be presented effectively in graphic form, which allows visual comparison. Other data has to be processed through a spate of mathematical formulas resulting in abstract mathematical expression. Many professional field biologists are themselves poor manipulators of data, but they team up with statisticians who help them design appropriate manipulations and thus determine the kind of data that will have to be gathered. They also get the statistician to help them process the data. A serious amateur need feel no embarrassment in seeking help with statistical design and data manipulation.

FIELD EXPERIMENTS

Field observations usually end up generating a great many questions. Would the seed sprout if there were less litter on the surface? What would happen if the soil were less acid? If there was more potassium, nitrogen, or phosphorus available, how would it affect the plant community? If more light reached the ground, what would be its effects on the vegetation? If a given species were missing from the community, what would happen to the community? Much information that might resolve these and other questions can be gathered through field experiments.

These experiments usually involve establishment of a number of quadrats to serve as study plots. For each specific experiment plots selected should have been compared and selected for their high degree of similarity in abiotic and zoologic factors and vegetational composition. Some of the quadrats must be left untouched to serve as controls for comparison; others are manipulated very carefully and specifically. Specific treatment of each quadrat is carefully noted and observations are made and recorded about such things as changes in species, density, cover, and growth rates in all plots, both manipulated and controlled, during the experimental period. Comparisons are made between control and experimental quadrats and, with proper assistance, statistical comparisons are made of the significance of observed differences or correlations of experimental abiotic factors and plant responses.

Experimental manipulations might include:

1. Removing all litter from some quadrats; putting that removed litter evenly over other quadrats, and, of course, leaving control plots untouched.
2. Liming one series of quadrats using different amounts of lime per quadrat to alter pH and comparing resulting changes with those of the control plots.
3. Adding measured amounts of given nutrients to some quadrats and comparing the results with those of the control plots.
4. Removing shading vegetation from around some quadrats and comparing differences with the undisturbed control plots.
5. Physically removing all members of the particular species from some plots and comparing them with the undisturbed control plots over time.

As you get more and more involved in exploring the plant world, you will find yourself devising many additional field experiments. The important thing to remember is to keep study plots as similar as possible and to limit manipulation in experimental plots to a single factor whenever possible. It is much more difficult to control or limit the experimental factors under field conditions than in the greenhouse or laboratory. Record carefully all the biotic and abiotic changes going on in the surrounding study area during the course of your experimentation. Any one of them might have influences that raise questions about the validity of your experimental conclusions. Despite the fact that rigorous control of the many factors that could influence conclusions is not possible, there is still much that can be learned from such field experiments. Do not let laboratory-restricted scientists convince you otherwise!

Laboratory experiments under rigorous conditions may actually be misleading. They reveal a potential of the plant that is seldom, if ever, seen in the wild. Similarly, captive plants in gardens and pots often react quite differently than they do in the wild because certain stresses of the wild are missing or new ones have been added. This all suggests that field experiments may yield much useful information about how plants are likely to respond to potential environmental changes in their world.

It may be many years before you progress from random observation of interesting plant species to more quantitative studies or simple field experimentation, but you will enjoy each step along the way as your curiosity becomes increasingly aroused and you channel your inquisitiveness into action.

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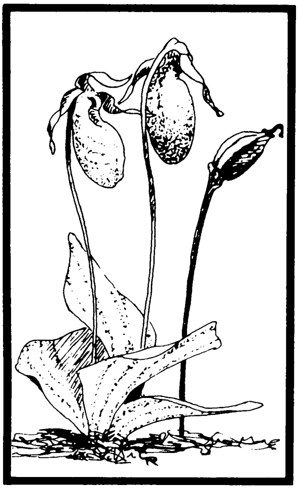

CHAPTER 8

RARE PLANT CONSERVATION

Throughout time some plant species have been common or abundant while other species have been rare. Each major *biome,* the largest land community unit, contains both categories. As people have expanded in numbers across the planet, they have intruded on habitat after habitat, often radically altering conditions for the native flora. A few "tramp" species of plants have expanded their range and number, thereby pushing out native species, even those once considered abundant. Also, physical conditions of the habitats have been altered so that they are no longer suitable for many species that once occupied them. Great numbers of species, and not only the naturally rare ones, show declines in their populations. Increasing numbers of species are being extirpated from large areas of their former range, and many are on the verge of extinction.

Concerned scientists have calculated that plant species are becoming extinct somewhere on the planet at a rate of one to two species a day and that by 1990 the rate will have increased to one species an hour! In large measure, this is due to the rapacious destruction of the planet's rain forests, but no section of the earth is immune to the destruction by humans. By the turn of the twenty-first century, we bid fair to have lost fifteen to twenty-five percent of all higher plant species; in other words, we will see a loss of about 40,000 species by the year 2000!

The causes are multiple, but essentially they can all be placed at the doorstep of humanity: clearing land for agriculture and settlement, flooding areas for irrigation and power, cutting forests for fuel, fiber, and wood, grazing livestock, polluting air, polluting aquatic environments, and collecting species for the garden and houseplant trade. For some time the public has been aware of the plight of endangered animal species; it is only now gaining awareness of the even greater plight of rare and endangered plants.

Although the United States has led the world in conservation activity, even its plant diversity has not escaped the worldwide decline. For example, the island paradise of Hawaii has lost at least fifty percent of its native plants and, by the reckoning of some scientists, as high as ninety-seven percent of its *endemic species*—that is, those species that evolved only on those islands. This means that today 273 species or subspecies are already extinct and 800 are endangered. California, one of our largest states, lists 650 plant species as endangered or threatened, and there probably are no states without one or more species either threatened or endangered.

All of this seems grim. It is. But plant enthusiasts have a greater opportunity to help save some plant species than most endangered animal enthusiasts do to save animals. Plant conservation provides opportunities to put to work the environmental dictum "Think globally, act locally." Inevitably, in addition to the habitat losses in the tropics and Third World countries, there are species under stress in the state where you live. This opens a variety of opportunities for *you* to take personal actions to retard or reverse decline in those species.

THE INVENTORY

The first step in dealing with rare plants is to make an inventory; prepare a list of your local flora. Check with botanical authorities at the local college, university, or extension service to find out what local floras already exist.

Most states have a list of their flora, as do some counties and a few townships. Many floras were compiled fifty to one hundred years ago; others quite recently. Both are worth examining.

Older floras should be compared with the newer ones to determine what species have declined or disappeared and what species have been added. If there are no recent floras, work on developing one, either with a group of similarly inclined people or by yourself if necessary. An inventory can be a great deal of work; when done well, it involves a thorough, systematic survey of a geographical area. In it, list all species found and prepare voucher specimens, particularly of those species about which there are any questions of identity.

Often the best unit to begin with is your township. Even that can take an active amateur a decade to do thoroughly; that is why group effort is desirable. But the work is needed because it is very hard to know what species you are losing if you don't know what you have now. Through networks of interested people, township inventories can be amalgamated into county and state floras.

In undertaking your flora, use aerial photographs and topographic maps. Outline the major habitats on them, then survey each habitat and record its flora. If there is an existing flora for your region, you can turn it into a checklist with a place for location comments. It will make your collection of data easier.

SPECIES	PRESENT	ABSENT	UNCERTAIN	COMMENTS

After you have given your area a reasonably thorough coverage, carefully review your floral checklist. Have most of the expected species been checked off? Of those species you haven't been able to locate, are there one or more habitats that have been severely decimated or eliminated they would be found in? If yes, try to locate any remnants of the habitats and scout them thoroughly for the errant species. Another strategy is to spend a few rainy days reading through notes of old botanists or checking location information on any herbarium specimens; then try to track down these locations in the field. It usually turns into quite a piece of detective work, one that often reveals more about the changes that have occurred in your area than about present plant locations.

A new flora provides important base-line data for the future. For our purposes, we are interested in determining which species are scarce or rare, or becoming so. Once that has been done, the task remains to learn as much about environmental tolerances and preferences of those species and the successional histories of the sites of the stations where they dwell. With such information we can begin to develop strategies to retain what remains: Perhaps we will even extend the species in both time and space.

A number of organizations are looking for cooperative amateurs to work with them in conducting floral surveys and mapping rare plant stations either for determining lands to be protected or managing already protected lands. Foremost among these is The Nature Conservancy, a nonprofit organization specializing in making it possible for important habitats to be secured and managed either by its own local chapters or other responsible environmental organizations.

One of its major programs has involved working with states to establish Natural Heritage Programs that coordinate inventories of local flora, fauna, and ecosystems so that sensitive areas can be identified, prioritized, and protected by any of a broad spectrum of techniques. The

Nature Conservancy is launching comparable programs internationally, particularly in Central and South America and New Zealand. Since 1974, the Conservancy has helped establish programs with more than twenty-eight state governments. Nature Conservancy staff brings inventory methodology to these programs, while partnership with the states tends to ensure longevity of the data base that is gathered and a potential for regular updating and refinement. As always, funds are limited and Heritage Programs depend heavily on amateur and professional volunteers to gather information.

As frustrating as the U.S.-based Heritage Program efforts sometime are, establishing and maintaining the international efforts are even more so. Areas to be inventoried are generally much larger, which increases the complexity of the task in both data gathering and data management. Many of the countries, particularly the tropical ones, have a much more extensive basic flora (Venezuela, for example, has four times the number of vascular plants as does California). Further complicating matters is the shortage of biologists, ecologists, taxonomists, and time in these regions. It is becoming increasingly important that amateurs do the inventorying work here in North America so that as many professionals as possible can work in the fast-disappearing tropical ecosystems.

The Nature Conservancy needs help with botanical field studies of many of its already preserved lands. Similarly, studies can be done at the preserved lands of Audubon societies, state reservations, land trusts, conservation commissions, county reservations, and some private reserves.

Whenever possible, do your inventory work with an organization like the Heritage Program, because they use a consistent format for data gathering to assure increased consistency of information collected and greater ease in storing, retrieving, and manipulating the data. Given the magnitude of the problems, this is very important.

The type of information generally sought is presented here so that anyone working where there are no convenient organizations to associate with can proceed to gather similar data. This is particularly geared to gathering information on rare plant populations. Key information to gather is:

- exact locality data for known stations of the species
- types of habitats and potential localities to be searched
- status of the extant stations and populations including threats to plants or their habitat
- ecological observations that will help outline potential population areas and critical habitats

You may also want to prepare recommendations for conservation of the populations and their habitats which include information about who presently owns the sites on which the stations or habitat is located and about the owner's attitudes and financial status that might suggest the best tactics to get the owner involved in achieving preservation.

The more information you can assemble about the species, the better. Build a file on the species; from this file you can assemble a basic status report. It can follow an outline somewhat as follows:

1. Species description. Keep it simple and straightforward, with good field characteristics that separate it from similar local species. If the local population seems to have some unique features, describe them. Give characteristics of different life history stages such as seeds, seedlings, dormant remains, and other vegetative changes. Back the description with photos of mature plants in the field; flowers; fruits; seeds, shoots, seedlings, and immature specimens. If the population can sustain it, also prepare a voucher herbarium specimen.
2. Year the species was first described in your area and year it was most recently observed, along with population estimates.
3. Taxonomic status of the species. Is yours an endemic population? A disjunct population? An edge-of-range population? A genetically unique and isolated population?
4. Ecological or evolutionary importance or potential of the species.
5. Plant or animal species with which this species has any obligate relations.
6. Complete as possible habitat description for the species. It is suggested that a good basis for this is "Ecological Diversity Classification and Inventory," an article in *Natural Heritage Classification and Information Strategies* (Radford, Otte, and Otte, 1978), available from the University of North Carolina Student Stores, Chapel Hill, NC 27514.
7. Herbivores, parasites, and diseases that afflict the species.
8. Its pollinators.
9. Its tolerances and preferences for light, moisture, pH, soil type.
10. Any evidence of hybridization with other species.

In addition to the detail on life history and phenology of the species, prepare as much as possible of a general successional and land-use history of the sites of each of the stations you locate. Have they been exposed to burning, tillage, grazing, forest thinning, pesticides, herbicides, salt, fertilizations, exclosure, (keeping animals out), or recreational activities? Can you reconstruct any of the stages of community succession that have occurred on the sites?

And finally, include any data from the literature or your own studies on ease or difficulty of various propagation techniques in regard to the species. If you have propagated the plant, what is the status of the propagated stock? Do you have only a few specimen plants, or is it a breeding, self-sustaining captive population? The more complete you make your report, the greater will be its value in contributing to potential conservation efforts of both the plants and of habitat types that with careful management might support the species now and in the future.

A plant observer should understand that one of the biggest contributions to be made to rare plant conservation is increased knowledge about the natural history of the species. Writing in *Rare Plant Conservation*, Morse, Henefin, and Lawyer remark that "natural history studies of each species are necessary in delimiting areas of essential habitat adequate for long-term survival of a species' populations. Such areas of essential habitat must include also the habitats necessary to maintain such associates as pollinators, and also provide adequate buffer zones to help protect the sites from edge effects such as invasion by exotics."

CONSERVATION STRATEGIES

Site Protection. The first and most basic strategy is to provide protection for the sites where rare species are located. This is often a two-step process; first, secure short-term protection through written or verbal agreements with the landowner until a more permanent solution can be sought. If you explored private land properly with permission, you know from whom you have to seek the short-term protection. Talk with the individual owner or the representatives of a corporate owner and inform them of what is on their property, trying at the same time to persuade them to guarantee protection for some specified period of time. Let your discussion wander to what plans have been made for longer-term use of the property. Does the owner anticipate development, lifetime use as is, that the estate will pass on to heirs, or something else? At some appropriate time, then or later, you can explore with the owner willingness to consider long-range protection for all or part of the site through any of the range of alternatives such as registration or deed restrictions, fee simple sale, or tax-deductible gift to a nonprofit organization or government agency.

For these more delicate negotiations, you should seek the assistance of an appropriate conservation organization, particularly if it is likely that funds will have to be raised for acquisition and/or management. Arranging permanent legal protection for sites inevitably is going to involve legal assistance; this too will cost money. A useful book that explains some of the available alternatives for getting land protected is Phillip M. Hoose's *Building an Ark* (Covelo, CA: Island Press, 1981).

When you have gathered preliminary information about an owner's willingness to negotiate regarding some form of long-term protection of a rare plant site—particularly the owner's attitude about involvement or noninvolvement of nonprofit or government agencies, you probably are best advised to take the information to your state's Natural Heritage Program, if it has one, or to a landholding conservation organization in the state. Present them with your information and seek their assistance. Do not be surprised if they do not always share your initial enthusiasms.

They usually have a number of worthy candidates for their attention in contrast to a limited supply of funding and staff time. Thus, they may feel they must give your project a lower priority than you do.

Building a Seed Bank. When long-term protection of a rare plant's site is out of the question, you may wish to build a seed bank either personally or in conjunction with members of a botanical club or other organization. The concept behind a seed bank is simply to provide long-term protection to viable seeds. In this way they may be germinated later and grown to be tapped for their genetic potential or reintroduced into suitable protected natural or rehabilitated environments. The basic process is simple enough. Seeds are collected, dried to reduce water content, and then frozen and stored for years in a freezer. As with any such process, the actual technology is a bit more complex than a general statement infers; however, it is still eminently doable, even by amateurs.

Seeds are chemical systems, and their chemical reactions are temperature-dependent. Researchers have discovered that for approximately every 5℃ drop in temperature, the viable life of the seed will double. Studies with onion seed showed that seeds with a ten percent moisture content remain viable for sixteen weeks at 35℃, but at 0℃ their life expectancy rises to seventy-eight years. Theoretically, if kept at −15℃, and if no ice crystals form, these seeds would still be viable after 624 years!

Moisture content alone also affects seed longevity, with seed life doubling with each one percent decrease in their water content. There are limits, however, because a seed needs a minimum of four to five percent water content to survive.

Put the two factors of temperature and moisture together, and you get a multiplied effect. Thus, when temperature is reduced 5℃ and moisture content is reduced by one percent, a seed will live four times as long.

Thus, creating a seed bank involves collecting, drying, and freezing the seeds. If you are doing your project with the distant future in mind, you will want to get seeds dried to around five percent moisture content and keep them frozen at about −18℃. Only the larger institutions are equipped to do that, and most freezers will give out before the seeds do. However, much can still be accomplished for less money and with reasonable results by using a basic chest-type home freezer that operates at about −15℃.

Collect seedpods as soon as they start to ripen. Remove seeds from the pods, put them in a labeled container, and expose them to the air for several weeks. In arid climates the dry air will usually be sufficient to dry the seed. In humid climates you will have to store them for several days in a tightly closed container with a dessicant, such as silica gel, or a calcium salt, such as Drierite. Put the dessicant on the bottom of the container, cover it with cheesecloth or fine wire mesh, and then add the seeds. Once a day for about a week, open the container and stir the seeds. The dried seeds, cleaned of any extra chaff, dried leaves, and other extraneous matter, are then ready for freezing.

Dried seeds must be placed in absolutely airtight containers to prevent them from imbibing moisture from the air. Disposable test tubes from scientific or medical supply houses are suitable containers. (Your local druggist may be able to help if you cannot locate them elsewhere.) The seeds are placed in the tube and the open end of the tube is melted shut with an inexpensive propane torch. Practice with a few empty tubes, and you should soon develop skill in sealing a tube in a few seconds without the whole tube getting too hot.

Seed containers should all be double-labeled—that is, there should be a label sealed inside with the seeds and on the outside as well. The reason is simple: The inside label is hard to read until the container is opened, but the outside label may fall off or be accidentally removed. Use a high-grade, permanent, waterproof ink and a high-grade paper that will not fade or become brittle under extended subfreezing temperature. Many prefer to use a metal foil label (available from biological supply houses, see page 200) with the information embossed in the foil with a blunt pen. Labels should include an accession number, species name, original source of seed, and dates of collection and processing. Your assession book also should contain data on the precise processing used and other pertinent information.

To assure a full range of genetic variation, a sample of about 10,000 seeds should be frozen. Most amateurs are unprepared to handle such an amount, but do try to get a large number so you get a good representation of diversity in the populations. You can put the bulk of the seeds in one container, but also prepare a number of smaller containers for the species, each containing somewhere between 20 and 100 seeds. It is better to take out a number of packets to do germination tests or to share with other seed banks than to have to thaw more seeds than you will need.

If you are also freezing fern or other spores in your bank, store them in gelatin capsules for drying. Label the capsules with a waterproof laundry marker and dry them in a frostfree refrigerator for about twenty-four hours. Next, put a little dessicant in the bottom of a plastic vial, add the labeled gelatin capsule containing the spores and then seal and freeze.

A few notes on maintenance are in order. Seeds can survive freezing and refreezing but, if possible, this should be limited to the occasional electrical brownout or power failure. Have a backup emergency generator for the seed bank and a battery-powered alarm connected to the freezer thermostat to alert you to any problems. You will also have to chip ice buildup from the sides of the freezer from time to time.

Most seed banks find it valuable to number the shelves in the freezer and keep a shelf plan outside the freezer. Each species is assigned a specific shelf number and position to aid in retrieving specimens conveniently, even when they are covered with frost crystals.

If you establish a seed bank, get in touch with others who are maintaining seed banks and exchange some of your seeds so that everyone avoids the syndrome of "all the eggs in one basket." Such sharing is a form of insurance for the species involved. Seed banks are not free; there are the costs of acquiring the freezer and the electricity to run it and, of course, the costs of the containers and supplies, but all in all it is a reasonably low-cost investment in species' survival and the genetic diversity they represent.

Relocating Live Plants. The time may come when any short-term protection is terminated and a site that contains stations of rare or declining species is going to be developed. An alternative to their destruction may be relocation of at least some of the plants. Often the temptation is to move them to your own wildflower garden, but this is often shortsighted and selfish because your site may be inappropriate to the plant's needs. Like it or not, you will not be living on the site forever and subsequent owners may not be sensitive to the plight of those plants.

Whenever possible, work with a wild plant organization. Check to see if there are any other protected stations of the species in the region, with unoccupied habitat nearby. Your specimens can be relocated to sites where they are most likely to thrive. Or perhaps there is a protected habitat that seems to have all the ingredients of the species' preferences but from which the species was extirpated long ago and from which no seed reserve remains. It may be worth reintroducing the species there. In any case, you should seek the best match possible between the threatened site and the site to which you relocate any plants. Your home wildflower garden should be considered the site of last resort and at best a temporary solution.

Even though a site is going to be bulldozed, always get permission from the owner before you move in to relocate plants. Avoid trespass and larceny charges! If you do not first seek permission, even though you feel morally justified to save the lives of the plants, you will find yourself technically an outlaw and vulnerable to prosecution.

Some species are protected by state and federal laws, such as the Endangered Species Act, and such species cannot be moved at all by unauthorized individuals. Familiarize yourself with what species are protected in your state by checking for a listing with a local wild plant society (see page 156) or the Natural Heritage Program office in your state.

Many species that are declining locally have not reached the legally protected lists or are not so uncommon that you shouldn't have some plants at your home. You may feel the desire to relocate some of these to your study garden when a site is to be bulldozed for development. Indeed, in some cases you may even want to relocate from sites that are not to be bulldozed. The rule about seeking permission from the landowner holds universally, for collecting seeds as well as whole plants. If taking from lands not immediately threatened by development, avoid plants near trails where other people may see and enjoy them (unless they are in imminent danger of being trampled). When possible, collect offshoots or young plants rather than the prime bloomers; they generally relocate better anyway and the parent plants are left to continue propagating at the site.

As a rule, wild plants should be left in place; relocation is a last-resort conservation measure. Relocating plants to a personal wildflower garden for study should be done with full recognition of your responsibility to study the species and not possess it merely for aesthetics and personal satisfaction. A wildflower garden for pure pleasure should be stocked with the more easily grown species from captive-propagated stock.

Watching Our Step and Those of Others. The natural world has many facets. Some habitats are rich in resources, and plant life that dwells in them is resilient. Many other habitats are poor in one or more resources, and their plants have special adaptations for survival and may be unresilient and fragile in the face of disturbance. Alpine and boreal tundra, shore, and many desert habitats fit this pattern, as do sand dunes and bogs. Plant observers visiting such habitats must be very sensitive to the impact their presence has on compacting soils, damaging root systems, and the like. For example, the rare silver-sword of the Hawaiian volcanoes has very shallow roots, and many plants have been damaged simply by visitors casually walking over the rocky soil, never touching the lovely foliage yet damaging the root systems that spread out well beyond the plants. Most alpine plants are slow-growing and cling precariously to existence with a low tolerance for disturbance. It is very important to keep to existing trails when visiting such fragile habitats.

Once we have our own behavioral house in order, educate others. Plant destruction is often the indirect result of other activities, and the participants are usually blissfully unaware of the impact they are having. These activities include random strolling about in sensitive habitats, particularly with lug-soled walking boots which crush plants and create erosion channels; rock collecting; driving vehicles such as cars, trail bikes, dune buggies, and other all-terrain vehicles around in what are perceived to be "waste areas"; and littering. Littering is not only aesthetically annoying, in many situations it kills plants directly and usurps potential seedling sites. All of these potentially damaging activities are density-dependent phenomena; the greater the numbers of participants, the more extensive the damage.

A responsible plant observer is constantly aware of the impact his or her presence may have on the nearby flora and acts accordingly. He or she also takes time to encourage others to be similarly aware and to modify their activity when it significantly threatens sensitive plant life.

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CHAPTER 9

INSIGHTS INTO EXPLORATIONS OF SPECIFIC PLANT GROUPS

Ferns and lichens are at least as different from orchids or pine trees as parrots are different from monkeys. Although there are many basic exploration methods that can be used across the board in plant studies, gathering information about some groups requires or permits the use of approaches that may be quite unsatisfactory to others. This variety of approaches is the focus of this chapter.

Botanist Ruth Davis suggested that "to many people green stuff is just green stuff." Of course that is not the case at all and, indeed, today all "green stuff" is not even regarded as being true plant life. Not many years ago, anything living that was not an animal was considered to be a plant. Further elaboration suggested that plant cells had stiff walls to bound them, while animal cells were bounded only by more flexible cell membranes. Only plants contained the green pigment chlorophyll that permitted them to trap energy from the sun. As a group, the fungi created some problems of classification. Although they had cell walls like those of plants, they lacked chlorophyll. They were nonetheless considered to be plants. There were also some one-celled organisms with cell membranes like an animal but with chlorophyll like a plant. Zoologists claimed they were animals; botanists encompassed them as plants.

In the past few decades those people who spend their lives trying to arrange living things into groupings that indicate some sort of evolutionary relationships have decided that living things represent not two major divisions, or *kingdoms* (plant and animal), but rather at least five major kingdoms. Not all taxonomists agree, but today the most widely accepted classification system recognizes the kingdoms Monera, Protoctista, Fungi, Plantae, and Animalia. *Monera* includes single-celled organisms in which the nuclear material is not bounded by a nuclear membrane. This group encompasses the various kinds of bacteria and blue-green algae. *Protoctista* have cells in which the nuclear material is enclosed in a nuclear membrane. Most are single-celled, but there are a number of multicellular forms including the seaweeds. This kingdom includes nucleated algae, water molds, slime molds, and the protozoa. *Fungi* are also organisms with nucleated cells, but all species lack chlorophyll and reproduce sexually by spores. Fungi include molds, mushrooms, and mycorrhizal fungi. *Animalia* are multicellular creatures that, after fertilization, develop from a hollow ball of cells called a *blastula.* They are unable to capture energy directly from the sun but get it directly or indirectly from autotrophic plants. *Plantae* are multicellular organisms with some form of vascular system that reproduce sexually and contain chloroplasts.

You can see that many of the organisms most people would call plants are now scattered over three kingdoms, or four—if you think of bacteria as plants. Many of these organisms are small and require considerable technical expertise and equipment in their study. However, in each kingdom, with the possible exception of Monera, there are large, conspicuous groups that the alert amateur is likely to encounter and be curious about.

Consequently, while appreciating the taxonomic niceties of the new classification, I have chosen to include in our discussion groups from kingdoms Plantae, Fungi, and Protoctista, because the average person will continue to think of these organisms as plants. However, I have also chosen to avoid discussing these organisms in a sequence that is strictly taxonomic. Rather, I have grouped them according to convenience in methods of study. The result is eight major subsections to this chapter: 1) trees, shrubs, and vines; 2) herbaceous land plants; 3) aquatic flowering plants; 4) ferns; 5) mosses and liverworts; 6) fungi; 7) lichens; and 8) marine seaweeds. Each section suggests some special tools or techniques and questions for dealing with the group under discussion and will alert you to some professional or amateur organizations that focus their attention on the group.

TREES, SHRUBS, AND VINES

All of these are clearly in the modern kingdom Plantae. In large measure they tend to be among the dominant members of their respective communities. Adult trees in general are characterized by a well-defined stem, a diameter at maturity in excess of two inches, and a height over fifteen feet. Trees also have a well-formed crown of branches. By contrast, shrubs have a number of stems at or near ground level and usually do not reach the fifteen-foot height, although there are exceptions. As with any attempt to pigeonhole living things, there are always borderline cases, like gray birch (*Betula populifolia*), that demonstrate aspects of both definitions.

Trees and shrubs are woody, with stems essentially erect and self-supporting. Vines, or more properly *lianas*, do not fully support themselves, but fasten themselves by twisting around a support or grasping to other plants with tendrils or other devices. Some merely trail over others. Lianas can be either woody or herbaceous and are found most abundantly in tropical forests.

Largely because of their many uses and high economic importance to humans, trees are among the best-known plants. They have not only been carefully examined to determine their potential uses, but their relationships to the physical environment and the impact of each species on other species have been well detailed so that forests can be effectively managed and plantations established for reforestation. Such study is known as *sylvics*. Several good publications detail for each species other trees with which it regularly associates, soil conditions, light preferences, seed production, growth patterns, and the like. This does not mean that there is nothing new to be discovered about our trees, only that much less is known about many other kinds of plants, including shrubs and vines.

There are a number of interesting projects relating to trees for the plant watcher. One involves hunting down the largest specimens of each tree species that grows in your community and recording their location, girth, and height. If you enjoy this, expand your territory by looking for the biggest specimens that still exist in your county and/or state. In your searches you will discover a variety of interesting places; some will be very wild places, others quite civilized. Many of these giant trees represent a long history and deserve some protection to let them persist in our modern world. Your list of the biggest and their challengers will help indicate areas that deserve attempts at preservation or other types of protection.

At a national level, the American Forestry Association (1319 Eighteenth St., N.W., Washington, DC 20036) has maintained since 1940 a National Register of Big Trees. As time passes, old champions die or are destroyed and their ranking must be taken over by one of the challengers. These may reside in the same state as the former champion or be elevated from a state champion elsewhere. These in turn come from town and county champs somewhere else. The list of national champions is not published annually. Look for the 1982 Register of such champions in the April 1982 issue of *American Forests*, Volume 88, Number 4.

If you decide to develop your own register of local and regional big trees, you may as well utilize the same measuring system as the National Register. This system combines several measurements on a point system to determine a rough estimate of the tree's volume. This helps eliminate arguments about one tree that is taller than another but smaller in circumference.

According to the American Forestry Association: "Trees are compared based on a total point score determined by adding the trunk circumference, measured in inches at 4½ feet from the ground, plus the height of the tree in feet, plus one quarter of the average crown spread of the tree in feet." Details of how to measure are found in the *American Forests* issue mentioned above.

If at some point you want to submit a nomination for the National Register of Big Trees, send the data to the address given earlier and include your name and mailing address. If you are interested in state registries, write the National Register and ask for the name and address of your state coordinator, if one exists.

Trees are good plants for urban plant observers to become involved with. Every city has street trees and parks, and some have an arboretum. Such trees comprise the "urban forest." Remove the buildings and you have a forest left behind. You will not be able to see all stages in a tree's life history, because city trees get little chance to reproduce on their own—but there is much else to observe. Urban trees are subject to a number of stresses, some of which are common to normal forest trees. But many of these stresses are unique to the urban scene, such as pavement crowding roots and blocking the soil from soaking up adequate water; shade from tall buildings; pollution from car exhausts; and road salt. Urban tree watchers can organize a street-tree inventory and keep notes on the health and condition of each tree. Note when trees bloom and produce seed; the time of leafing out; leaf coloration (yellow and brown patches may indicate nutrient or moisture depletion); insect infestations; diseases; and other such information. If a tree appears to be suffering from some stress, the appropriate officials can be notified and encouraged to take remedial action. A number of cities are even beginning to have urban foresters. You should find out if your city has one; if it does, make his or her acquaintance—you probably share a number of common interests. You may want to work with the forester in planning and developing expansion of the urban forest and/or replacement of aging members of the present forest.

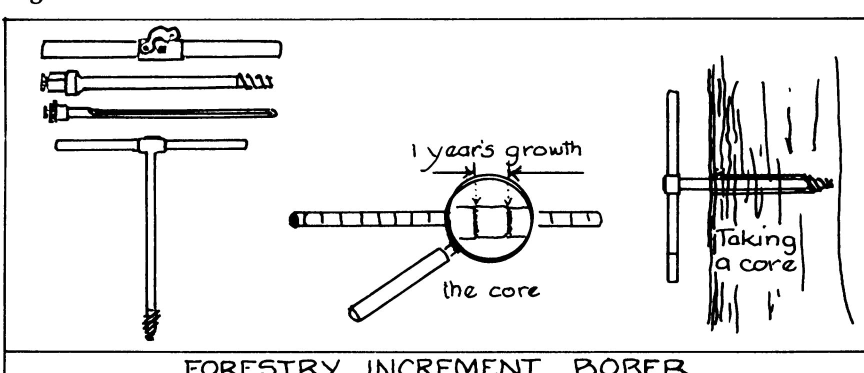
GROWTH RINGS

During their growing seasons, trees lay down a record of seasonal weather conditions at their site that permits the perceptive field botanist to build a historical record of changing conditions there. During spring and early summer, tree stem cells grow rapidly and are larger; in winter, growth is greatly reduced and cells are much smaller. In the cold of winter or the dry heat of summer, depending on the region's climate, no cells are produced. Thus, each year produces an annular ring composed of one wide, light ring and one narrow, dark ring. In special cases, one year may have two such double bands; and in tropics, trees usually show no annual rings unless there is a wet-dry climate. Much can be deduced about a tree's historic struggle for existence by examining these rings. If the tree has been cut, the rings can be examined and its life story read, at least approximately. A section with wide, even rings signifies a period of good conditions and fast growth. If these are followed by a section of increasingly narrow rings, it probably signifies increasing competition from neighbor trees. A widening of rings again is an indicator that somehow competition was reduced, perhaps because of a blowdown of a neighboring tree or trees or a timber harvest. Of course, the narrow rings could also signify a drought period and the widening that follows a return to a heavier rainfall pattern. If the pattern of narrow and wide rings is consistent for all the trees in the area, the regional weather pattern is probably the cause. If only a few scattered trees show the pattern, and then even in different years, competition is the more likely explanation.

Obviously we don't want to cut down each tree to read its annular autobiography. There is another way to proceed, using an instrument called an *increment borer.* These are available in several sizes that remove different diameter cores up to about the size of a pencil. The instrument is horizontally twisted into a tree and extracts a core that shows a number of lines which are the seasonal rings. You can reconstruct the history from these cores which can be labeled, dried, and stored in plastic straws and capped at both ends for future reference.

Cores should be taken from three or four different radii of each tree and the orientation of each radius should be noted on the core label. Each label should also include species, locations, date taken, and individual tree number where appropriate. Later you will want to prepare the cores for more accurate reading of the rings. Take small strips of wood and cut a

Figure 9.1



groove in each about half the diameter of the core samples. Cement a core in a groove and then shave or sand the core down to the level of the wood strip. A permanent label can be attached to the wood strip. Just before examining the core, wipe it with water, kerosene, or other light oil to make the growth rings more distinct. It may help to view the core with a dissecting microscope.

Cores collected from woodlots throughout an area can be correlated to provide a fascinating history of the growth history and succession of species in that woodland. Be aware that all the cores may represent trees of the same age, even though the trees seemed markedly different in diameter. Tree core analysis may indicate approximately when that plot of land was last cleared for human use, burned over, or blown down. You will find many interesting things if you take a large sample of cores from a broad spectrum of species. Some species will show good growth followed by increasingly smaller rings. Others will show narrow rings at the center and then a period of wider and wider rings. Probably the first example came early in the succession but is being out-competed by the second species, which had difficulty getting established but then began to get free of the competition of the first species and gained the upper hand. Increment borers are moderately expensive, but they do help enrich one's knowledge of a forest's recent past.

(*Note:* Removing a core provides an opening in the tree for potential infection by an insect or fungus pest. In comparison to the number of broken limbs and other naturally occurring gashes, the risk is not a great one—but it is a risk just the same. Plugging the hole where the core was removed with grafting wax will help reduce the risk.)

If you want to keep track of growth rates over the past three to five years—comparing growth among different branches, different individuals of the same species, or between different species—you may use terminal bud scale scars to delineate each year's growth. Most woody plants in temperate regions have buds that develop into stems, leaves, and/or flowers. Most buds that opened this year were formed the previous season. Buds are found along the sides of stems located just above the axil, where the leafstalk (*petiole*) joins the plant stem. As you may recall, these buds are called lateral or *axillary buds.* When a dead leaf falls off, it leaves a scar, so in winter we find axillary buds just above leaf scars. In addition, many species are characterized by a *terminal bud* at the end of twigs. Buds are usually enclosed in scales; when buds open, the bud scales fall and leave bud-scale scars. For terminal buds these bud-scale scars completely encircle the twig and remain visible on branchlets for several years until obliterated by increased growth of the bark.

The distance between two sets of these encircling terminal bud-scale scars is one year's growth. (It is also the specific definition of a *twig.*) In autumn, winter, or early spring look back from the terminal bud to the first set of encircling bud-scale scars—that space represents growth during the previous summer. That summer's date is the year to be assigned to that section of the branch, but if you are doing your study in the summer that same space represents the present year. Look back along the twig and assign appropriate years until the scars are no longer visible.

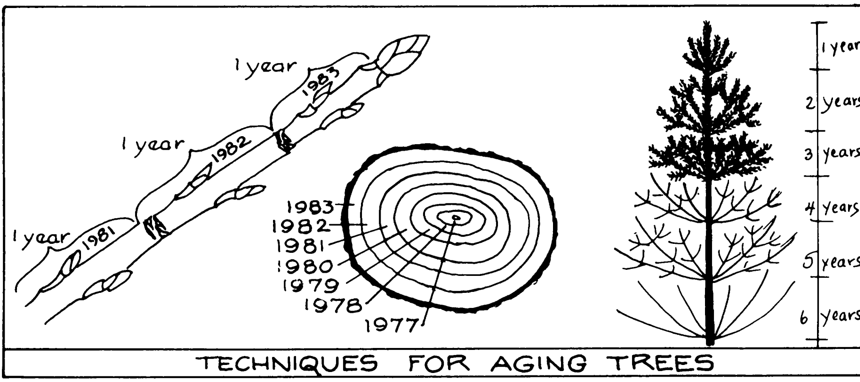


Figure 9.2

You may then want to correlate these data with a variety of environmental factors such as average rainfall during the growing period; number of growing days between the time frost left the ground and ground refreezing in the autumn; percent of trees defoliated by insect pests such as gypsy moths; number of rainfalls with pH below some figure such as pH 5; or any of a number of other factors. Unfortunately, not all species have true terminal buds. A number have "false" terminal buds—for example, birches and poison ivy. Opposite these on the twig we find a short stub or scar that tells us where the season's growth ended. A clue to whether or not the end bud is a false terminal is its presence directly over a leaf scar. This makes it an axillary rather than a terminal bud. Since false terminal buds do not leave encircling bud-scale scars, plants with buds of this type cannot be explored in the same manner as those with true terminal buds.

You can study annual growth in a number of pine species that have their buds in a whorl at the tips of their branches. Normally there is a central bud that will be the leader, plus a surrounding crown of buds that will grow sideways. The distance between whorls of branches normally equals one year's growth. Not infrequently the leader may be injured by insects, large browsers, or mechanical injury of other kinds and will die. When that occurs, one or more of the lateral branches usually reorients its position and assumes a somewhat vertical orientation as a new leader. Nonetheless, it still holds that the distance between whorls represents a year's growth. If you want to know approximately how high the pines were in the woodland twenty years ago, look to the top of a tree and count down twenty whorls. If you want to know how many years ago a pine woods was infested with white pine weevil, a pest that kills the leaders, count back the spaces from the top of the tree to a jog in the trunk where a side branch took over as leader. Some trees may have been victimized several times at different ages.

Professionals have fairly well determined the species of native trees growing in North America and, indeed, for many parts of the world, but much remains to be learned by amateurs and professionals alike about the life histories and ecological relationships of many species.

If you are a traveler, take good photo sequences of trees in the countries through which you travel. Try to get pictures of the general terrain in which the species grows and then focus in on shots of a whole tree with additional close-ups of distinctive and unusual features. Be sure to note the location of each specimen as precisely as possible. As more and more of the world's forests are cut each year, in a very short time those photos you take could become the only records of the dominant species that once occupied those landscapes. If you are going to reside abroad for a number of months or several years, attempt to rephotograph some of the same trees in different seasons, or at least the same species at different stages in their life cycles.

VOUCHER SPECIMENS OF TREES

Preparing herbarium specimens of trees presents a few problems. Obviously you can't collect and press a whole tree! Furthermore, even a twig with leaves presents some problems because thickness of the twig prevents the press from contacting the leaves firmly so they tend to curl instead of pressing flat. This can be compensated for in one of two ways. The twig can be split in half with a knife so that it presents less thickness. If this is not adequate, pads of absorbent toweling the thickness of the stem can be placed under the leaves before they are put between the normal driers (see page 62). Whenever possible, get samples of a tree's flowers as well as its leaves. This can present problems because some species flower before they leaf out and some have male and female flowers on separate trees. This will necessitate some diligent and persistent hunting on your part. A good photograph of the whole tree also adds considerably to the value of your voucher specimen.

Because trees may have rather large fruits and seeds, these too may present some preservation problems if you include them with your voucher specimen. Dry fruits and seeds, even most small nuts, can be placed in transparent plastic envelopes and attached to the herbarium sheets. Large nuts and fleshy fruits have to be kept separately, so be sure they carry the same identification number as the other preserved parts. Fleshy fruits can be kept in jars of alcohol or formalin, or be dried thoroughly before being put in a fruit and seed collection.

Trees are among the largest life forms on earth and are found on virtually every continent except modern Antarctica. They are located in most cities and in wilderness areas, but trees are facing heavy destruction almost everywhere, particularly in tropical regions and Third World nations. They need and deserve people's respect and conservation. In the United States, The Wilderness Society (2114 P Street, N.W., Washington, DC 20006) and The Nature Conservancy (1800 North Kent Street, Arlington, VA 22209) work to secure and protect significant tracts of untouched forest ecosystems. You may find it worthwhile to support their efforts and perhaps even work with their professionals to survey the plant life of such areas.

While trees have been well investigated, shrubs and vines have received far less attention except for a comparatively few species. Shrubs tend to get their "day in the sun" in the middle of a number of successional sequences. In mature forest habitats, they generally end up as only minor members of the community understory.

Vines, or lianas, compete with trees and shrubs by clambering over them and using them for support. The leafy areas of many vines, such as kudzu and Japanese honeysuckle, may block out light from the very trees that support them, eventually killing them. Lianas are far more abundant in tropical and subtropical regions than in temperate ones. They use a number of strategies for reaching up to the top of the canopy. Some begin on the ground and go up, while others have seeds that sprout high in the trees and grow down to the ground as well as up into the canopy. Parasitic vines, like dodder, begin as seeds in the ground. Their seedlings reach up and grasp a plant, penetrate its tissue with fingerlike processes called *haustoria,* and eventually break their contact with the ground altogether. They then spread over the autotrophic plant mass with no further direct contact with the ground. Much remains to be learned about development of vines and lianas, their rates of growth, dispersal mechanisms, and many other aspects of their life histories and roles in plant communities.

HERBACEOUS PLANTS

Nonwoody, flowering land plants are those that generally come to mind when people talk about herbaceous plants. These are the wildflowers, grasses, cacti, and other succulents that attract wildflower buffs. Many of these kinds of plants have been transformed by selection and breeding into our garden and house plants. For most plant watchers these are the kinds of plants that first demand our attention. Because the bulk of the chapters of this book were written with herbaceous plants strongly in mind, there is little need to elaborate further on special techniques of exploring this grouping of plants.

I do, however, want to call your attention to some organizations that focus primarily on herbaceous plants, although most don't limit themselves to them. Through such organizations you can locate other individuals who may share your enthusiasm and from whom you may learn new skills and gain field companionship. Most of the organizations offer field trips, workshops, meetings with visiting speakers, and usually a newsletter or periodical journals with helpful articles and information. Membership in most of the organizations is tax-deductible.

NATIVE PLANT SOCIETIES

- Arizona Native Plant Society
  P.O. Box 18519
  Tucson, AZ 85731

- California Native Plant Society
  2380-D Ellsworth
  Berkeley, CA 94704

- Southern California Botanists
  ℅ Rancho Santa Ana Botanic Gardens
  1500 North College
  Claremont, CA 91711

- Colorado Native Plant Society
  P.O. Box 200
  Fort Collins, CO 80522

- Florida Native Plant Society
  ℅ Mulvane Art Center
  17th and Jewel Streets
  Topeka, KS 66621

- Hawaiian Botanical Society
  ℅ Dr. D. D. Palmer, Native Plant Committee
  1481 South King Street
  Honolulu, HI 96814

- Missouri Native Plant Society
  ℅ Jim Wilson, Missouri Dept. of Conservation
  Box 180
  Jefferson City, MO 65102

- North Nevada Native Plant Society
  P.O. Box 8965
  Reno, NV 89507

- Native Plant Society of New Mexico
  P.O. Box 5917
  Santa Fe, NM 87502

- Native Plant Society of Oregon
  1920 Eagle Avenue, N.W.
  Salem, OR 97304

- Pahove-Idaho Native Plant Society
  ℅ Dr. Pat Packard
  Herbarium, College of Idaho
  Caldwell, ID 83605
- Native Plant Society of Texas
  P.O. Box 23836
  TWU Station
  Denton, TX 76204
- New England Wildflower Society
  Garden-in-the-Woods
  Hemenway Road
  Framingham, MA 01701
- North Carolina Wildflower Preservation Society, Inc.
  Tooten Garden Center
  457-A University of North Carolina
  North Carolina Botanical Garden
  Chapel Hill, NC 27514
- Tennessee Native Plant Society
  Department of Botany
  University of Tennessee
  Knoxville, TN
- Utah Native Plant Society
  3043 Brighton Place
  Salt Lake City, UT 84121
- Washington Native Plant Society
  Department of Botany
  University of Washington
  Seattle, WA 98195

REGIONAL OR NATIONAL PLANT ORGANIZATIONS

- The Wildflower Preservation Society
  3740 Oliver Street, N.W.
  Washington, DC 20015
  Pub.: *Wildflower*
- Association of Western Native Plant Societies
  ℅ Anne Kowalishen
  Portland, OR 97211
- The Fauna & Flora Preservation Society
  ℅ The Zoological Society of London
  Regents Park
  London NW1 4RY England
  Pub.: *Oryx*
- Botanical Society of America
  Department of Botany
  University of Texas
  Austin 12, TX 78712
  Pub.: *American Journal of Botany*

- The Torrey Botanical Club
  Hunter College
  New York, NY 10021
  Pub.: *The Bulletin of the Torrey Botanical Club*
- New England Botanical Club
  Botanical Museum, Oxford Street
  Cambridge, MA 02138
  Pub.: *Rhodora*

SPECIAL-INTEREST ORGANIZATIONS

These organizations attract people whose primary interests are horticultural, but there are always some members whose primary interests lie in study of the plant group in the wild.

- The International Organization for Succulent Plant Study
  ℅ D. R. Hunt
  Royal Botanic Gardens
  Kew, Richmond, Surrey, England
- American Orchid Society, Inc.
  6000 South Olive Avenue
  West Palm Beach, FL 33402

In other sections of this book we have downplayed flower listing, but it can be a thoroughly enjoyable activity when you are on vacation or a business trip and builds a general familiarity with the flora of an unfamiliar region. In fact, it is fun to schedule trips to desert, prairie, and mountain regions during the peak of their bloom period just for the sheer visual delight of it.

In the United States and Canada it is possible to acquire relatively inexpensive local identification guides to the most common flowers at gift shops and visitor centers of most national parks. These booklets generally are useful for a much broader geographical area than just the designated park. Often there are several different booklets available; look over each one carefully before buying it. Try to get as many well-illustrated species as possible for your money. Most of these small guides also point you in the direction of the most authoritative references for the region so that if necessary you can dig deeper later.

These guidebooks can also be used as a checklist on your trip. I usually put a checkmark in the margin next to each species sighted, along with the date it was first observed and where. On a recent trip through the northern Rockies, for instance, my wife and I ticked off 85 of the 125 plants listed in the little guidebook we had bought and we also noted a number of other species not included in that book but identified elsewhere. It wasn't the kind of record one would keep for a real exploration of that flora, but it was a pleasant enrichment of what was fundamentally a wildlife photography trip.

Don't hesitate to make sketches and color notes of unidentifiable (from your particular guidebook) flowers. Take the sketches to park naturalists who can help you with at least tentative identifications. A set of colored pencils is helpful for such sketching. Be sure to represent leaf shape and positioning on the plant accurately, as well as individual flower shape and arrangement of flower clusters. The more detail and accuracy in your sketch, the greater the likelihood that the ranger/naturalist can positively identify it or that you can work it through more extensive keys later.

AQUATIC FLOWERING PLANTS

Our wetlands and waterways are home to an extensive variety of flowering plants. Many grow only partly submerged; others are truly aquatic, living entirely submerged except at flowering time. It was once believed that such freshwater aquatic plants represented the transition of plants from saltwater dwellers to land dwellers, but today botanists feel sure that almost all freshwater flowering plants represent a return from the land to water. In a sense, freshwater environments represent a refugium for some species that could not compete well on land.

Until quite recently, such aquatic groups were poorly studied. Emergent plants of shallow waters had received some attention, but submerged species were largely ignored. Perhaps the aquarium hobby did as much as anything to stimulate interest in submerged aquatic plants, triggering particular interest in species that might provide decoration for the aquaria. Many handsome species were discovered, along with a knowledge that they were not all easy to grow. Sensitive to water chemistry that supplies or mediates many nutrients and the vital gas exchanges, many species prove very fussy to grow. Indeed, they often do best in the absence of the fish in which aquarists are primarily interested. Field studies of aquatic plants remain uncommon, getting far less attention than these for terrestrial species.

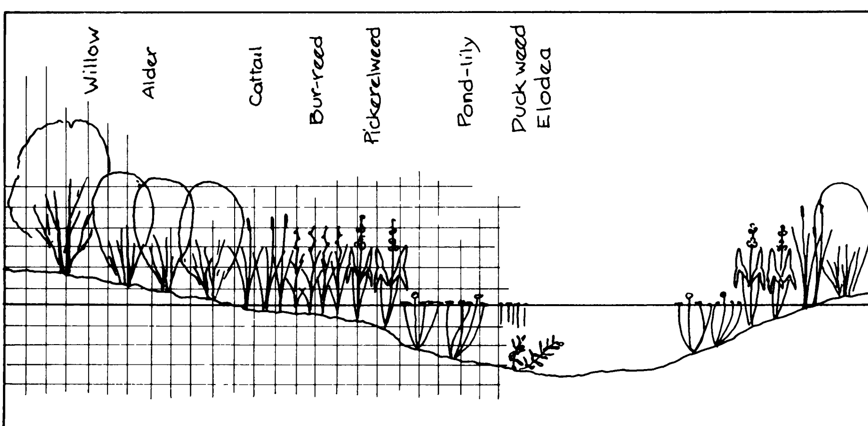
Every type of wetland habitat has its unique aquatic species. A good initial project is to survey various wetlands of your area—bogs, marshes, swamps, ponds, lakes, streams, and rivers—to determine what species live in which habitat. Some will show up in more than one habitat; others will be restricted to only one. Gather data on the amount of time each year that the overall site is underwater and how the depth of the water varies throughout the seasons. If these data are mapped, they often reveal a number of depth zones and/or zones of inundation. If you map the dominant species, chances are you will find a strong correlation between the plant species and these zones. Not all wetlands are freshwater; in coastal areas the water may be brackish or salt, subject to tidal flooding.

After some exploration, you will probably note that certain species can tolerate having their roots and lower stems underwater for a period of weeks or months as long as their leaves are above water. These are the water-tolerants. Others have adapted to total submersion for most of their life history, poking up into the air primarily to carry on their reproductive rites. These two major groupings need to be explored with slightly different techniques. Emergent species can be explored using most of the same approaches you employed with land plants, except that you must also gather data on water depth and water chemistry. In most cases, emergent vegetation grows in water less than waist deep. Of importance is the nature of the substrate. It may be gravelly, clayey, sandy, or rather thick organic ooze. The first types are easy to work in; but clay and ooze can be a problem, often being deep and exerting sucking forces almost like quicksand. Ooze must be treated with caution and respect.

Transects across wetlands from dry land out to chest-deep water reveal many subtleties about the preferences or tolerances of various species, and relatively small changes may have strong influences on which species are present or absent. In addition to the actual water level at the time of your investigations, try to obtain some data on normal high and low water levels.

If plants are growing as isolated individuals, it is relatively easy to record the location of each along your transect, but if the plants are reproducing vegetatively and forming dense patches of a single species, record the distance along the transect where a patch begins and ends (i.e., eelgrass patch—5 m to 8 m). Represent the data on a scaled version of the transect with symbols that represent each species. This is essentially an aquatic bisect similar to the terrestrial one described on page 127 (see Figure 9.3).

Figure 9.3



COMMUNITY BISECT OF AN AQUATIC ENVIRONMENT

Seeing below the water surface in shallow water is often difficult because of reflections. It is very helpful to build and use a simple waterscope (essentially a glass-bottom bucket). Placing the glass below water and viewing will give you a much clearer perception of what is happening at the base of the plants. You can spot the appearance of new shoots, aquatic animal life on the plants, and the nature of the substrate. Waterscopes are a bit awkward to handle until you get the knack, but they are worth the effort for what they permit you to observe. When you work beyond waist-depth, a snorkel and mask can replace the waterscope.

You may want to extend your partial transect of a wetland or waterway by making a complete cross section of it, including depths considerably beyond waist-deep. You can do this from a boat by sending down a grappling hook to snare plant samples, but this is unsatisfactory from a number of viewpoints. Much more is learned from going below the surface with snorkel and face mask or, better yet, with SCUBA gear. Use of a snorkel and mask can be frustrating because you have to surface frequently. This interrupts observation; and the deeper the plants are, the greater the frustrations. SCUBA gear, on the other hand, allows far longer periods of uninterrupted observation.

The underwater world is a fascinating one, with plants only a tiny fraction of the fascination. Learning SCUBA diving is well worth the time and expense because it gives you access to a whole new universe. But never undertake SCUBA diving without proper certification; diving may be mind-expanding, but it is potentially very dangerous if not done properly. Diving for plant study will usually not take you to great depths, because light, which is essential to plant growth, does not penetrate very deep, even in the most sparkling clear water. In heavy vegetation a diver must be alert and careful not to get entangled.

When using SCUBA gear to extend your transects or general observations into deeper waters, carry the following in addition to your basic regulator and tanks: compass, depth gauge, light meter, armored thermometer, underwater notetaking device (see Chapter 10), plastic jars, and net carrying-bag. This equipment permits a considerable amount of data gathering.

Proper SCUBA procedure requires a diving buddy. For underwater botanical explorations, one partner sets a compass course, which is the transect line, while the other partner makes observations and collects samples. Information to gather includes temperature readings at various depths, depths at which each species occurs, and light readings at different depths, changes in the substrate, and vegetation samples for identification purposes. (*Note:* Light readings should be taken off the observer's hand with the meter a foot away and the diver's back to the light source.) Occasionally you may want to collect water samples at various locations for later chemical testing. Samplers can be simply plastic tubes that are corked at each end when at the appropriate depth. A grease pencil will permit marking the samples with identification codes while you are underwater.

In addition to transects, you can easily set up study plots underwater. They are generally less subject to vandalism than those established on land. Use polyrope of an appropriate length to act as the perimeter of a quadrat. String it through the eyes of four surveyor's pins or homemade equivalents, and tie the ends. Put tape markers on the rope at the proper spots to act as corners of your plot. Now you have a quadrat to take below the waves. Stick a pin in the substrate and fasten the rope at a corner marker. Set the other pins in the substrate near the other corner markers. Quadrats will let you sample essentially the same data underwater as on land.

There are extensive questions yet to be answered about the autecology of many aquatic species and about their phenology. When do the plants emerge from the dormant period and when do they go dormant? When do they begin flowering? Under what conditions do they flower rather than reproduce vegetatively? For instance, duckweeds (*Lemna*) are one of our tiniest flowering plants, but they flower rarely; under what conditions do they do this? What animals have effects on the various aquatic species? Does a species have clear-cut tolerances for certain substrates, chemical conditions of the water, or strength of current in flowing waters?

Because submerged plants are in such intimate contact with their environment, the observer of aquatic plants has only a limited view of what is going on if he or she does not gather information on physical and chemical characteristics of the body of water in which they are growing. Basic testing can be done with one of the various testing kits available from Hach Chemical Company (Box 907, Ames, IA 50010) and LaMotte Chemical Company (Chestertown, MD 21620). Chemicals and instructions are available as kits, or you can buy chemicals directly and conduct the tests as instructed in several of the further readings mentioned at the end of this chapter. Gather information on dissolved oxygen and carbon dioxide, for these gases play a major role in a plant's ability to respire and photosynthesize, respectively. Also, test for soluble salts in the water which can serve as nutrients for the plants, or which may be pollutants. Data on pH and alkalinity are likewise important; the latter indicates something of that water's ability to buffer acidity. Because these chemical factors often show vertical gradation, to get useful readings take water samples from various depths.

Among the physical factors to be explored is *turbidity*, or color, of the water, since this affects the depth to which light can penetrate and thus the light quality and intensity available to submerged plants. These data can be gathered from a boat by lowering a black-and-white patterned Secchi disc and noting the depth at which it disappears from view.

Readings may vary throughout the season because of changing turbidity from heavy rains that increase silt in the water or from blooms of plankton.

When exploring stream and river plants, be sure to gather information on the length of the stream section explored and, at various points, collect measurements of the breadth and depth of the stream and rate of flow (velocity) of the water. You can do the latter by timing a float's movement between a measured distance.

If you do not have equipment with you to measure stream velocity, you can extrapolate a rough estimate by noting the size of the material on the stream bed. The British ecologist A. G. Tansley determined the following relationships:

SUBSTRATE	VELOCITY IN FT/SEC.	VELOCITY IN M/SEC.
Rock	4+	1.2+
Heavy shingle	3–4	0.91–1.21
Light shingle	2–3	0.60–0.91
Gravel	1–2	0.30–0.60
Sand	8″–1	0.20–0.30
Silt	5″–8″	0.12–0.20
Mud	0–5	–0.12

A brief word is in order about collecting and preparing voucher specimens of submerged plants. Most emergent plants can be dealt with in the normal ways but the submergents may need some special attention, particularly if they are very filamentous. Collect them in plastic bags and keep them in water; store in a refrigerator if you can't prepare them for a day or so. When you want to prepare them as regular herbarium specimens, use a flat tray an inch or two deep and large enough to accept an herbarium sheet. (Such trays are usually available at photographic supply stores and are meant for use in developing photographic prints.) Submerge the herbarium paper; then float the specimen in the tray over the paper. Carefully lift the paper, drawing it over the tray edge while draining the water and lightly holding the specimen in place on the sheet with your fingers. Move slowly and gently. Squirting a pipette (medicine dropper) of water on the specimen will help rearrange any filaments too closely matted together. Once removed from the water, let the specimen dry onto the sheet and reinforce its positioning with strips of Archer's mounting medium (see page 63).

You will profit from penciling the appropriate data on the lower right-hand corner of the sheet with a soft pencil before you wet the paper. Later, after all drying has been done, cover the pencil work with a glued-on, inked label. In the meantime, specimens will not get mixed up and separated from their data.

Some people prefer to preserve their aquatic specimens in liquid, using a four-percent formalin solution prepared by mixing four parts commercial formaldehyde (see your pharmacy) and ninety-six parts water. If the mix tests acid, neutralize it to pH 7 with borax. Use tall, slender jars and be sure to put a waterproof label inside the bottle as well as on the outside. External labels come off from time to time, but the label inside will assure that the data are not lost.

No organization that I am aware of focuses its attention solely on aquatic flowering plants, but you will find members of the *American Littoral Society* who share your interests. Contact the society at: Sandy Hook, Highlands, NJ 07732. They publish a journal called *Underwater Naturalist.* For information on aquatic plants, investigate periodicals of the tropical fish hobby—particularly *Tropical Fish Hobbyist*—which regularly feature aquatic species. As might be expected, such material tends to be biased toward warm-water species.

FERNS AND THEIR ALLIES

All groups we have discussed so far have shared several traits in common. All had a vascular system for transporting food and water among the living cells, and all were capable of reproducing through seeds. Seeds have a tough outer coating surrounding an embryonic plant.

Ferns and their allies are similar to these other plants in having a vascular system; however, instead of seed they reproduce from spores. Spores do not contain an embryo, and the cellular structure that grows from them has in each cell only half the normal number of chromosomes to be found in the mature fern plant. Fern spores develop into a thin, flat, ribbonlike structure known as a *prothallium.* A prothallium develops two small structures on its lower surface; one is shaped like a little upside-down flask and known as an *archegonium,* containing an egg cell, while the other kind of structure, an *antheridium,* appears like a little pimple. Inside the antheridium are spiral-shaped male cells which botanists call *antherozoids.* The underside of a prothallium also has a number of threadlike structures that help hold the plant in place. Unlike roots, these *rhizoids* have no vascular structure.

If a small film of water is present, antherozoids can swim to the eggs and one will fuse with an egg forming a structure with the normal (diploid) number of chromosomes, called a *zygote.* This is a sexual union. A zygote will go through a series of cell divisions that will produce leaves, called *fronds,* that we recognize as being ferns. In due time some fronds develop structures that produce new spores.

Notice that in a fern life cycle there are two kinds of fern plants: a prothallium which develops asexually from a spore, and fern fronds which develop from a sexually produced zygote generated by the prothal-

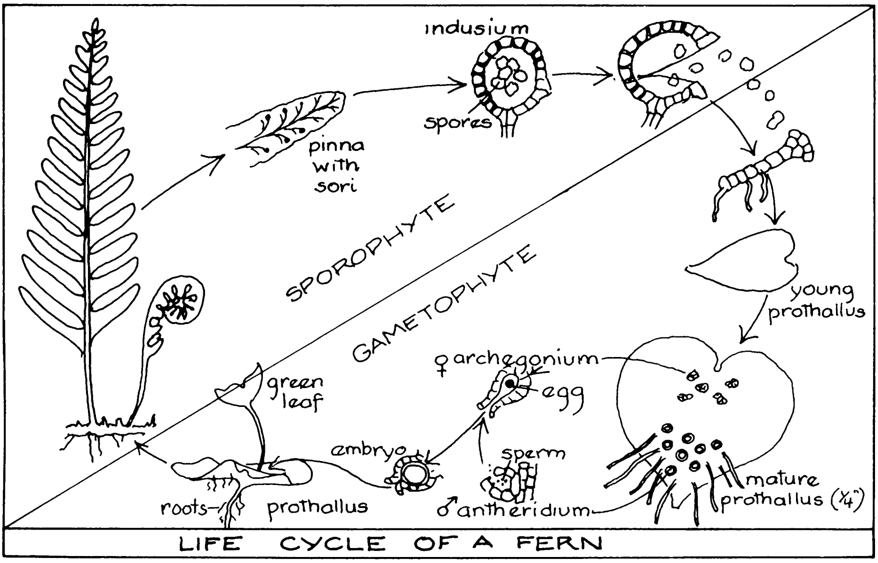


Figure 9.4

lium stage. This alternation between asexual and sexual development stages is the phenomenon known as alternation of generations. Ferns and fern allies are not totally restricted to reproducing through this process. In some species there are forms of vegetative reproduction.

Although ferns are most widespread in tropical regions, they can be found in almost every habitat except the most arid. There are even a few truly aquatic species, such as *Marsilea,* which resembles an underwater four-leaf clover. Ferns tend to have rather specific habitat requirements and the plant observer needs to take careful note of the physical conditions where each species is found. Some, of course, show a broader range of tolerance than others.

Forms of fern growth are worth noting. Some species send up their fronds from around a vertical stem, or rootstalk, and the leaves tend to create a graceful crown. With such species, new fronds appear at the outside of the rootstalk so each year the circle of fronds gets somewhat larger. With evergreen species you may find a circle of winter-flattened, green leaves on the ground with a new circle of coiled fronds, or *croziers,* poking up through. Other species have a horizontal stem, or rhizome, that lies on or just under the surface. New growth emerges from the tip of the rhizome. A rhizome will continue to grow for years, sending down new roots near the fronds and often slowly decaying away at the other end. In this way, a particular plant may slowly march along the ground, moving a fair distance from its original germination spot.

Ferns are handsome plants that are fun, though often frustrating, to identify. Fortunately, there are fewer species to master than among seed plants. Identification of many ferns is possible based on growth habit, habitat, and similar factors, but positive identification of confusing species depends upon close examination of the spore-bearing structures. You will need a good hand lens for much of that. Most ferns bear their spores on the underside of some or all of the leaflets (*pinnules*) of the fronds, but there are species that produce separate fronds devoted solely to producing spores. Fronds that produce spores are known as *fertile fronds*, others are called *sterile fronds*.

On a typical fertile frond you find bundles of sporangia, or sori. Often a sorus is covered with a flap or umbrellalike lid known as an *indusium*. The indusium may be attached to the sorus at its edge or in the middle. There are round indusia, curved indusia, long and narrow indusia, and absent indusia. The presence or absence of an indusium, its method of attachment, shape, and spacing are specific for each species of fern. The language of fern parts seems confusing and awkward at first, but with persistence it won't be long before you grasp it and use it to begin unraveling the mysteries of which fern is which.

You can then begin to gather some phenological information about local ferns. When do the croziers first appear? How long does it take for the average crozier to fully uncoil? How long to reach full size? How long does the average frond survive? How many fronds does a plant put up in a season? When do sori begin to appear? Do all fronds become fertile? If not, is it younger or older fronds that become fertile? When do fronds die back?

There are also a great many questions to explore about a species' preferences, tolerances, and habits. What are its soil and light requirements? Its moisture requirements? How long do individual plants live? Is the species a competitor or a stress-tolerator? How rapidly, and in what fashion, does a colony establish itself and expand? Do the individual plants move about? If so, at what annual rate? Is there evidence of any individuals actually moving out of a good habitat? What animal life feeds on ferns? Are there species of animals associated closely with ferns in any other way (i.e., hummingbirds using cinnamon fern fuzz to line nests)? Can you locate any prothallia in the area? If so, under what conditions have the spores germinated and survived? How near is the nearest spore-bearing fern to this prothallium? How do the adult ferns weather periodic drought?

Even though the variety of species is relatively small compared to seed plants, there is a great diversity among ferns. There are tree ferns in the tropics, and tree-dwelling, epiphytic ferns as well. There are climbing ferns; ferns with strap-shaped leaves that root at their tips; and both emergent and submergent species of water-dwelling ferns. Such beauty and diversity has attracted many people to an interest in ferns both in the wild and as captives in garden, greenhouse, and dwelling. Some organizations devoted to ferns include:

- The Los Angeles International Fern Society
  ℅ Jo Myers
  14895 Gardenhill Drive
  La Mirada, CA 90639
  Pub.: *Lasca Leaves*
- The American Fern Society
  ℅ Dr. Terry R. Webster
  Biological Sciences Group
  University of Connecticut
  Storrs, CT 06268
  Pub.: *American Fern Journal*
- The British Pteridological Society
  ℅ Mr. J. W. Dyce
  46 Sedley Rise
  Loughton, Essex, England
  Pub.: *The British Fern Gazette*

Because people are usually more familiar with seeds and seedlings, you are urged to broaden your experience by trying your hand at growing some spores to produce prothallia. Indeed, you may want to attempt growing as many as possible different species of ferns from spores and develop a photographic record of their prothallia and the first young fronds that arise from them. Growing ferns from spores is not particularly difficult, but it does take time and patience. On average, it takes six to ten months from the time of sowing spores until young ferns are large enough to be transplanted.

Several methods can be used, but for a beginner the inverted pot method is probably most satisfactory. Take a clean, porous, clay flowerpot, one not too large to be completely covered with a glass jar. Fill the pot with sphagnum or peat moss, then invert it into a shallow dish or saucer. Pour boiling water over the pot and saucer several times to sterilize them. Drain and cool. Sprinkle the spores over the surface of the inverted pot, and then cover it with a glass jar. Place water in the saucer from time to time as needed.

Collect spores when sporangia are light brown and the indusia are still intact. Green indusia indicate that the spores are not yet ripe; frayed and/or shriveled sporangia indicate that the spores have already been shed. Put the fronds, with sporangia down, on paper. Cover with a jar to keep the spores from blowing away. In a day or so carefully remove the fronds from the paper, leaving behind as little else as possible beside spores. Replace the jar and avoid drafts while carefully moving the paper and jar to your sterilized pot. Tap the spores off the paper onto the clay pot.

After sowing the spores, place the flowerpot and glass jar setup in filtered sunlight of low to medium intensity, or under a fluorescent lamp, where it can receive eight to sixteen hours of light per day. Temperatures between 68°F and 86°F are best. Water when necessary, preferably with cooled, boiled water or distilled water. Weak solutions of liquid fertilizer can be added to the water every couple of weeks after a green mat of prothallia appears.

Once the mat of prothallia has formed, you can transplant small 1/4" pieces of the material onto the surface of a planting medium (for instance, sphagnum peat) in a clear plastic container with a lid. Place pieces about 1/2" apart. The planting medium should be sterilized, disinfected, and drenched with fungicide before being used with the prothallia. Press prothallia clumps firmly onto the medium and mist them with distilled water. Cover and continue to observe. As young fern fronds begin to grow, you may want to divide them again. In time you can remove the cover and let the young fronds toughen. They can then be transplanted to individual peat pots for eventual transfer outdoors or to indoor or patio planters.

FERN ALLIES

Like ferns, the fern allies—clubmosses, horsetails, quillworts and selaginellas—reproduce by spores, although there are anatomical differences in the spore-bearing structures. It was once believed that these groups of plants were closely related to ferns, but more recent studies indicate a more distant relationship. We still are learning much about them, for they have not received even as much attention as the ferns.

It seems strange that the existence of spores was not discovered until 1669 although seeds and their purpose have been well known since the dawn of humankind. It wasn't until 1848 that science learned how spores grew into fern plants. Remarkably, there are still fern allies who have not had their life cycle completely documented. Unfortunately, many of them do not respond as readily as ferns to laboratory propagation.

Most diverse in form of the fern allies are the clubmosses, or *lycopodiums*. In ages past, ancestors of today's species included some rather large, treelike species, although today's species are all comparatively small. Clubmosses do have some mosslike qualities to their appearance, but because they have a vascular system to distribute food and water, they are able to be larger than true mosses. Many species resemble four- to six-inch high evergreen trees, a characteristic that is reflected in such common names such as "ground pine" and "running pine."

Lycopodiums tend to spread by creeping stems that send down roots at intervals and send up evergreen shoots. It is on the shoots that reproductive organs are borne. In most clubmosses this is a cone-shaped structure called a *strobilus*. There are species, however, like shining clubmoss (*Lycopodium lucidulum*), that have pinhead-sized, spore-bearing sacs in the axils of the upper leaves instead of a strobilus.

Exploring life cycles of clubmosses takes considerable time, patience, and luck. The small percentage of the millions of spores produced that do germinate tend to do so beneath the soil surface. Researchers believe that it may take clubmoss spores as long as seven years to develop into a prothallium and another decade for that structure to send a new clubmoss shoot above the ground. It is little wonder that clubmosses are only poorly known at present!

Existence for a clubmoss is a constant race between life and death. It grows from new shoots at the stem tips while dying back at the other end. It must be able to provide new growth at least as fast as it decays. In many areas, clubmosses have suffered greatly from overcollection for Christmas wreaths and terraria. This is unfortunate since their slow development means they recolonize an area very slowly, if at all. What's more, they are generally unsuited to terraria and wild gardens for which they are collected because they do not transplant readily.

You may find it informative to tie markers loosely at the growing points of some plants and keep track of the rate of growth of individuals along with their accompanying rate of decay.

Horsetails and scouring rushes are another group of fern allies. Fertile fronds of horsetails look as though they were designed by a Middle Eastern religious architect since they are composed of tiers of crownlike scales at each stem joint piled one atop the other, culminating in a club-shaped minaret which is the strobilus. Sterile fronds follow the same stem pattern, but branches at the joints grow out into green stringy leaflets that give the plant a bushy appearance suggestive of the tail of a green horse! If you keep phenological records of these plants, you will note that their fertile fronds appear very early and die back by summer. So different are the fertile and sterile fronds of some species, it would be easy for the uninitiated to believe they were dealing with two distinct species on the same site.

Scouring rushes are green and manufacture food in the stem. The hollow stalks, which are beautifully banded in black and white at each joint, also contain grains of silica, the mineral of most sands. Because of this, people have long used the stalks to scour pans and the like, thus the name. Unlike horsetails, scouring rushes do not have fertile and sterile forms, but produce strobili at the tips of the food-producing stalks.

Look for the horsetail tribe in wet meadows, along stream banks, and in disturbed, loose, sandy-gravelly, wet soils such as railway embankments and roadsides. There are a number of species of horsetails (*Equisetum*) to be found in temperate zones. One must be careful in identifying them for some, like the common field horsetail (*Equisetum arvense*), have a wide variety of forms of the one species and, unfortunately, these many forms blend with one another creating considerable confusion. Those of you with an ecological bent should examine the location of the rootstalks in the ground for this varies considerably, affecting the plant's role in its community.

Not to be forgotten among fern allies are quillworts, all of which belong to one genus, *Isoetes*. There are about seventy species worldwide, almost all of them aquatic or semiaquatic in habit. Quillworts all look similar and prefer similar habitats. They tend to resemble clumps of chives or small onions with a flattened, spoon-shaped base to each leaf. They often grow among similar-appearing aquatic and semiaquatic grasses so that they get overlooked. As might be expected, quillworts have received relatively little attention from researchers.

Quillworts do have some features that bear attention, however. They have the largest spore cases of any living vascular plants. These spore cases contain two types of spores: the large female *megaspores* and tiny male *microspores.* Sporangia are located in pockets at the base of a corm, and the outer leaves are the oldest; the innermost ones youngest. In most species young leaves are sterile; the outermost, fertile ones. Sporangia of the outer leaves are filled with megaspores, while the middle, fertile leaves bear microspores in their sporangia. However, there are some species that bear both spore types within one sporangium.

The two different spores both produce prothallia, but microspore prothallia produce only male spermatozoids and macrospore prothallia produce eggs. Young quillwort leaves grow only from macrospore prothallia. Macrospores of quillworts are large enough to be seen by the naked eye, but examination under a binocular microscope reveals a variety of surface textures depending on the species. The upper segment of each macrospore has three ridges that meet at the apex; the opposite ends of these ridges are joined by a circumferential ridge. The area between the ridges may be pitted (*reticulate*), pebbled (*tuberculate*), prickly (*echinate*), or crested (*cristate*), characteristics that are used to make positive identification among the quillwort species. Because it is awkward to carry a binocular microscope into the field, you will have to take home appropriate voucher specimens.

Last of the fern allies to be included in our brief discussion are the spikemosses, or selaginellas. This is not a large group of plants, with only about 800 species worldwide. The creeping, prostrate forms are largely tropical in distribution and prefer moist habitats. The more upright, stiff species are found in drier, rockier areas and are more common outside the tropics. There are only a few dozen species of this group in North America. Like quillworts, selaginellas produce both macro- and microspores. Sporangia are born in the axils of upper leaves. It takes a sharp observer to spot colonies of these plants and a determined one to follow their life histories.

MOSSES AND LIVERWORTS

Mosses and liverworts form a natural grouping of plants of considerable similarity. Besides being associated together in lay peoples' minds, scientists assemble them all under one plant phylum, *Bryophyta.* Modern bryophytes are all low-growing plants, with most species ranging between 1/16 of an inch to about two inches in height. They all lack roots with a vascular system, having instead only tiny, hairlike rhizoids that anchor the plant to its substrate and absorb a little moisture that must be transmitted directly from cell to cell. Some bryophytes are thin, flat, scalelike growths (*thallus plants*) that press close to the substrate, held by the rhizoids on their underside. Most bryophytes do have true stems and leaves with some form of vascular system. Because they do not have roots to bring them water and nutrients, and must take moisture in through the individual cells and pass it from cell to cell, they must either establish themselves in habitats that are perennially moist and/or shielded from solar dessication, or develop good conservation techniques and capacity to withstand drought while concentrating growth and reproduction during the brief periods of adequate moisture.

Bryophytes are all spore-bearing plants exhibiting a pattern of alternation of generations. With bryophytes the sexual (*gametophyte*) stage is the dominant one. The asexual (*sporophyte*) generation grows from the gametophyte stage and is partially or totally dependent upon it for its nutrition. Although bryophytes are land plants, with very few exceptions, they undoubtedly evolved from aquatic species. They still depend upon presence of a water film for their mobile sperms to swim to a waiting egg cell.

Mosses are among our most aesthetically pleasing plants, often forming extensive velvety or springy carpets over the ground. During a hike or forest stroll, nothing quite beats a spread-eagled rest break on a mossy carpet or the joy of stripping off shoes and socks to walk barefooted over such a cool, velvety rug. Unfortunately, common usage has bestowed the name moss on a number of nonmoss plants such as the tree-dwelling Spanish moss of the southland (a bromelaid); the "beard moss" of northern evergreen forests (*Usnea*, a lichen); the "reindeer moss" of the arctic (*Cladonia*, a lichen); or such "flowering mosses" as moss rose, moss pink, and the like (all are flowering plants; no true moss has flowers). Although this is unfortunate, it should not confuse any true plant observer.

The life cycles of bryophytes are observable by those who look close to the ground with a hand lens. Each begins when the single cell of a germinating spore grows into a branching, green, threadlike structure (a *protonema*). Many partitions along the thread are at an angle rather than straight across and some of its branches penetrate into the ground. A protonema may cover several inches, occasionally even several feet, of ground. In due time a bud or buds form on the protonema from which, depending on the species, a thallus or a leafy stem will grow. Branches that grew into the soil become rhizoids.

The thallus or leafy plants have only half the normal number of chromosomes. These haploid plants produce the sexual structures. Borne in a cluster of leaves or in a pocket of the thallus, the *antheridia* produce male cells that swim using two hairlike *cilia*. Eggs are borne in the base of a structure, the *archegonium*, that looks like a long-necked vase. When an egg is ripe, its archegonium exudes a sugary or proteinaceous mucilage through the neck of the vase. Male cells are attracted to the mucilage like bees to honey, and they swim to the substance, then down the tube to where one will arrive to fertilize an egg, thus creating a *zygote*.

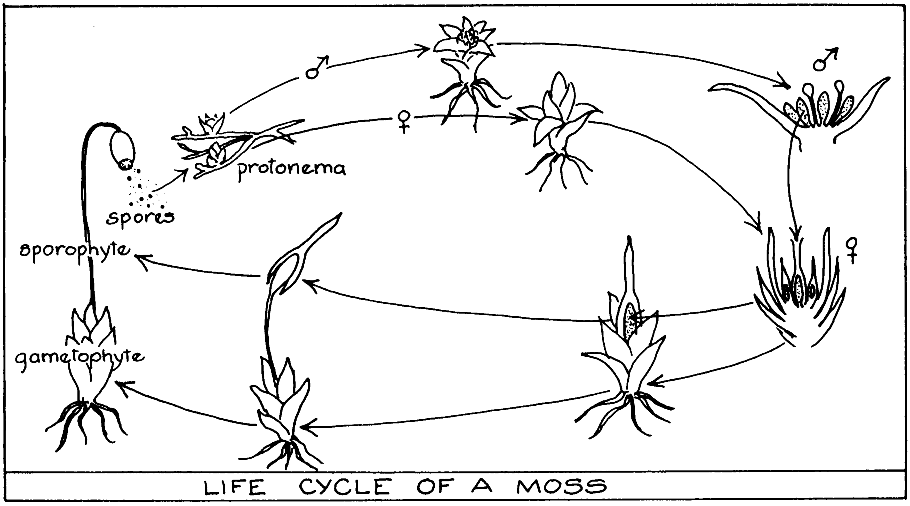


Figure 9.5

Zygotes remain in place in their archegonium and grow into rather strange diploid plants, the sporophytes. Each has a cluster of cells (*foot*) in the base of the archegonium, along with a long, flexible hairlike structure (*seta*), topped off by a capsule in which the spores form. Thus, spore cases are not organs of the basic carpetlike moss plants but are actually sporophytes riding piggyback on gametophytes. When a seta and capsule push out of an archegonium, they often wear the tip of that structure like a cap. In fact, it is from this hairy, netlike structure that haircap mosses get their name. This cap is called a *calyptera*; its shape is often a diagnostic feature for identifying certain mosses.

The thallus of a liverwort produces rather strange structures that house antheridia and archegonia. In some species these structures look like umbrellas or flat discs; in other species they are cone-shaped. It is a challenge for male cells from an antheridiaphore to reach an egg in an archegoniaphore, and with many species it is not at all clear how this is accomplished. In any case, once a zygote is formed from the fusion of the two sex cells, it divides to form a sporophyte. Its foot embeds in the tissue of the gametophyte and the seta with its capsule form as described above; eventually spores form and are released.

Not all liverworts have a thallus; many have stems and leaves. Three rows of leaves are formed, two rows side by side with the third row on the underside of the other two. These create some beautiful and distinctive patterns. Archegonia form at the tip of stems. At the point where a zygote forms and the sporophyte develops, there usually is a circlet of modified leaves (the *perianth*) surrounding the spore-bearing capsule.

A serious observer, willing to prostrate him- or herself regularly to peer through a magnifying glass, can follow much of the reproductive process and perhaps even note the subtle differences in the process among the various species.

Bryophytes, particularly liverworts, have several means of vegetative reproduction in addition to the alternation of generations. Thalli grow and branch at the tips, and the material behind the growth points slowly decays away. As decay works its way to a fork in a thallus, it may cause a separation that results in two plants. Each continues to grow on its own. You can record such development through a photo-sequence of the same area over time. As a frame of reference for relocating a spot, paint a small enamel dot near the plant you are studying; always frame the dot at the same place in your subsequent photographs allowing you better comparison of the changes.

On some thalli you may see little cups about ⅛ inch in diameter. These are called *gemmae cups,* because they hold little flat pieces of thallus tissue called *gemmae.* Splashing water, or raindrops, can wash out these gemmae, each of which is capable of growing into a new liverwort plant. Are you a good enough observer to spot some freshly established gemmae nearby?

To get a better idea of what protonemata look like so you can more effectively locate them in the wild, you may wish to grow some at home using essentially the same setup as described in the preceding section of this chapter on growing fern prothallia. The only difference is that you substitute moss spores for fern spores and you do not transplant a protonemata. Instead, you leave them on the clay pot. If you can get clear plastic-lidded boxes about 4″ × 8″ × 2″, they also make good rearing boxes for moss protonemata. Put down a ½″ layer of peat and cover it with a ½″ layer of sterilized soil. Carefully drench the soil and peat with boiling water; then drain and cool. Spores from a capsule of your moss are then scattered over the surface and the lid is put on. The box is then placed in filtered sunlight at a temperature in the mid-70° range. Spores will normally germinate in about two weeks with branched protonemata developing by about four weeks. Once you are familiar with protonemata, you should search for them in the field, and then note the places and conditions under which they are found.

There is much phenological information to be gathered about mosses and liverworts. When do sporophytes appear on the plants? How does this correlate with the temperature and rainfall patterns of your area? When do protonemata appear? How long does it take before they start sending up young leafy shoots or thalli? How long-lived are individual moss plants? How long-lived is the moss bed or colony?

There is also much to explore about bryophytes' environmental needs and their plant associates. You can set up a number of small quadrats for studying bryophytes, carefully mapping distribution of the species and noting the substrates (such as soil, rock, decaying stumps, bark, etc.) on which they occur. You also can record pH of the substrate and general moisture regimen of the microclimate, light intensities, and temperature of the microclimate where the particular bryophytes are growing. Are any of the species specific enough in their requirements that they can serve as environmental indicators?

Collect some of each moss for identification and voucher specimens, taking about two square inches of a clump. This will allow for breaking of plants when separating them and permit you to maintain some moist and some dry while trying to identify them. Wrap each specimen in a separate paper, mark it with place, date, and habitat, and assign it a collection number. Put all the specimens in a tight plastic or metal box to keep them fresh for several days. Select the best-looking, largest, greenest-looking plants, preferably those bearing spore capsules. You can assign to genus many species without the capsules present, but there are species that cannot be determined accurately without them.

To prepare voucher specimens, separate the individual plants and spread them out to dry in a warm, dry spot. Do not use pressure in the drying process and do not hasten the drying process by using excessive heat because the plants become too distorted. Dried specimens can be attached to herbarium paper with Archer's solution or placed in glassine envelopes (available from photography supply stores for filing black-and-white negatives). When necessary, you can rejuvenate a dried specimen with a brief soaking in hot water. It can subsequently be re-dried, and this process can be repeated over and over without harming the specimen for identification purposes.

If you have been successful in growing protonemata, you may want to experiment with growing each species on different substrates. Is the nature of the substrate a determining factor in whether or not a spore germinates or a protonema becomes established, producing a thallus or leafy stem?

Moisture conditions affect behavior of mosses in several ways. Notice the position of leaves in wet and dry weather. How do they differ? Examine closely ripe spore capsules with your magnifying glass. If a capsule has a calyptera, remove it gently. The capsule usually has a lid (*operculum*) which when ripe falls off, revealing a set of fleshy teeth around the opening (*peristome* from *peri* = around and *stome* = opening). During moist periods, these peristome teeth fold inward over the opening, holding in the spores. In dry times, they open outward, permitting the spores to float away. Variations in peristome teeth are often identifying characteristics for moss species. Sphagnum mosses are plants of very wet areas such as bogs and marshes, but they need dry periods to disperse their spores. Dryness builds up such tension in their spore cases that produces a distinctly audible popping sound when they finally rupture. It is a strange experience to sit in sphagnum country at the proper time and listen to these miniature "fireworks" going off about you.

Bryophytes may appear small to us but, relatively, they are giant forests to some animals. Observe the species that associate with these plants. They are invariably so small that you will need your hand lens and perhaps a binocular microscope. There is evidence that several species of small insects are particularly fond of the mucilage produced by sexual organs of these plants and that these insects play a role in transferring male gametes to eggs. There are also large numbers of strange little animals, like *tardigrades* (so-called water bears), and mites found on many species. Are they feeding on the plants? Do they have some other relationship with them, and if so, what?

The world of bryophytes is wide open for exploration. Although there are not large numbers of people studying them, there are enough to have formed an organization, *The American Bryological and Lichenology Society* (℅ Department of Botany, Southern Illinois University, Carbondale, IL 62901), which publishes *The Bryologist*, a magazine that is must reading for serious amateurs.

THE FUNGI

With the fungi, by modern classification proposals, we technically step outside the true plant kingdom. All members of Kingdom Fungi reproduce by spores and, unlike "true" plants, lack ability to create their own food through photosynthesis. Fungi secure nutrients by excreting powerful enzymes that break down complex materials around them into simpler molecules they can absorb through their cell walls and membranes and use as food. Because fungi have long been considered to be plants by laypersons and scientists alike, we include them here.

There are an estimated 100,000 or more species of fungi, many of them small and difficult to distinguish one from another except by professional scientists using sophisticated techniques. Large groups of fungi will remain outside the sphere of concern of most amateur plant observers; on the other hand, there are a number of conspicuous fungi that catch the eye of field botanists and stimulate their curiosity as well. It is these fungi that are addressed in the following remarks and suggestions for exploration. Discussion is restricted essentially to the fungus phylum *Basidiomycota* and a few members of the phylum *Ascomycota* which together encompass these organisms called mushrooms, toadstools, and bracket fungi.

Fungi are essentially filamentous creatures. Our contrary perception of them, based on seeing only their fruiting bodies, is akin to knowing flowering plants only from their flowers. Fungi are almost unique in having nucleated cells with firm cell walls that have a growing point only at one end, or apical growth. Only one group of algae and the root hairs and pollen tubes of flowering plants show such an apical growth pattern.

When a fungus spore germinates, it absorbs water and swells, and then begins to manufacture cell wall material, laying it down all around. At a few points a tube protrudes through the wall to form an elongated cell known as a *hypha*. As a hypha's tip continues to grow and as it reaches a species-appropriate length, it lays down a perforated dividing wall known as a *septa*. The perforations permit cellular cytoplasm to move throughout the hypha. Each cellular segment contains a nucleus. Each hypha thus becomes a string of cells of increasing age behind an apical cell. Hyphae branch at an apical area near a septum of one of the cells behind the apex, but never at the current apical cell. Each of these hyphal branches then begins growing apically, and so it continues as the organism begins to look more and more like a network of fibers. Such a network of hyphae, called a *primary mycelium*, is the true body of the organism. As it grows, it secretes enzymes that digest the substrate on which it is growing. The organism absorbs some of the digested material, using it to sustain the existing cells and to support further apical growth. The number of apical hyphae is largely a function of available nutrients.

Mycelia tend to fan out, enlarging in roughly circular fashion with the newest cells at the outer margins and aging cells at the center. In time, some of these older cells die and decay, leaving an organism resembling a netlike donut. Nuclei of primary hyphae are haploid—that is, they have half the full complement of chromosomes. As they expand in their environment, a hypha from one mycelium may contact a hypha from another mycelium of the appropriate species and the two hyphae fuse to form a new hypha containing two nuclei.

Dikaryotic hyphae are less likely to branch; instead, they tend to grow parallel to each other at certain points, developing into the structures we recognize as mushrooms and which botanists who are mycologists call *carpophores.* Among other things, carpophores, more complex structures than mycelia, develop cells that actually produce a fusion of their two nuclei, creating true diploid cells. These cells quickly undergo a reduction division (meiosis), creating spores with a haploid nucleus. High nutrition and a plentiful water supply are required to create carpophores with their spores.

Because fungi are not autotrophs—that is, they cannot manufacture their own food by photosynthesis—they must get nutrients directly or indirectly from those that are autotrophs. They exist either by decomposing dead plants, animals, or animal material as *saprophytes*, or as *parasites* attached to and utilizing tissue of living plants or animals. A middle ground of sorts is that of a *mutualistic relationship* whereby the fungus is functionally a parasite but the host profits about as much from the presence of the fungi as the fungi does from the host. This type of relationship exists for many fungi that live on plant roots, extracting excess carbohydrates from them while assisting the roots to absorb water and mineral nutrients. These are known as *mycorrhizal fungi*, and some flowering plants can barely survive without them.

Take careful note of the various fungal carpophores you find, being sure to note the substrate on which each is found and the plant association in which it occurs. Careful whisking away of litter, duff, and soil with a brush may allow you to uncover the delicate mycelium of a carpophore, thus revealing something of its extent and food sources. The first time you try this, it is best to choose a species that has a large carpophore because it will usually have larger hyphae that are easier to trace.

During their journey from dust to dust, trees may receive the attention of several different types of fungi. While the trees are living, mycorrhizal fungi may be attached to their roots, sending carpophores to the surface periodically. Their decaying leaves may provide an existence for other species even as the tree is being attacked by parasitic fungi that may eventually kill it. The fallen stump provides a food source for still other species. Clearly, fungi are major components of plant communities and must be sought in any exploration of plant associations and successional changes.

In open areas, it may be possible to observe and follow the development of "fairy rings" of carpophores. These are formed as a result of the phenomenon of radial growth of mycelia fostered by apical growth of hyphae. Each growing season, a mycelium continues to expand outward as long as it encounters no physical barriers and there is an adequate food supply. Carpophores tend to be produced at the newer growth of the mycelium. Rings are easily spotted among species of *Amanitas, Lepiotas, Agaricus,* and *Marasmius.* When you find a ring of mushrooms, you can mark next to each carpophore by pushing a colored golf tee into the ground; or mark the center of the ring with some sort of pin and measure, and record the distance to each carpophore from that pin. Repeat this process the following fruiting season, noting the new distances; or measure from the golf tees to the nearest carpophore to determine the amount of growth the mycelium has made in the year. You can follow development of the plant year after year, noting how it changes as it eventually dies out in spots and gradually changes form to a wavy or curved line instead of a neat circle as it grows into a nonhomogeneous environment.

By studying fungi in plant communities, you will discover that some species are found exclusively in certain communities, others clearly prefer one or two communities, and still others are indifferent and are found throughout a broad range of habitats. The same is true, of course, for other plant groups. Take pH readings where you find each species, for some are confined to acid soils, others to basic or alkaline ones. Be accurate with your readings and sample the general area along with the actual site of the mycelium because the root systems and/or the decaying leaves of some plants can significantly alter the soil conditions within the immediate sphere of their influence.

Another phenomenon to watch for is one carpophore growing upon the carpophore of a different species; there are indeed certain fungi that live upon their relatives. They provide a rather surprising sight to the uninitiated. There also are a number of species of small mushrooms that grow only on animal dung or animal carcasses. Such organic remains provide only a limited food supply, so these *coprophilous fungi* tend to be short-lived. But the presence of one species is likely to set the chemical stage for another and an observer with a strong stomach, or perhaps a poor sense of smell, can follow a rather rapid succession of species until the original object is completely decayed and its materials recycled. Fungi are, after all, critically important to the flow of materials through functioning ecosystems.

Fungi can generally be identified by characteristics of their carpophores, the presence or absence of gills or pores, the way gills are attached to the stem (*stipe*), the color of the flesh, the presence or absence of a veil on the stipe, and the color of the spores. Many good books are currently available to help identify a broad range of species; some are listed in the Bibliography.

Development and senescence of carpophores can easily be recorded with photographs and/or drawings, but preparing voucher specimens is somewhat more complex. Woody fungi, such as bracket or shelf fungi, are nearly dry when collected and pose little problem. Fleshy fungi are another story. They can be dried and stored with moth crystals to protect them, but they shrink and become very distorted. They can be better stored in liquid, either five percent formalin or alcohol. Be sure any specimens preserved in liquid have labels both on and in the jar. To aid identification, make spore prints of each species collected and keep them in your notes with appropriate reference numbers to the preserved specimens.

To prepare a spore print, carefully remove the stipe from the cap, and lay the cap, with gills or pores down, on a piece of paper. (Blue is a good color for the paper, although some mycologists prefer a half-black, half-white paper under the cap. A wad of moist paper for humidity may hasten spore discharge.) Cover the cap with a glass jar to keep out drafts and leave it for twenty-four hours. When you carefully remove the cap, a layer of spores will have been deposited on the paper. To preserve the pattern, let a spray of artists' fixative drift down onto the paper and dry.

Many of the people fascinated by fungi join the *North American*

Mycological Association (℅ The New York Botanical Garden, Bronx, NY 10458). This organization includes people interested in studying, photographing, collecting, and eating mushrooms. The parent organization can put you in touch with local mycological groups in your area.

LICHENS

Strong argument can be made for including lichens under the fungi heading, but we are treating them separately nonetheless. Although at first glance lichens appear to be autotrophs with chloroplasts, they actually are two organisms living intimately together—a heterotrophic fungus and an autotropic alga. Ever since the discovery of this partnership of these two different life forms, it has been widely proclaimed as a classic example of *symbiosis*. Originally people conceived of symbiosis as two organisms living together for mutual benefit. Today such a relationship is called *mutualism* and is thought of as only one aspect of living together along with such other aspects as *parasitism*—where one partner benefits at the expense of the other—and *commensialism*—where one partner profits but there is neither significant benefit nor expense to the other. Results of recent research still point to the lichen relationship as a symbiotic one but present it as a range of degrees of parasitism rather than mutualism. Lichenologist Mason Hale has called it "balanced parasitism." The fungal partner, which gives structural form to a lichen, is absolutely dependent on the algal partner and, in most species, cannot survive without it. On the other hand, the algal species can, and do, live without the fungus and may even grow better without it. In a number of cases, more than one algal species may be the partner of a specific lichen fungus. Our understanding of lichens is growing and changing. Although most lichen study goes on in the laboratory and involves meticulous technical procedures, there are lichen investigations to be undertaken by the field botanist.

One area of exploration is lichen growth rates. Lichens grow exceedingly slowly, probably because they contain significantly less chlorophyll than regular green plants. It has been suggested that, at least for some species, individual growth may follow a logarithmic progression rather than an arithmetic one, growth being faster as the plant matures. More extended field studies will have to be carried out to confirm or deny this. Photograph lichens, taking care to put paint or other markers on the surface where the plant is growing so you can return to the spot again and again and rephotograph exactly the same area. Mounting a millimeter ruler at one edge of the focal area where the divisions on it can be clearly seen clarifies the scale of the magnification. A problem with such a photographic method is the need to use a small f-stop such as f-16 or f-22 to get maximum depth of field while working close up. Also, measure and record the exact distance of the camera lens from the center of the spot to be pictured. Since many lichens prefer sunny, exposed locations, this may not be too difficult, but be prepared to use artificial light when necessary.

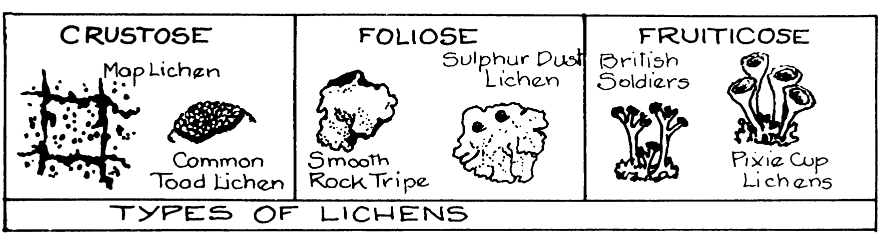
A different method involves placing a transparent plastic sheet (available from most large office or stationery supply stores) over the place where the lichens are growing and then tracing the outline of the lichens using one of the colored markers designed for preparing overhead transparencies. Mark the locations of the corners of your transparent sheet on the tree or rock substrate with paint (model airplane dope works well) so you can replace the plastic sheet exactly at a later date and retrace the outline of the plants, preferably with a different color. These overlays will show not only the amount of growth but its degree of evenness around the plant.

Do your tracings or photographs at regular intervals, perhaps every three months or once a year to begin with. Be sure to give each tracing station a code number and put it on the transparency, or on a card that will show in your photo. This will help you to match the right tracing or photo to the proper station. Use the photos or tracings to calculate the rate of growth. Eventually you may gather enough data to plot the amount of growth on a graph and determine whether it produces a logarithmic curve or an arithmetic straight line.

There are three basic lichen growth forms. One is characterized by very tiny plants that look like a scaly crust and grow primarily on rock. These *crustose* lichens are very hardy; some even live in the spaces between the rock crystals of snow-free Antarctic rocks! Crustose lichens are very difficult for an amateur to identify, and there are no amateurs' keys to these species. The second form has leaflike thalli, often in rosette patterns. These are the *foliose* (from the Latin for "leaf") lichens. The third growth form takes the shape of upright structures of diverse shapes such as goblets, minarets, and open sponges. These are the *fruticose* lichens. Fruticose species need to be recorded three-dimensionally; photographs work best.

Take careful note of where the various lichen species are found and the substrates upon which they reside. This involves gaining familiarity with rock types as well as recognizing trees by their bark. Different types

Figure 9.6



of rock are acidic or basic and the lichen species have preferences. Lichens get their minerals primarily from rainwater and dew. Which mineral they get is dependent upon what the water has passed over and dissolved. Some lichens also show preferences for certain species of trees and particular exposures and heights on them. These data should be noted so you can determine whether a species has a preferential or undifferentiated distribution pattern in the community.

Theoretically, cities provide many good places for lichens to thrive but instead of increasing with urban expansion, lichens are on the decline there. This is because of their sensitivity to air pollution, particularly sulphur dioxide (SO_2). Urban plant observers can scout metropolitan areas to map the locations of the different species of lichens. The resulting maps often reveal much about the intensity and drift patterns of air pollution in the region. By repeating the search and mapping every few years, it is possible to determine increases or reductions in local air pollution.

Much remains to be discovered about ways in which lichens disperse and colonize in the wild. Although the fungal elements of the partnership form spores, and you can usually find spore-bearing structures on the lichen thallus, no one has yet observed a developing fungal spore recruiting or capturing algae to form a functioning lichen plant. All observed lichen reproduction appears to be vegetative.

Three major lichen structures, in addition to pieces of broken primary thallus, permit vegetative reproduction: *isidia*, *soredia* (or *soralia*), and *squamules*. Isidia are very tiny, coral-like outgrowths of the upper layer of the lichen thallus. About fifteen percent of foliose lichen species possess them, and isidia are often used as clues to species identification in lichen keys. Soredia are interior structures that lead to the surface where they erupt in powdery clumps called soralia. Soralia are found in six different patterns, depending upon the species. About thirty percent of lichens have them. Their powdery texture differentiates them from isidia. The powder consists of clumps of algal cells enmeshed in some fungal hyphae. Certain lichens, like those of the common genus *Cladonia*, have a base composed of many scale-like thalli called squamules which can break off to form new individuals. This is particularly common among soil lichens that get trampled by animals.

Much remains to be observed concerning how these structures get freed from the parent plant and are transported. Look carefully at appropriate substrates with your hand lens to see if you can locate any pieces of isidia, dust from soredia, or tiny squamules. When you do, mark them and watch and record their progress; remember that patience is a virtue. So, too, is persistence.

You will, of course, want to identify the lichen species you are investigating. Fortunately, a number of kinds are quite easy to identify to the species level, while others can readily be assigned to genus. Unfortunately, a larger number can be accurately identified only through a series of chemical tests. A serious amateur can learn to do these, and the latest lichen keys explain how. However, most people prefer to send specimens to a lichen expert at a state university or a museum such as the Smithsonian Institution for identification. Be courteous; send well-prepared, well-labeled specimens, which will probably be retained for the institution's collection in return for the information. You should retain a duplicate set as your voucher specimen.

If possible, collect specimens approximately the size of the palm of your hand. Use a knife or hammer and chisel to free them from the substrate. If the specimen is dry and brittle, wet it for several minutes before collecting; this will turn it rubbery and pliable. Put each specimen in a small paper sack and label it appropriately. With lichens, do not use plastic bags for collecting as we have recommended for some other groups! These bags trap moisture and the lichens quickly discolor and/or get moldy.

Dried specimens on bark can be trimmed of excess wood and glued to 3″ × 5″ cards. Fruticose specimens should be dampened and then lightly pressed between blotting paper to reduce their bulk. Dry your specimens using circulating warm air and then place them in labeled packets or envelopes. These packets can be stapled to herbarium sheets and filed with voucher specimens of other plant groups or stored separately in file boxes.

At present, there are no organizations devoted solely to lichens, but many papers on lichens are published in *The Bryologist* and many lichen watchers belong to the American Bryological and Lichenology Society (see page 175). Even though lichens are more closely related to fungi, many people still tend to think of them as somehow allied with mosses and liverworts with which they frequently grow.

MARINE SEAWEEDS

Some people are attracted to the sea as if by a magnet, and those with a botanical bent can find a whole new world to explore there. Although a few species of flowering plants live in the shallow waters, Kingdom Plantae is essentially replaced in marine environments by various phyla of the Kingdom Protoctista. This is the realm of the red, green, and brown algae and their relatives.

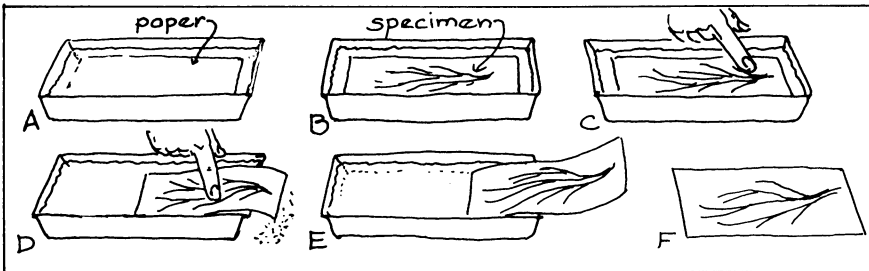
For landlubbers there must be a whole new orientation because the vegetation here is not one they have grown up with and the "plants" all seem unusually strange and confusing. Their life cycles are complex, often alternating between microscopic forms and relatively large forms—indeed, some of the giant kelps rival redwood trees for title of world's tallest plants. However, after spending time with a few appropriate field guides to acquire a mental picture of some of the more common species to be encountered, people are ready to enter the marine realm to familiarize themselves with the plants on their home ground. It does not take long to realize that in the ocean, as on land, the various species tend to grow in association with others, forming communities; they encounter grazers, parasites, and diseases as do land plants; different substrates host different species; and there are vertical zones with distinctive associations as well as horizontal expanses of a few species. Following plant activity in an area throughout a year or more reveals that, as on land, some species are perennial and others annual. In short, both major realms show similar broad patterns of living while varying widely in detail.

Many of the same techniques used for observing plants on land can be adapted to life beneath the waves and between the tides. Transect lines can be run from above the tide line out to any depth to which you are skilled enough to dive. Quadrats can be established. Underwater trails can be laid out that can become routine routes for your observations of an area. Observations are to be made on the appearance and disappearance of annual species and these correlated to environmental changes. Successional patterns of plant communities can be determined. Animal associates and their impact on the plants should be noted.

But there are some major differences that must be taken into account. Marine botanists must learn to differentiate between organisms that are autotrophic members of the Protoctista or Plantae and the heterotrophic Animalia that are sessile and loosely resemble plants in form. There are also different hazards to be encountered and dealt with, such as slippery rocks in the tidal zone; the tides themselves; tidal currents; and local organisms that may sting, bite, or perforate.

Marine botanists need essentially the same aquatic skills and equipment described in the section on freshwater plants (page 161). In general, marine habitats are more diverse than freshwater ones, and the forces of tidal surge and currents provide greater hazards. If you intend to undertake marine botanical studies, be sure your SCUBA skills are well-developed and carefully follow all safety procedures. This is particularly important when studying rocky coasts. Much can be learned about the zonation when the tide is out, but to get a good understanding of a community at work, it has to be observed underwater. It is all too easy for tidal surge or wave action to thrust an unwary diver hard against a rock. Also, as you, an inquisitive marine botanist, move into deeper water and into kelp forests, caution must be taken not to get yourself or your equipment tangled in the fronds.

When preparing voucher specimens, you will find that big, coarse algae species and the flowering plants can be dried and pressed in in the usual way but many of the smaller, more delicate and filamentous species cannot be handled directly in the same manner. They should be collected and put in plastic bags or Ziplocs and stashed in your mesh collecting bag until you return to shore. There, water is put in a flat pan such as a photographic developing tray. Herbarium paper is slid to the bottom of the pan and the specimen is then floated above it and spread out in an attractive fashion, sometimes with squirts from a medicine dropper. The paper is then carefully lifted while you hold the plant in place at a convenient point. The paper with the spread plant is slid over the pan's edge and drained. Cover both algae and paper with a sheet of gauze. Then cover all with a blotting paper and press as usual. The gelatinous material in the algae will glue them to the paper sheet but, after drying, the gauze can be gently peeled off.



HOW TO FLOAT A MARINE ALGAE OR AQUATIC PLANT SPECIMEN ONTO AN HERBARIUM SHEET.

Figure 9.7

Some people prefer to keep their voucher specimens in formalin. It does preserve them well, but is difficult and obnoxious to work with. Formalin for marine algae is suitably prepared from one part forty percent formaldehyde plus eight to ten parts of sea water. Fresh water can be used but is not preferred. Formalin is often quite acid and should be neutralized by adding one tablespoon of borax for each quart of formalin, or a pound of hexamine per gallon. For most amateur work, dried specimens are preferable to those preserved in formalin. Formalin solutions sometimes evaporate unless containers are absolutely tight; so jars should be periodically checked to ensure adequate liquid for preservation.

There are marine botany enthusiasts as members of the *American Littoral Society* (Sandy Hook, Highlands, NJ 07732). Their journal is called *Underwater Naturalist*, and people who can assist you with your interest in this field can usually be found at one of the various marine biological stations located along our coasts.

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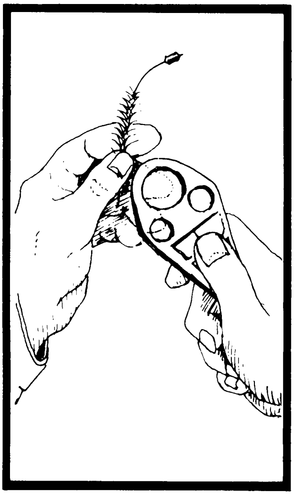


CHAPTER 10

THE PLANT OBSERVER'S TOOL KIT

A hallmark of the human species is our capacity for making and using tools to compensate for the limitations of our anatomy. Field botany, from its inception, has relied less on a complex tool kit than a great many other human activities, but it certainly does have its basic tools. The more deeply involved you become in the why's and wherefore's of plant activities, the more you have to rely on sensory-extending tools. Unfortunately, some of these are very sophisticated and expensive and, thus, beyond the reach of most amateurs.

In the sections that follow, we will discuss some of the criteria to consider in choosing commercially available equipment and also indicate a few reliable sources for those specialized items not widely available. In addition, we will describe how you can make some pieces of equipment where that seems appropriate. Much more equipment is discussed here than is needed on a regular basis; much is appropriate only to certain special studies.

Despite elaboration on equipment here, remember that considerable fun and enlightenment can be had with only the perceptual equipment you were born with and a notebook and pencil to record your observations. A good hand lens and a camera also greatly enrich your general ability to observe and record. Beyond these few items, your need for any other equipment depends upon your degree of involvement in specific types of study. Never let the tools of the trade obscure the purpose of your exploration; they should always remain means rather than ends in themselves.

Magnifiers. Among the most rewarding tools of the field botanist is a hand magnifying glass. It reveals enlarged details of plant structures that are ordinarily missed by the unaided eye, such as the architecture of flower parts, location of nectaries, various textures of a leaf's surface, and much more. A diversity of magnifiers is available, but some types are much more suitable for field work than others.

The big round "Sherlock Holmes" magnifiers are available in many local stores. While good aids to reading for some people, they are not particularly useful for plant watchers. They do have a large field of view, but they usually have magnification too small to be very useful in plant observation. With most reading glasses, magnification is only around one-and-a-half to two times actual size, but for most botanical viewing, magnification from 5× to 10× is most useful.

The larger the magnification, the smaller the field of view you have, and to achieve sharp focus the closer the magnifier must be to the object to be viewed. Thus, greater magnification creates a tradeoff problem of getting adequate light on the subject. The chart below gives a close approximation of the working distance (distance between object and lens when in focus) available for a variety of magnifications.

MAGNIFICATION (×)	WORKING DISTANCE (in.)
1.75	14
2.25	8
2.75	6
3	3.5
5	2
7	1.5
10	1
14	.75
20	.5

To use a magnifier, put it to your eye and then maneuver the object to be viewed to the proper distance from the magnifier. Some magnifiers are designed with a clear plastic base that lets in light while spacing the object correctly from the lens for paper focus. With such magnifiers the instrument is either placed on the object or the object is brought to rest on the magnifier base.

Some excellent and relatively inexpensive hand lenses have been designed for elementary schools. The best of these can be nested together to increase magnification. The lenses are plastic, however, and scratch easily. When in the field I carry one around my neck on a lanyard and use it more than my better lenses. Glass lenses are more durable and more expensive. Among botanical hand lenses, the best is considered to be the Hastings magnifier, a highly corrected, triplet lens. Judged almost as good is the optically corrected, single-lens Coddington magnifier. Many people prefer a magnifier with three fold-out lenses for differing magnification. Each lens can be used singly or can be combined for greater magnification. Only you can determine which type or brand is best for your needs and pocketbook.

Pocket Microscopes. For most field work, magnifiers are quite adequate, but some people are interested in examining stomata of leaves and other very small plant structures. For them, one of the pocket microscopes may be a useful field tool. Most of these instruments are four or five inches long and range in magnification from 20× to 60×, with 50× being the most common. Because they must be brought within less than half an inch of the object to achieve focus, adequate light is often a problem. The field of view of most of these scopes is only about two millimeters. Some of the instruments have optional reticles calibrated for accurate measurement of objects under the scope.

Standard Microscopes. A high-quality microscope costs several hundred dollars and, unless you plan to use it frequently, is not a profitable investment for an amateur. To meet most needs for a microscope, you are best advised to establish a relationship with a local high school or college biology teacher who will permit you occasional access to the school's microscopes. For most field work a stereomicroscope is usually far more useful than a simple monocular microscope. Those who want their own instrument for the field will find the affordable Bausch and Lomb high impact-resistant, plastic stereomicroscope for elementary schools light, durable, and quite adequate for most field botany purposes. It costs only a little over $100. Its field of view is less than the bigger professional stereomicroscopes but generally quite adequate.

BOTANICAL COLLECTING EQUIPMENT

Vasculum. When collecting specimens, voucher or others, you should keep them as fresh as possible until you can take time to prepare them properly for pressing and drying. A large, plastic, self-sealing bag is generally suitable for keeping specimens moist and uncrushed; I always carry a few in my day pack just to be prepared. Carry a few paper towels as well, to be moistened and put in the bag with the specimens. Leave air in the bag when you seal it to provide a cushion against accidental crushing.

More advanced collectors may want to acquire a "proper" vasculum in which to carry their plants. A vasculum is usually a lightweight metal cylinder with a hinged door and catch. The whole device is carried over the shoulder by a strap. Usually each specimen is tagged and wrapped in moist toweling or newsprint before being put in the vasculum. Such a vasculum does provide good protection to the specimens, but is an awkward, clumsy addition to the field gear. It is most valuable only to an avid, systematic collector.

Plant Press. A plant press is the key device in preparing your voucher specimens. For casual use, an old city phone book may be used as a plant press, but if you plan to prepare any number of specimens it is probably worth the $15 to $20 to purchase a good press made from high-grade materials. When selecting a commercially made plant press, remember that softwoods are more subject than hardwoods to bowing under frequent use and this results in uneven pressure on the specimens; hardwood construction resists bowing longer and survives more hard usage in the field. Brass or copper rivets and fasteners are less likely to corrode or rust than other commonly used metals. Straps should be made of tightly woven cotton webbing with positive locking, lever-controlled spring buckles, and strap-ends with a metal protector to prevent fraying. You can make your own press for only occasional use. The simplest are constructed of two pieces of half-inch plywood and two straps. Specimens and driers are placed between the plywood, and pressure comes from tightening the straps. A slightly more sophisticated homemade press is constructed from sheets of pegboard, some 1″ × 2″ strips of wood, four long, threaded bolts (each 6″ long), and four wing nuts. The 1″ × 2″ strips are screwed to the ends of the 12″ × 20″ pegboard, and holes are drilled through the wood at the four corners. The threaded bolts are placed through the four corners and capped with the wing nuts. The specimens and driers are placed between the pegboard sheets and pressure is applied by tightening the wing nuts.

Plant Press Accessories. For occasional preparation of voucher specimens, pieces of corrugated cardboard box and newspapers, or desk blotters, will suffice as ventilators and absorbers, respectively. But if you plan to press plants regularly, it is worth investing in professional-grade corrugated ventilators and driers, for they have a higher rate of absorption and ventilation than most homemade equivalents. Between uses, hang your driers on a clothesline in the sun to remove moisture and ready them for reuse. For best results, keep them stored in a dry place with a supply of moisture-absorbing crystals.

One item you should not scrimp on is your herbarium mounting paper. Most readily available papers in stationery stores are acid-based and become brittle and yellow with age. A specimen may well outlast its paper. A good herbarium mounting paper is one with a high rag content that will remain flexible and not discolor with age. If you are preparing voucher specimens with the future in mind, assure that future by using high-grade paper and Archer adhesive.

Miscellaneous. When collecting specimens from woody plants, be sure to cut them as cleanly as possible from the plant. Pruning shears are best, and a good, sharp pair is a real asset to any collecting kit. Be sure they have a lock on the handle to keep them closed when not in use.

MEASURING AND TESTING EQUIPMENT

Choosing equipment for environmental measuring and testing first involves determining the degree of accuracy your investigations demand so you can select instruments that deliver that degree of accuracy. The more accuracy required from an instrument, the greater its price is as a rule. For example, a simple test kit for determining pH of soil samples costs about $5.00, but it will only indicate the broad pH category which may be generally sufficient for a gardener's purposes. But pH is calculated on a logarithmic scale, each numerical division representing ten times more or less hydrogen ions than the adjacent number. When you need to know the pH level within each division, as you might if you are monitoring impact of acid rain or soils, you need a much more sensitive pH measuring device. Such devices are likely to cost you $200 to $300, or more.

pH Testing. The most readily available pH testing materials are those from garden supply companies for testing garden soil and from pool supply companies for testing water. These materials are convenient but often limited in the pH range they cover. Test papers to test the full range of pH are available from most biological supply houses and are the most practical for moderately accurate measurements.

The pH meters available in many garden supply stores for around $20 are useful enough for crude calculations but, although they look more sophisticated than the color-matching chemical kits and papers, they are not more accurate and their probe-elements must be carefully cleaned after each use or they become even less accurate.

With all these simple testing devices—indeed, with all pH testing—you must be alert to the pH of any water you use to mix with the sample because its own pH contaminates the sample. Use distilled or bottled spring water that has a pH as close as possible to 7.

Soil Moisture Testing. Measuring soil moisture is difficult, but today there are much more sophisticated instruments available for doing this than there were only a few years ago. In most horticultural shops you can purchase two-pronged moisture meters to test the degree of dryness of your flowerpot soil. These instruments work in open fields and woods but not as well as in containers. They do not seem to be highly reliable, although they are affordable. A better device available today is called an irrometer and it is, in effect, a "dummy root." It has a gauge attached to indicate the amount of tension a root must exert to get water. Irrometers come in a variety of lengths from 6" to 72" to test different root zones in the soil. They cost from $30 to $40 apiece but are useful in detailed studies of certain habitats.

Another type of moisture meter used for various studies consists of the meter itself, which costs between $150 and $200, along with gypsum blocks attached to wire leads. These blocks, which cost about $300 apiece, are buried at the desired root zone; you then visit them with the meter, insert the exposed lead into the meter, and take a reading. These devices are particularly valuable for longer-term area studies.

Perhaps the most convenient device is a pocket-sized pH and soil moisture meter in the $60 range. It gives soil moisture readings from 0 to 100 percent and also pH values from 3.5 to 8. Its drawback is that it only penetrates the soil about three inches, which is fine for the garden work for which it was designed but makes it less adequate for studies of deep-rooted plants.

Chemical Testing Kits. Testing water and soil for minerals, nutrients, and other chemicals is time-consuming and can become quite expensive if you do a number of tests of a variety of sites. There is virtually nothing that you can do along this line with homemade materials; you must rely on the commercial kits and their refills. The companies listed on the chart below are reliable and sell a wide range of kits and refills ranging from those for a specific test to those for doing broad spectrum studies. Some kits are designed with an individual researcher in mind, others for classes of students. Scan the catalogs carefully and buy only what you need.

COMPANY[1]	SOIL TESTING	WATER TESTING	AIR TESTING
Sudbury Soil	X		
LaMotte Chemical	X	X	X
Hach Chemical	X	X	X

Light Meters. To test the light intensity of an area, you can use standard photographic light meters. Unfortunately, with the advent of cameras with built-in light meters, independent light meters are getting more scarce and more expensive. Some meters are scaled only to show

[1]See end of this chapter for addresses.

the appropriate photographic f-stops, but these are of relatively little use in botanical field studies. You need a meter that registers directly in foot-candles. Fortunately, light meters last well and you may be able to pick up a good secondhand one at reasonable cost. Longtime photographers may have an unused one around the house that was retired when they bought a new, up-to-date camera.

Thermometers. Thermometers are among those measuring instruments where degree of desired accuracy is a particularly key factor in deciding how much of an investment to make. Another factor to consider is the degree of use they will receive; thermometers tend to break easily, and if they are likely to get plenty of field use and abuse it's worth investing in more rugged models.

Inexpensive models tend to be glass tubes clipped to a calibrated metal frame. These tubes can move slightly in the frames and thus give inaccurate readings. If you purchase several of these thermometers for cost reasons, you should lay them all out together along with a thermometer of proven accuracy. After the temperature readings have had a chance to stabilize, either shift individual tubes slightly so that all register the same reading as the master thermometer or add a taped note to each instrument indicating how many degrees plus or minus it varies from the standard so you can adjust any future readings of each to achieve a constancy among your instruments. With better thermometers, the glass tube itself is calibrated, thus reducing error.

Most thermometers are designed for use in air or water. If you want to take a soil reading, first poke a hole with a pencil or stick, then insert the thermometer; fewer thermometers get broken that way. Better still, purchase an armored soil thermometer designed for such work.

Make a protective case in which to carry your thermometers to reduce breakage and keep calibrations from wearing or chipping off. For general work, a thermometer that screws into a metal or plastic carrying case is a worthwhile investment that will save money in the long run.

When making a series of vertical temperature readings in a habitat, a temperature pole is often useful. Such a device is easy to construct. You need a stake about six to eight feet long that is either sharpened at one end to push into the ground or screwed to a square base that allows it to stand upright on the ground. Take a number of mailing tubes, as many as you want temperature readings; cut them to be a little longer than your thermometers and wrap them with aluminum foil to reflect the sun. Tie or nail the tubes to the stake at the heights you want the readings taken. Then put the stand in place and slip in the thermometers. Wait five or ten minutes and then take your readings (see Figure 10.1).

If you become interested in investigations of plants that generate their own internal heat to melt their way through frozen earth or snow, or the solar reflector powers of some white flowers, you need a more sophis-

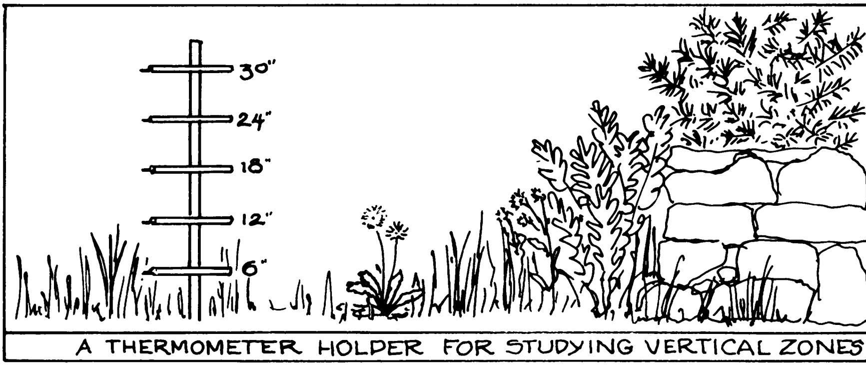
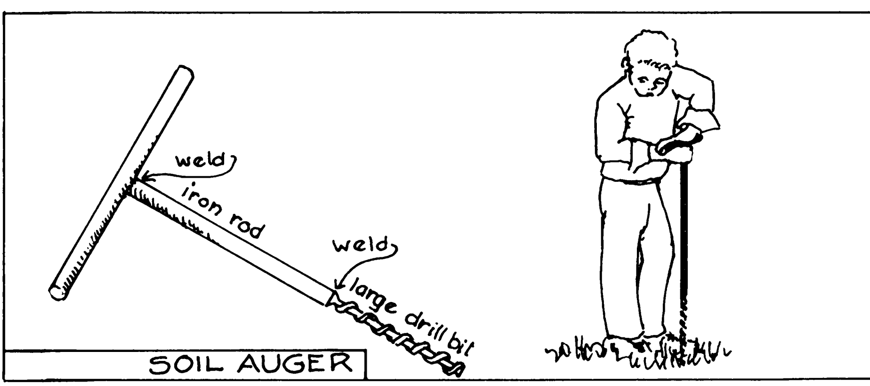


Figure 10.1

ticated thermometer that can probe small spaces. Such instruments use thermocouples to take the reading and are primarily wired to give a digital readout (although some models still use a needle and dial). They cost in the $200+ range but permit considerable flexibility and pinpoint accuracy.

Soil Auger. When testing soil, you may want to examine the soil profile or take samples at various depths for chemical testing. The tool for this is a soil auger, which is simply a large bore bit on a long handle that can be bored into the soil and will remove a core of it. They are commonly engineered to unscrew at various points for convenient storage and handling and so that the shank can receive extra lengths to go deeper. Also a special core tip can be attached that removes a solid soil plug from soils of appropriate consistency. A perfectly usable soil auger can be constructed by welding the shank of a large (1½"diameter or larger) wood auger bit to a three-foot steel rod. A foot-long piece of the same rod is welded to the other end to form a T-bar handle (see Figure 10.2).

Figure 10.2



Soil Sieves. To determine the nature of aggregates in the soil and the amount of certain categories of particles, put soil samples through a set of soil sieves. Standard-sized mesh openings are provided by commercially obtainable nesting sieves, but you can make a useful set of nesting sieves using 1″ × 3″ stock to make a set of frames to which is nailed ½″ hardware cloth, ¼″ hardware cloth, and window screening as in Figure 10.3.

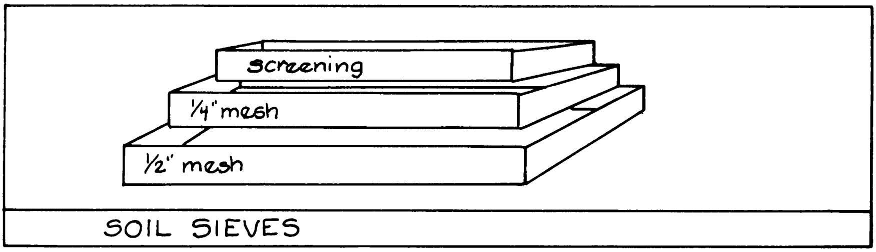


Figure 10.3

Increment Borers. Unlike soil augers, tree augers or increment borers cannot be readily improvised at home. They are precision instruments that require good care in use and maintenance. In the $70 to $150 range, they are very useful because the cores they remove reveal much about the history of a particular tree or woodland. They are well worth the investment if you enjoy discovering what has been happening in an area.

There are two major parts to the instrument: the borer and the extractor. The borer drills into the tree to create the core; the extractor frees the core and removes it from the borer for examination. Borers come in a variety of lengths ranging in essentially two-inch increments from 6″ to 20″. The most common core diameters are .157″, .169″, and .200″. It is easier to drill the smaller diameters since friction is less, but the resulting core is also a bit harder to preserve and read.

When you purchase an increment borer, two accessories are worth your consideration: a holster for ease of carrying and to help prevent loss in the field; and a sharpening kit, for a dull bit makes for hard work in securing a core. Increment borers should be cleaned with a solvent after use because tree pitch or dried sap on cutting blades and tube increases friction, making the instrument more frustrating to use.

Diameter Tape. Those people who keep track of tree size may want to carry a diameter tape with them in the field. Such tapes are available commercially, but you can make one simply enough by purchasing a roll of binding tape and marking off that tape at $3^1/_7$″ intervals. Each such interval equals one inch of tree diameter, thus the tape will let you read the tree's diameter directly. Lacking a diameter tape, you can use a regular measuring tape to get the circumference in inches and then multiply that figure by .318 to get the diameter. With today's pocket calculators, that is no real chore.

Hypsometer. To determine the approximate height of trees, use a homemade hypsometer constructed from an 11" square block of plywood to which you have attached a block of wood or dowel for a handle. On the top of your block, glue a plastic soda straw as a sighting device. One half inch up from the bottom edge, mark off a series of points one inch apart beginning at the edge that will be closest to your eye. Label the points from 9 back to 0 once, again beginning at the corner to be nearest your eye. Now take a 15" length of string, attach a small fishing sinker to one end, and tack the other end at the top edge of the board above the 0 point.

To use this device, you must know the height of your eye level. You may want to record it on the hypsometer for easy reference. Now, sight through the straw to the top of the object to be measured and note the number at the point where the string rests against the scale. Next, measure the horizontal distance from where you took the reading to the base of the object. Multiply this figure by the number indicated on the hypsometer scale, then divide the resulting figure by ten. Now add your height at eye level figure and you have the approximate height of the object. This assumes, of course, that you are standing on the same plane as the base of the object being measured (see Figure 10.4).

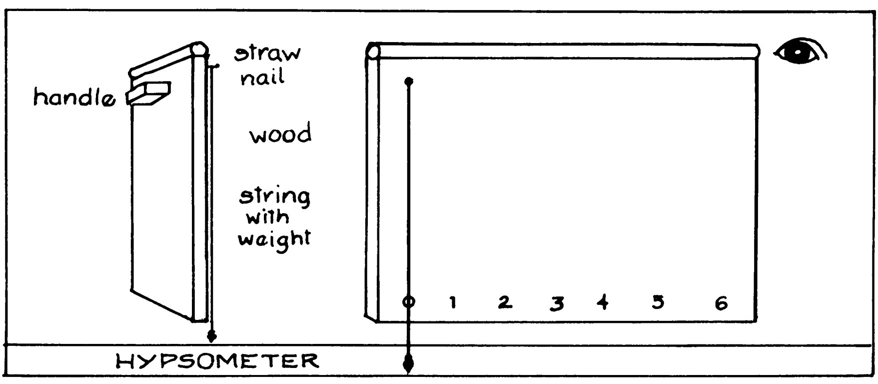


Figure 10.4

UNDERWATER GEAR

The world of diving equipment continues to expand rapidly so it would be foolish to try to give specific advice on selecting materials. Comments here are limited to general things to be looking for with particular reference to underwater botany needs.

Face Mask. One of the more important pieces of equipment for underwater studies is the face mask. Choose one with maximum visibility, peripheral as well as forward. Human faces vary extensively in shape, so you may have to examine many masks to find one that fits properly. To test a mask for fit, put it up against your face, being sure there is no hair under its edges, and breathe in through your nose to create a negative air pressure. Air pressure from outside alone should hold the mask in place for a minute or so if the fit is proper.

Today many masks come with a purge valve through which to expel water that inevitably leaks in, but most experts feel these valves are superfluous and not worth the extra money. You should learn how to clear your mask of water by lifting a lower corner slightly while exhaling air from your nose to push out the water. This is a technique that should be learned as part of your most basic snorkeling instruction.

If you normally wear eyeglasses, it is well worth having prescription lenses installed in your face mask. Although it is an added expense, it greatly enhances your underwater viewing and enriches the whole experience.

Snorkel. Extremely basic, a good snorkel is also extremely simple. It should have a soft, comfortable mouthpiece over which your lips will seal and which your teeth can grip. Beyond the J-turn, the tube should be essentially straight and unencumbered by any valves or other devices.

Fins. Swim fin designs are undergoing a variety of modifications, and fins should be purchased from someone who really knows the strengths and weaknesses of various styles for different purposes. The wrong fins can result in tired muscles and severe foot cramps that are both uncomfortable and dangerous. The trend has been to create fins that give greater power. Power fins are less important for most freshwater snorkelers and divers, but for those diving where river currents are strong or there is much tidal surge, power fins can almost be considered a necessity.

Dive Suits. For most temperate areas, a neoprene dive suit is a must for spending any extended time underwater even when the water seems quite mild for swimming. This is because heat is constantly being drained from your body while you are underwater without a suit, and hypothermia can overcome you easily. Even the thickness of the neoprene is important; a dive suit appropriate for Florida waters is not suitable for New England waters. One poor fellow I know recently learned the hard way and was only saved from extreme hypothermia and potential drowning through good fortune, not good sense. In reverse, a thick, northern dive suit can cause overheating in Caribbean waters; this is less dangerous but no less uncomfortable.

Miscellaneous. Underwater recording is best done on pads of mylar plastic. This can be purchased in sheets from well-stocked art supply houses. When putting together pads, use plastic rings for fasteners, if possible, since metal ones rust or corrode. Instead, you may want to construct the mini-slate described on page 74.

It always pays to swim with a rubber inner tube that carries a dive flag to alert others that someone is diving nearby. Extra dive bags can be hung from the tube, and a useful holding tank for specimens and extra gear is created by stuffing a plastic laundry basket in the center hole of the tube.

MAPPING EQUIPMENT

Compasses. The core of any good mapping tool kit is a good compass and your knowledge of how to use it. The range of available compasses is great and somewhat confusing. A full range of quality compasses, along with a topnotch instruction guide, is offered by Silva Systems. A reasonably inexpensive but very useful general compass, the Silva Explorer III–Type 3 is an excellent choice both for direction finding and simple map-making. A more sophisticated model, at about three times the price, is the Silva Ranger–Type 15. It has a liquid-filled transparent housing, a sapphire bearing for the needle, luminous points, and a sighting mirror. It is an excellent compass for those who spend much time afield, particularly in wild land. With a good compass, you are set to do sound basic mapping and to find your way in unfamiliar country.

Plane Table and Alidade. Professional surveying transits and related equipment are very expensive, but you can construct your own plane table and alidade for map-making at relatively little expense. A plane table can be constructed of a 24″ square of ⅜″ outdoor-grade plywood. Purchase two horizontal bubble levels to install on two adjacent edges of the table or one circular bubble level that can be anywhere on the surface. Set all levels flush with the surface of the board. Purchase at a photo supply store a threaded top plate for a tripod that can be screwed to the center of the underside of the board. The finished table can then be mounted on a standard photographic tripod. Hang a plumb bob from the center of the tripod to guide you in setting the table directly over your base points (see Figure 4.4, page 71).

An alidade, or sighting device, can be made in a variety of designs. Basically you need a sighting bar about 12″ long with two upright sights and a pin on the underside that can stick in the board and act as a pivot. The point is inserted at a base-line point on the map and the bar rotated to be sighted on each object. Once the object is sighted, a mark is made at the far end of the sighting bar and a line is drawn from the pivot point to that point. Alidades have been made from bent pieces of metal, from wooden strips with two needles or nails for sights with one driven all the way through to make the pivot, from a wood strip with a plastic straw glued on top and a needle driven through one end as a pivot, or by using a triangular drafting ruler as an alidade with a finishing nail driven in and its end filed to make a pivot point. All will work.

If you want to take only azimuth readings in the field rather than construct the actual map on-site, you can use a smaller plane table and a plastic circular drafting compass with a sighting bar. Drill two holes in the plastic circle so you can thumbtack it down firmly once you have oriented its 0° point due north. Insert the sighting bar so that it pivots in the hole in the center of the drafting compass. Sight each object. Record the degree on which the pointer rests. By setting up and recording azimuth at the two end points of the base line, you will have all the data needed to construct a scale map later (see Figure 10.5).

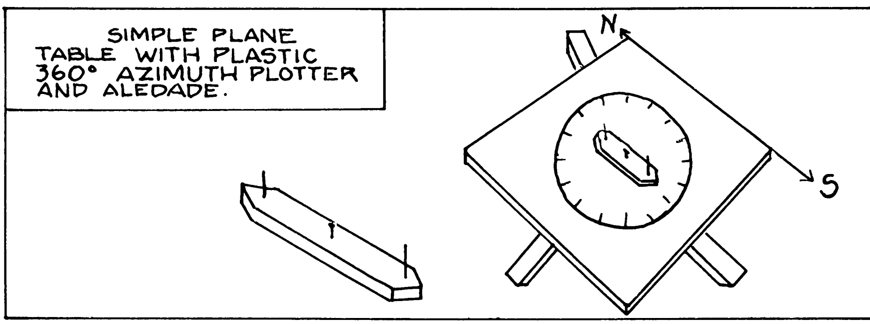
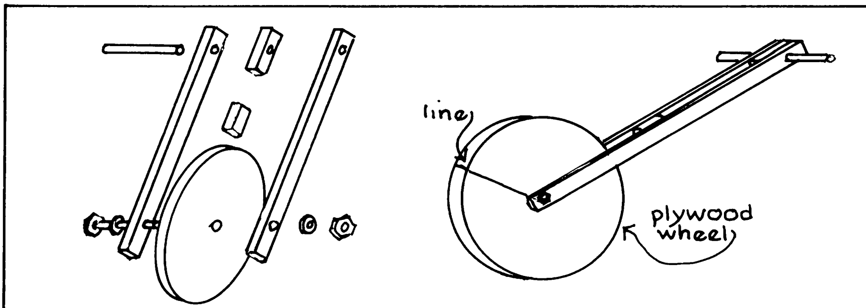


Figure 10.5

Distance Measuring Devices. For much of your work laying out transects or quadrats, you need a good measuring device. Many people like a measuring tape on a reel. These can usually be had in 50-, 100-, 165-, 200-, and 300-foot lengths and many come with English measurements on one edge and metric units on the other, offering you a choice of systems. For most botanical work, fiberglass tapes are quite accurate, durable enough, and less expensive than steel ones. For laying out transect lines and quadrat boundaries, some people prefer to use a measuring wheel. These can be purchased for $50 to $70, with accurate meters recording to the inch. However, you can construct a less sophisticated model at home if you are willing to be your own counter.

You will need about eight feet of 1″ × 3″ stock; a piece of ¾″ plywood large enough to cut the wheel from; a ¾″ dowel for a handle about 1 foot long; and a carriage bolt about 3¼″ long with nut and four washers. Cut the wood and install as per the exploded diagram and use the carriage bolt and washers as the axle for the wheel. For a wheel that will turn once in every 36", the diameter of the circle will be $11\frac{3}{8}$". For a one-foot measuring wheel, the diameter will be $3\frac{3}{4}$". Use a colored marker across one point. Each time the mark passes through the fork, the wheel will have traveled its designated distance. For greater refinement, you can put more subdivisions on the wheel in a different color. The number of subdivisions you put on the wheel is up to you and the accuracy you desire.



MEASURING WHEEL

Figure 10.6

SOURCES

A number of items for a botanical tool kit are not commonly found in stores of the average community. To help you locate some of these items, we have indicated some good catalog sources. The accompanying chart lists categories of items on the left and indicates which of the selected catalogs carry them. The chart is followed by a list of addresses of the catalog companies. Note that some have eastern and western branches and one has a Canadian subsidiary.

ITEM	GSC	CB	NASCO	ES	WNSE	LC	HC	BC
Magnifiers	•	•	•	•	•			•
Microscopes	•	•	•	•	•			•
Herbarium supplies		•	•		•			
Plant press, vasculum		•			•			
Increment borers	•	•			•	•		
Thermometers	•	•	•	•	•			
Weather equipment	•	•	•	•	•			•
Soil testing equipment	•	•	•		•	•	•	
Water testing equipment	•	•	•		•	•	•	
Air testing equipment	•	•	•		•	•	•	
Aluminum label	•	•						
Compasses	•	•			•			

	GSC	CB	NASCO	ES	WNSE	LC	HC	BC
Surveying equipment	●							
Tally counter	●	●			●			
Moisture meters	●							●
pH meters	●	●	●		●			
Grafting knives, wax	●							
Altimeters	●	●						
First-aid equipment	●	●			●			
Labels and markers	●	●						
Light meters		●						●
Garden tools								●

(BC) Brookstone Company (hard-to-find tools)
127 Vose Farm Road
Peterborough, NH 03458

(CB) Carolina Biological Supply Co.
Burlington, NC 27215

Powell Laboratories Division
Gladston, OR 97027

(ES) Edmund Scientific
101 E. Gloucester Pike
Barrington, NJ 08007

(GSC) General Supply Corporation
P.O. Box 9347
Jackson, MI 39206

(HC) Hach Chemical Company
P.O. Box 389
Loveland, CO 90537

(LC) LaMotte Chemical Products Co.
Box 329
Chestertown, MD 21620

(NASCO) Nasco
EAST: 901 Janesville Ave.
Ft. Atkinson, WI 53538

WEST: 1524 Princeton Ave.
Modesto, CA 95352

Sudbury Laboratories, Inc. (Soil Test Kits)
572 Dutton Road
Sudbury, MA 01776

(WNSE) Wards Natural Science Establishment, Inc.
P.O. Box 1712
Rochester, NY 14603

P.O. Box 1749
Monterey, CA 93940

Arbor Scientific Co., Ltd.
Box 113
Port Credit, Ontario, Canada L5G-4L6

APPENDIX

LIFE HISTORY OUTLINES

Outline may be a somewhat inappropriate term here because what is actually presented is a list of questions relevant to each of the life history stages. The answers to those questions can provide the framework for a reasonably thorough life history study of a plant species. No one set of questions provides for all groups of plants, but those several sets are presented to cover a broad range. Questions such as these clearly are not complete, but they do establish a basic quest for knowledge about the lifeways of plants. If you get deeply involved in understanding how plants live, you will formulate a number of additional questions to these lists.

FOR FLOWERING PLANT SPECIES

A. SEEDS

What do the seeds look like; what are their distinguishing features?
In what kind of structures are the seeds borne?
How many seeds per structure?
How big is the average seed?
What adaptations do the seeds have for dispersal?
What is the average time from flower fertilization to seed ripening?
Do the seeds sprout immediately or do they have a dormant period?
If the seeds have a period of dormancy, is the period determined genetically or environmentally?
What is the normal season for germination?
What are the enemies of the seeds?

What is the average distance seeds are dispersed?

How long on average do the seeds remain viable under field conditions?

B. SEEDLINGS (JUVENILE STAGE)

How does the embryo emerge from the seed? Which structures grow first and fastest?

What do the seedlings of the species look like; what are their distinguishing features?

What temperature, moisture, and light conditions are needed for sprouting?

What temperature, moisture, and light conditions are needed for successful seedling establishment?

How long after germination do the first true leaves appear?

Are young leaves significantly different in shape from mature ones? If yes, in what ways?

How old is the seedling before it develops a fibrous or corky stem?

Which develops more vigorously at first, root systems or leaves and stem?

How long between germination and flowering?

C. MATURE PLANTS—FLOWERS

How long between formation of flower bud and the opening of that flower?

Do individual flowers remain open around the clock or do they open and close on a fairly fixed time schedule?

How long does an individual blossom last intact? What is the sequence in which various flower parts are lost?

What adaptations does the plant have for either self- or cross-pollination?

During what part of the bloom period does the flower produce odor or nectar, if it does at all?

What is the blooming period for the plant? For the species? In your locale? In its geographic range? Is it a long- or short-day-length bloomer or is it neutral?

What is the average number of blossoms per plant? Does this vary widely from year to year? If so, what factors influence the amount of bloom?

What factors injure the flower parts as the fertilized flower transforms into a fruit?

What is the sequence of opening of individual blossoms in a cluster?

D. MATURE PLANT—FRUITS

How long does it take for the ovary to develop from the flower into a fruit ripe for seed dispersal?

What is the method of seed release from the fruit?

What is the average number of seeds per fruit and fruits per plant?

What adaptations does the fruit have for dispersal?

E. MATURE PLANT—VEGETATIVE REPRODUCTION

What structures of the plant are regularly utilized for vegetative reproduction?

What times of the year is vegetative reproduction most actively utilized?

Are different structures more heavily utilized at different times of the year?

What environmental conditions favor vegetative reproduction over sexual reproduction?

F. MATURE PLANT—STEMS AND LEAVES

Is there a reasonably consistent number of leaves on any given stem at the time it ceases upward growth?

Is there a relationship between leaf size and shape and environmental conditions?

What factors seem most to affect rate of growth and/or premature cessation of growth?

What kinds of buds does the stem have? Where are they located?

What is the pattern of leaf arrangement on the stem (phyllotaxy)?

Are stems primarily above, on, or below ground?

What are the enemies of the leaf?

What is the average life span of a leaf?

G. MATURE PLANT—ROOTS

How far down do the roots penetrate?

How far out do the roots spread?

Do the roots have corky bark? If yes, how extensive?

Do the roots enlarge for food storage?

What are the enemies of the roots?

Are there aerial or other adventitious roots?

Do the roots host mycorrhizal fungi?

H. GENERAL ITEMS

How long does an individual of the species live on average?

How does the species tolerate stress and/or disturbance?

With what species does it regularly associate? Does it have an obligatory relationship with any of these?

What are its soil, moisture, light, and temperature preferences?

What is the species' appearance like at various key stages throughout an annual cycle?

What is the degree and nature of variability within the species?

How is the species adapted to (or coevolved with) animal species?

What behavioral responses does it exhibit and to what stimuli?

FOR SOME FUNGI SPECIES

The observations called for below are only for things that are reasonably accessible in the field. Much of the full life history of a fungus species demands microscopic studies under laboratory conditions, thus any assemblage of data based on the questions below is of necessity only a partial life history.

A. SPORES

What are the conditions of light, temperature, humidity, and soil moisture under which spores are released?

Over what period of time are spores released? Is there a diurnal rhythm to spore release?

What is the duration of viability for spores?

Under what conditions of temperature, humidity, light, and soil moisture will spores germinate?

B. CARPOPHORES

What are the conditions of light, temperature, humidity, soil moisture, and substrate that promote formation of carpophores?

What is the relationship between the size (bulk) of the carpophore and the mycelium of the species?

What is the rate of growth of the carpophore?

What organisms feed on the carpophores?

C. MYCELIUM

What is the substrate on which the mycelium is feeding?

What is the average size of a mycelium with fruiting bodies?

What is the impact of removing fruiting bodies on subsequent fruiting?

Does the same mycelium fruit every year?

What happens to the mycelium when its substrate freezes?

What are the environmental conditions of soil temperature, soil horizon structure, soil texture, and soil moisture at the point where the mycelium grows?

Is the mycelium mycorrhizal?

D. GENERAL ITEMS

What is the habitat where the species is found?

What species of plants does it regularly associate with? Does it have an obligate relationship with any of them?

What appear to be the species' distinguishing features? What degree of variation seems to occur in the species? Does such variation appear to be related to differences in environment?

OUTDOOR MANNERS FOR THE PLANT OBSERVER

All outdoorspeople must learn to exhibit good outdoor manners if they are to be welcome afield by both Nature and other people. Increasingly, outdoor recreationists have been unmannerly and have stimulated a spate of No Trespassing signs and unfriendly attitudes among landowners. Those with poor outdoor manners stress the natural systems and the goodwill of thoughtful people. No group of outdoor users is without its slobs; let's not count you among them.

- If you pack it in, pack it out, whether on land or at sea. Leave no debris from eating, photography, and the like. Also, go the extra mile: When you find someone else's thoughtless refuse, pack it out too.
- Always seek permission to use private lands. A thank-you note never hurts either.
- If you use gates, be sure they are securely latched behind you.
- Always walk the edge of tilled fields; never walk through crops or hay.
- Do not park vehicles so they block the passage of others.
- Particularly in back country, leave a rough itinerary of your travels, along with expected time of return, with a responsible person who will then know where to look for you if you are detained.
- If you are traveling in a motorboat, reduce your speed drastically near shore so the wake will not erode the banks or shore.
- Be alert for, and honor, dive flags.
- Never tamper with lobster traps or other aquacultural devices.
- If you use trail bikes or other motorized, rough-terrain vehicles to gain access to wild lands, choose routes very carefully to minimize erosion and destruction of vegetation. Avoid all ecologically fragile lands such as dunes, tundra, and most desert sites.
- Never collect living plant material without the landowner's prior permission.
- Keep collecting to the barest minimum—take only voucher specimens and then only when identification is questionable. If there are flower pickers in your party, urge them to observe the rule of ten; that is, pick one only if you can see ten others from that point.
- Just because plants don't run away, don't be unduly noisy and frighten away wildlife that others may want to observe.
- Keep markers for quadrats and other study devices inconspicuous and unobtrusive so as not to intrude unduly on the aesthetic experiences of others.

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