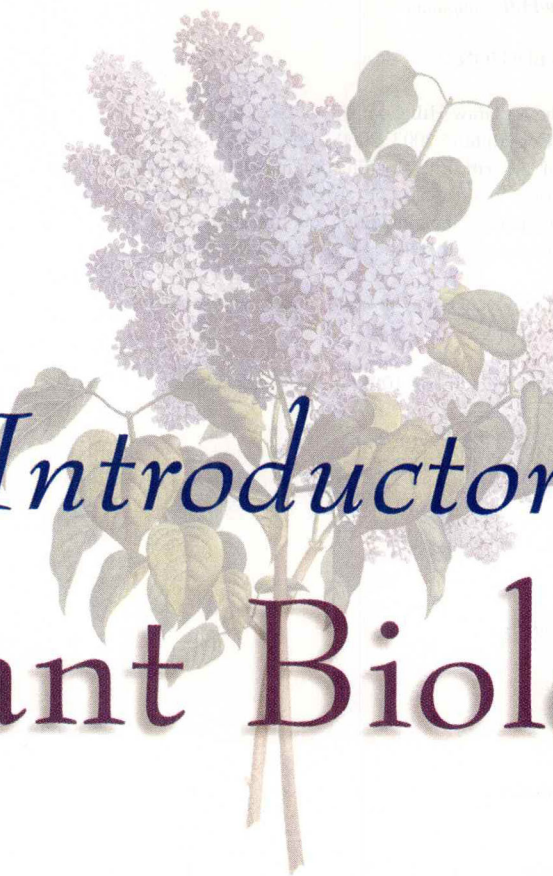




Edition Nine

S I E R N

Edition Nine



Introductory
Plant Biology

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Preface

This book is designed as an introductory text in botany. It assumes little knowledge of the sciences on the part of the student. It includes sufficient information for some shorter introductory botany courses open to both majors and nonmajors, but it is arranged so that certain sections—for example, “Soils,” “Molecular Genetics,” “Division Psilotophyta”—can be omitted without disrupting the overall continuity of the course.

Botany instructors vary greatly in their opinions concerning the depth of coverage needed for the topics of photosynthesis and respiration in a text of this type. Some feel that nonmajors, in particular, should have a brief introduction only, while others consider a more detailed discussion essential. In this text, photosynthesis and respiration are discussed at three levels. Some may find one or two levels sufficient, and others may wish their students to become familiar with the processes at all three levels.

Despite eye-catching chapter titles and headings, many texts for majors and nonmajors give relatively minor coverage of the current interests of a significant number of students. This text emphasizes current interests without giving short shrift to botanical principles. Present interests of students include topics such as global warming, ozone layer depletion, acid rain (acid deposition), genetic engineering, organic gardening, Native American and pioneer uses of plants, pollution and recycling, house plants, backyard vegetable gardens, natural dye plants, poisonous and hallucinogenic plants, and the nutritional values of edible plants. The rather perfunctory coverage or absence of such topics in many botany texts has occurred partly because botanists previously have tended to believe that some of the topics not covered in their departmental economic botany courses are more appropriately addressed in anthropology and horticulture courses. I have found, however, that both majors and nonmajors in botany, who may be initially disinterested in the subject matter of a required course, frequently become engrossed if the material is repeatedly related to such topics. Accordingly, a considerable amount of ecological and ethnobotanical material has been included with traditional botany throughout the book—without, however, resorting to excessive use of technical terms.

ORGANIZATION OF THE TEXT

A relatively conventional sequence of botanical subjects is included. Chapters 1 and 2 cover introductory and background information; Chapters 3 through 11 deal with structure and function; Chapters 12 and 13 introduce meiosis and

genetics. Chapter 14 discusses plant propagation and biotechnology; Chapter 15 introduces evolution. Chapter 16 presents a six-kingdom system of classification; Chapters 17 through 23 stress, in phylogenetic sequence, the diversity of organisms traditionally regarded as plants, and Chapter 24 deals with ethnobotanical aspects and information of general interest pertaining to sixteen major families of flowering plants. Chapters 25 and 26 constitute an overview of the vast topic of ecology, although ecological topics and applied botany are included in most of the preceding chapters as well. Some of these subjects are broached in anecdotes that introduce the chapters, while others are mentioned in the ecological review summaries and in the human and ecological relevance sections (with which most of the chapters in the latter half of the book conclude.)

AIDS TO THE READER

A chapter outline, review questions, discussion questions, learning online topics, and additional reading lists are provided for each chapter. New terms are defined as they are introduced, and those used more than once are boldfaced and included in a pronunciation glossary. The use of the scientific names throughout the body of the text has been held to a minimum, but a list of the scientific names of all organisms mentioned is given in Appendix 1. Appendix 2 deals with the biological controls and companion planting; Appendix 3 lists wild edible plants, poisonous plants, medicinal plants, hallucinogenic plants, spices, tropical fruits, and natural dye plants. Appendix 4 gives horticultural information on house plants; information on the cultivation and nutritional value of vegetables is included. Appendix 5 gives some metric equivalents.

NEW TO THIS EDITION

In addition to a complete updating of all chapters, based on over 100 reviewers' comments, the following major changes can be found in this edition:

- Chapter 3 (Cells) has been modified to include several rewritten sections, the incorporation of changes suggested by reviewers, more logical organization of topics, and many new photographs and illustrations.
- Chapter 10 (Plant Metabolism) revisions include new sections on energy transfer in the introduction and secondary metabolism, as well as several sections rewritten to simplify complex topics. Additional changes suggested by reviewers were made, a more consistent

use of terminology was introduced, several new/revised figures were added, and a summary table for ATP production in cellular respiration has been included.

- Chapter 13 (Genetics) has been completely reorganized to present molecular genetics first. The chapter now has new sections on cytogenetics, extranuclear DNA and quantitative genetics, a completely revised section on gene expression, revised and expanded content on mutation, new material on Barbara McClintock's discovery of transposable elements, a new illustration on the linkage map of pea, and a new Awareness Box on the Polymerase Chain Reaction.
- Chapter 14 (Plant Propagation and Biotechnology) has also been completely rewritten. This chapter includes a new section on crop plant evolution, including discussions of the origins of agriculture and steps in domestication; a new section on plant breeding, including breeding strategies, gene banks, protoplast fusion and transgenic plants; an updated discussion of the pros and cons of transgenic plants; over 20 new photos, and a new illustration on the origins of crop plants.
- A new feature, Learning Online, can now be found at the end of every chapter. This list of chapter-related topics mimics an identical list on the Online Learning Center, which is linked to crucial information on each of these topics. The links are updated periodically through our database to help students stay on top of their research and study responsibilities.
- Much of the appendix information has received extensive revision, particularly in the area of medicinal plants.
- Glossary definitions have been updated and over 40 new words have been added.

and staff of the Department of Biological Sciences, California State University, Chico, my many inspiring students, the Lyon Arboretum of the University of Hawaii, the editorial, production, and design staffs of McGraw-Hill Publishers, and most of all, my family. Special thanks are due the artists, Denise Robertson Devine, Janet Monelo, and Sharon Stern.

Finally, the ninth edition of *Introductory Plant Biology* would not have been possible without the considerable feedback from the following reviewers, to whom I am indebted:

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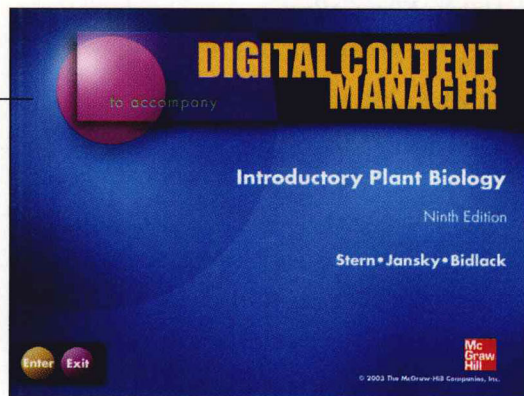
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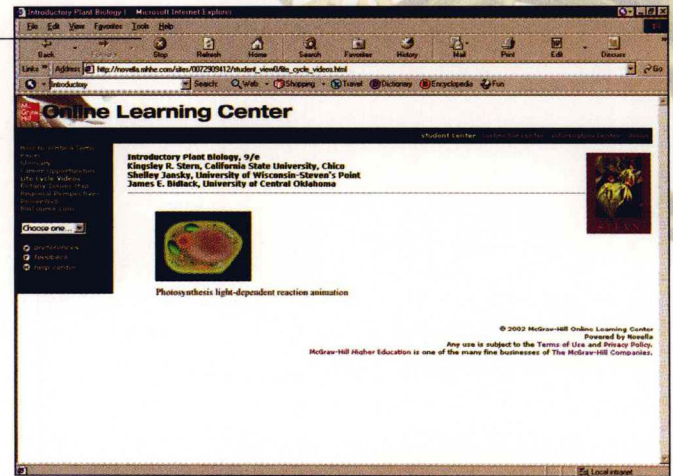
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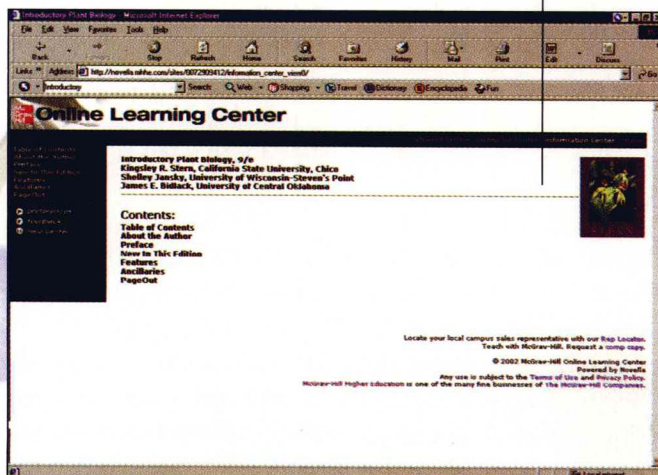
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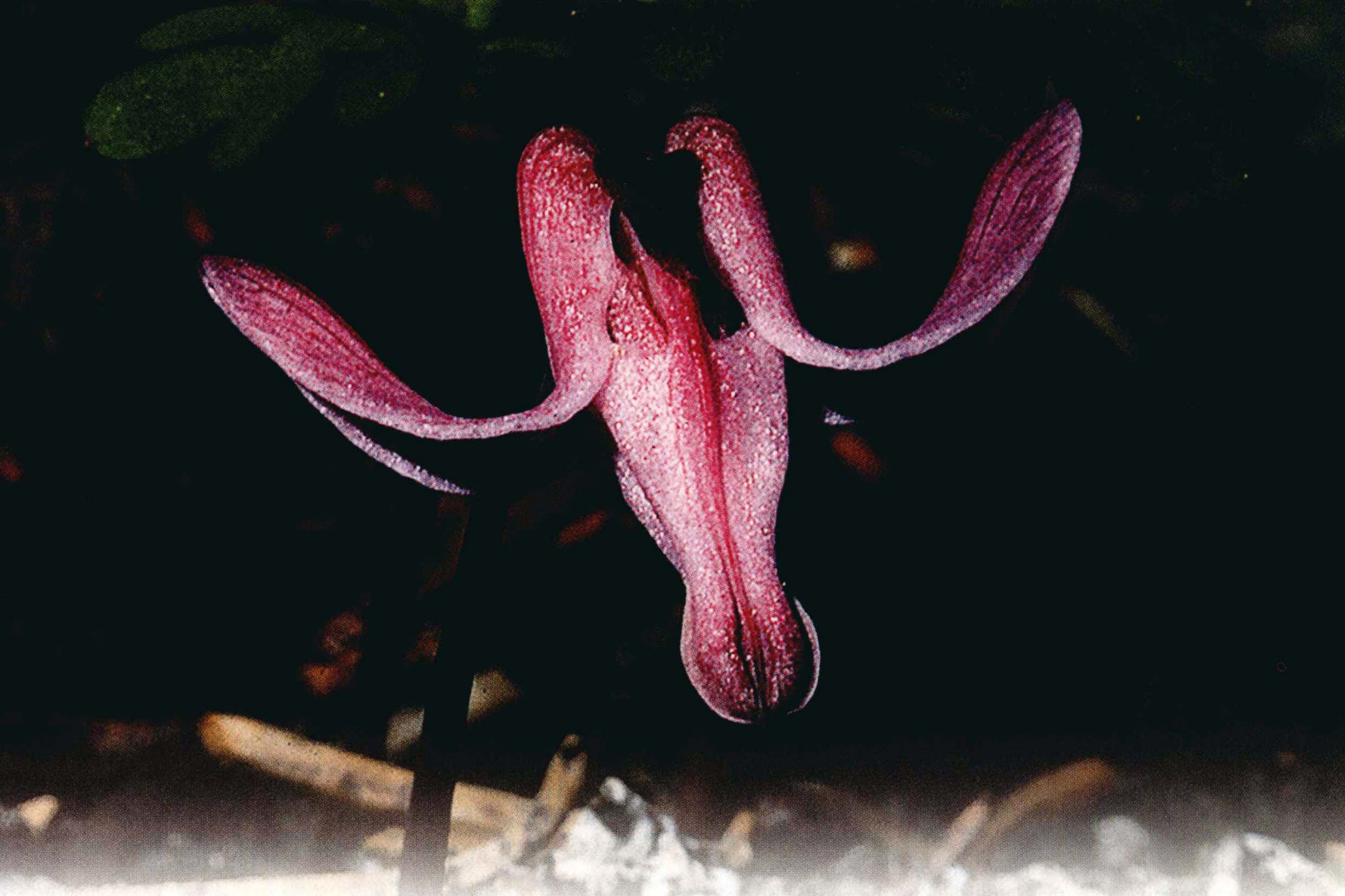
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Steershead (*Dicentra uniflora*), a diminutive relative of bleeding hearts, native to the mountains of the western United States and Canada.

What Is Plant Biology?

Chapter Outline

The Relationship of Humans to
Their Environment
Human and Animal Dependence
on Plants

Botany as a Science
Hypotheses
Microscopes
Diversification of Plant Study
Summary

1

Overview

This chapter introduces you to botany: what it is, how it developed, how it relates to our everyday lives, and what its potential is for the future. The discussion includes a brief introduction to some common questions about plants and their functions, an examination of the scientific method, and a brief look at botany after the invention of the microscope. It concludes with a brief survey of the major disciplines within the field of botany.

Some Learning Goals

1. Understand how humans have impacted their environment, particularly during the past century.
2. Explain briefly what the scientific method is and what hypotheses are.
3. Explain how and why all life is dependent on green organisms.
4. Be able to indicate briefly the particular aspects of botany with which each of the major botanical disciplines is concerned.

Upas trees (*Antiaris toxicaria*), which are relatives of the common fig tree, flourish in the jungles of Java and some of the neighboring islands. There are legendary tales of people having died while sleeping beneath these tall trees or even from merely being downwind from them. Whether or not there is truth to the stories, we do know that upas trees produce a deadly sap, which for centuries has been used to tip poison arrows used in hunting. On the other hand, the cow trees of Venezuela and Brazil (e.g., *Brosimum utile*; *Mimusops huberi*) produce a sweet, nutritive latex that is relished by the natives of the region. Still other plants, such as opium poppies, produce latex that contains narcotic and medicinal drugs (Fig. 1.1). Why do plants such as upas trees produce poisons, while parts of so many other plants are perfectly edible, and some produce spices, medicines, and a myriad of products useful to humans?

In late 1997, a fast-food chain began airing a television commercial that showed a flower of a large potted plant gulping down a steak sandwich. Most of us have seen at least pictures of Venus's flytraps and other small plants that do, indeed, trap insects and other small animals, but are there larger carnivorous plants capable of devouring big sandwiches or animals somewhere in remote tropical jungles?

Occasionally we hear or read of experiments—often associated with school science fairs—that suggest plants respond in some positive way to good music or soothing talk; conversely, some plants are said to grow poorly when exposed to loud rock music or to being harshly yelled at. Do plants really respond to their surroundings, and, if so, how and to what extent?

When a botanist friend of mine invited me to his office to see a 20-gallon glass fish tank he had on his desk, I expected to find a collection of house plants or tropical fish. Instead, I saw what at first appeared to be several small, erect sticks that had been suspended in midair with large rubber bands; there were also beakers of water in the corners. When I got closer, I could see that the “sticks” were cuttings (segments) of poplar twigs that were producing

roots at one end and new shoots at the other end. The roots, however, were growing *down* from the tops of the cuttings, and the shoots were growing *upward* from the bottoms (Fig. 1.2). My friend had originally suspended the cuttings upside down, and new roots and shoots were being produced in the humid, lighted surroundings of the fish tank—regardless of the orientation of the cuttings. If I'd seen such bizarre plants in a movie, I might have assumed that the fiction writers had imagined something that didn't exist. There right in front of me, however, were such plants, and they were real! When

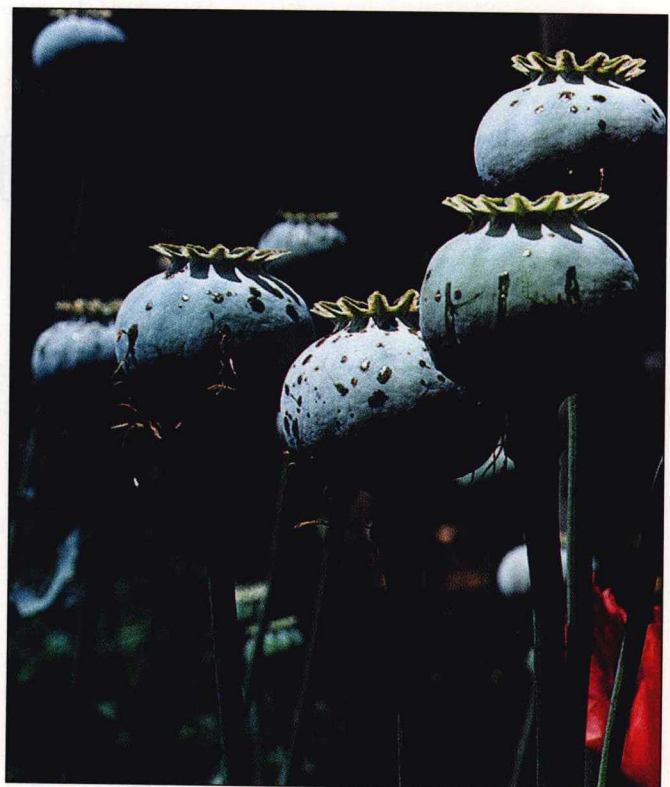


Figure 1.1 Immature opium poppy capsules that were gashed with a razor blade. Note the opium-containing latex oozing from the gashes.

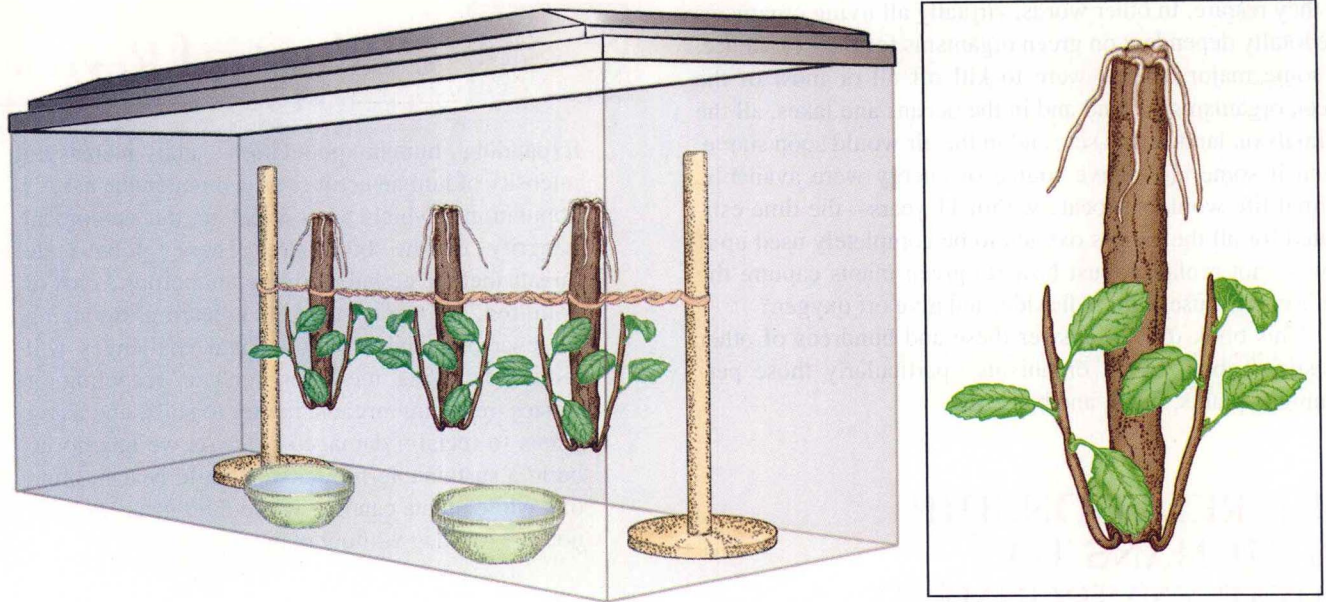


Figure 1.2 Cuttings (segments) of twigs that were suspended upside down in a humid, lighted glass tank. New roots are growing down from the top ends, and new shoots are growing up from the bottom.

cuttings are separated from the parent plant how do they “know” which end is up, and why would the roots and shoots grow the way they did?

California’s huge coastal redwoods and Tasmania’s giant gum trees can grow to heights of 60 to 90 or more meters (200 to 300 or more feet). When these giant trees are cut down, there is no evidence of pumps of any kind within them. How then does water get from the roots below ground to the tops of these and other trees? How does food manufactured in the leaves get down to the roots (Fig. 1.3)?

Our tropical rain forests, which occupy about 5% of the earth’s surface, are disappearing at the rate of several acres a minute as the plant life is cleared for agriculture, wood supplies (primarily for fuel), cattle ranching, and for other human activities such as mining for gold. Is the dwindling extent of our rain forests, which are home to 50% of all the species of living organisms, cause for alarm? Or will the same plant and animal life simply return if the human activities cease?

There is currently much debate about global warming and the potential effects on life as we know it. Are those who proclaim that global warming will eventually have disastrous effects on modern civilization and living organisms simply exaggerating, or is there a scientific basis for the claims? What about the many forms of pollution that exist? Will we be able to either ignore or overcome the effects?

Plant life constitutes more than 98% of the total biomass (collective dry weight of living organisms) of the earth. Plants and other green organisms have the exclusive capacity to produce oxygen while converting the sun’s energy into forms vital to the existence of both plant and animal life. At the same time, plants remove the large amounts of carbon dioxide given off by all living organisms



Figure 1.3 California coastal redwoods (*Sequoia sempervirens*). Coastal redwoods may grow for thousands of years and some may reach heights of nearly 100 meters (330 feet).

as they respire. In other words, virtually all living organisms are totally dependent on green organisms for their existence. If some major disease were to kill off all or most of the green organisms on land and in the oceans and lakes, all the animals on land, in the sea, and in the air would soon starve. Even if some alternative source of energy were available, animal life would suffocate within 11 years—the time estimated for all the earth's oxygen to be completely used up if it were not replaced. Just how do green plants capture the sun's energy, use carbon dioxide, and give off oxygen?

This book tries to answer these and hundreds of other questions about living organisms—particularly those pertaining to plants, fungi, and bacteria.

THE RELATIONSHIP OF HUMANS TO THEIR ENVIRONMENT

It has been estimated that the total human population of the world was less than 20 million in 6000 B.C. During the next 7,750 years, it rose to 500 million; by 1850, it had doubled to 1 billion; and 70 years later, it had doubled again to 2 billion. The 4.48-billion mark was reached in 1980, and within 5 years, it had grown to 4.89 billion. It is presently increasing by nearly 100 million annually, and estimates for the year 2000 are 6.25 billion. The earth remains constant in size, but humans obviously have occupied a great deal more of it over the past few centuries or at least have greatly increased in density of population.

In feeding, clothing, and housing ourselves, we have had a major impact on our environment. We have drained wetlands and cleared natural vegetation from vast areas of land. California, for example, now has less than 6% of the wetland it had 100 years ago. We have dumped wastes and other pollutants into rivers, oceans, lakes; we have added pollutants to the atmosphere; and we have killed pests and plant disease organisms with poisons. These poisons have also killed natural predators and other useful organisms and, in general, have thoroughly disrupted the delicate balance of nature that existed before humans began degrading their natural surroundings.

If we are to survive on this planet beyond the 21st century, there is little question that humans have to stop increasing in numbers, and the many unwise agricultural and industrial practices that have accompanied the mushrooming of human populations must be replaced with practices more in tune with restoring some ecological balance. Agricultural practices of the future will have to include the return of organic material to the soil after each harvest, instead of adding only inorganic fertilizers. Harvesting of timber and other crops will have to be done in a manner that prevents topsoil erosion, and the practice of clearing brush with chemicals will have to be abolished. Industrial pollutants will have to be rendered harmless and recycled whenever possible.



Ecological Review

Expanding human populations and increasing intensity of human activity now threaten the earth's populations, which are critical to the ecological integrity of the biosphere. These global-scale threats include global warming, numerous forms of pollution, and widespread land clearing. Reducing or reversing these environmental challenges will require applying measures such as recycling of wastes, returning organic matter to soils, and using plants to reclaim damaged land. As we attempt to build a sustainable future, we should bear in mind that while plants can live without humans, we cannot live for long without plants.

Many products that now are still largely discarded (e.g., garbage, paper products, glass, metal cans) will also have to be recycled on a much larger scale. Biological controls (discussed in Appendix 2) will have to replace the use of poisonous controls whenever possible. Water and energy conservation will have to be universally practiced, and rare plant species, with their largely unknown gene potential for future crop plants, will need to be saved from extinction by preservation of their habitats and by other means. The general public will have to be made even more aware of the urgency for wise land management and conservation—which will be especially needed when pressures are exerted by influential forces promoting unwise measures in the name of “progress”—before additional large segments of our natural resources are irreparably damaged or lost forever. Alternatives appear to be nothing less than death from starvation, respiratory diseases, poisoning of our food and drink, and other catastrophic events that could ensure the premature demise of large segments of the world's population.

In recent years, scientists, and increasingly the general public, have become alarmed about the effects of human carelessness on our environment. It wasn't until the 1980s, however, that damage to forests and lakes caused by acid rain, the “greenhouse effect,” contamination of ground water by nitrates and pesticides, reduction of ozone shield, major global climatic changes, loss of biodiversity in general, and loss of tropical rain forests in particular gained widespread publicity.

Human and Animal Dependence on Plants

Our dependence on green organisms to produce the oxygen in the air we breathe and to remove the carbon dioxide we give off doesn't stop there. Plants are also the sources of