edition eight

# Stern

# Introductory Plant Biology

edition eight

Kingsley R. Stern

California State University~Chico

Boston Burr Ridge, Il Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Lisbon London Madrid
Mexico City Milan New Delhi Seoul Singapore Sydney Taipei Toronto

*McGraw-Hill Higher Education*

*A Division of The* **McGraw-Hill** *Companies*

INTRODUCTORY PLANT BIOLOGY, EIGHTH EDITION



1 2 3 4 5 6 7 8 9 0 QPD/QPD 0 9 8 7 6 5 4 3 2 1 0

ISBN 0–07–012205–9

Vice president and editorial director: *Kevin T. Kane*
Publisher: *Michael D. Lange*
Sponsoring editor: *Margaret J. Kemp*
Senior developmental editor: *Kathleen R. Lowenberg*
Marketing manager: *Michelle Watnick*
Senior project manager: *Kay J. Brimeyer*
Production supervisor: *Sandy Ludovissy*
Coordinator of freelance design: *Michelle D. Whitaker*
Senior photo research coordinator: *Lori Hancock*
Senior supplement coordinator: *Candy M. Kuster*
Compositor: *Precision Graphics*
Typeface: *10/12 Times Roman*
Printer: *Quebecor Printing Book Group/Dubuque, IA*

Freelance cover designer: *Jamie O'Neal*
Front cover image: *©Darrell Gulin/Tony Stone Images*
Back cover image: *©SuperStock*

**Library of Congress Cataloging-in-Publication Data**

Stern, Kingsley Rowland.
Indtroductory plant biology/Kingsley R. Stern. — 8th ed.
p. cm.
ISBN 0–07–012205–9
1. Botany I. Title
QK47.S836 2000
580—dc21 99-14461
CIP

INTERNATIONAL EDITION ISBN 0–07–117791–4


www.mhhe.com

To the memory of Franklin Charles Lane
1928–1971

*Botanist, Teacher, Friend*

# 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 subjects 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 are more appropriately covered 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 materials 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 five-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

Review questions, discussion questions, 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, hallucinogenic plants, spices, and natural dye plants. Appendix 4 discusses pruning and grafting and 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

The introduction to this subject matter has been completely revised, and several new or revised illustrations have been added. Information throughout the text has been updated or augmented, particularly in the areas of basic chemistry and physics; molecular genetics; genetic engineering; evolution; and the Appendix 3 information on medicinal plants. Some of the boxed inserts about interesting recent specific events and discoveries have been revised or changed, all except one having been contributed by Dr. Daniel Scheirer. Highlighted summaries of the ecological aspects of each chapter, prepared by Dr. Manuel Molles, have been added. The contributions of Dr. Scheirer and Dr. Molles are gratefully acknowledged.

# Additional Aids

## Instructor's Manual

The Instructor's Manual available with *Introductory Plant Biology* offers a variety of course schedules while providing overviews, goals, suggested answers, film sources, and examination questions for each text chapter.

## Laboratory Manual

The Laboratory Manual that accompanies *Introductory Plant Biology* has been revised throughout, particularly in some of the exercise introductions and illustrations. It is written for the student entering the study of botany for the first time. The exercises utilize plants to introduce biological principles and the scientific method. The exercises are written to allow for maximum flexibility in sequencing.

## Student Study Guide

A Student Study Guide, prepared by Daniel Scheirer, Northeastern University, is available. The study guide provides students an opportunity to study at their own pace. It contains learning objectives, chapter outlines, key terms/concepts (referenced to the text), and a set of objective questions for each chapter.

## Transparencies

The transparency package includes 100 two- and four-color acetate overlays that are available free to adopters. These figures represent key illustrations from the text that merit extra visual review and discussion.

## Visual Resource Library and Web Sites

A Botany VRL (Visual Resource Library) and a comprehensive web site have been added. The web site will offer an online study guide and an interactive NetQuest (*Exploring Botany*). Other web sites will support specific chapters and will provide practice quizzes, sample syllabi, and other sources.

## TestPak

*Computerized Testing Software*
This user-friendly computerized software is available at no charge to instructors for testing and grading. It can be ordered in either the IBM (DOS or Windows) or MacIntosh version.

# Acknowledgments

The contributions of many individuals to the development of this book are gratefully acknowledged. Critical reviewers, who provided many valuable suggestions for improving and updating the text, include:

# Reviewers of the Eighth Edition

Ligia Arango, *Stone Child College*
Joseph Arditti, *University of California, Irvine*
Tasneem K. Ashraf, *Cochise College, Sierra Vista*
Ralph A. Backhaus, *Arizona State University*
Sharon Bartholomew-Began, *West Chester University*
Dorthea Bedigian
Patricia Bedinger, *Colorado State University*
Robert A. Bell, *University of Wisconsin, Stevens Point*
James Enderby Bidlack, *University of Central Oklahoma*
Richard R. Bounds, *Mount Olive College*
Michelle Briggs, *Lycoming College*
George M. Brooks, *Ohio University*
William J. Campbell, *Louisiana Tech University*
Ajoy G. Chakrabarti, *South Carolina State University*
James A. Christian, *Louisiana Technical University*
Richard Churchill, *Southern Maine Technical College*
Jerry A. Clonts, *Anderson College*
David B. Czarnecki, *Loras College*
John Cruzan, *Geneva College*
Stephen S. Daggett, *Avila College*
Roy Darville, *East Texas Baptist University*
Bill D. Davis, *Rutgers University*
Jerry D. Davis, *University of Wisconsin, LaCrosse*
John W. Davis, *Benedictine College*
Ben L. Dolbeare, *Lincoln Land Community College*
Patricia M. Dooris, *Saint Leo College*
Tom Dudley, *Angelina College*
Robert Ediger, *California State University, Chico*
David G. Fisher, *Maharishi University of Management*
Stephen W. Fuller, *Mary Washington College*
Sibdas Ghosh, *University of Wisconsin, Whitewater*
Richard Glick, *Winston-Salem State University*
Scott A. Gordon, *University of Southern Illinois*
Steve Greenwald, *Gordon College*
Mark F. Hammer, *Wayne State College*
Laszlo Hanzely, *Nothern Illinois University*
Joyce Phillips Hardy, *Chadron State College*
David Hartsell, *Phillips Community College*
David L. Herrin, *University of Texas, Austin*
Elisabeth A. Hooper, *Truman State University*
Vernon R. Huebschwerlen, *Reedley Community College*
William A. Jensen, *Ohio State University, Columbus*
Toney Keeney, *Southwest Texas State*
Helen G. Kiss, *Miami University*
Martin LaBar, *Southern Wesleyan University*
Vic Landrum, *Washburn University*
James M. Lang, *Greenville College*
Donald C. Leynaud, *Wabash Valley College*
Michael H. Marcovitz, *Midland Lutheran College*
Bernard Marcus, *Genesee Community College*
Dave Martin, *Centralia College*
Margaret Massey, *Mississippi University for Women*
William Mathena, *Kaskaskia College*

Timothy Metz, *Campbell University*
David H. Miller, *Oberlin College*
Subhash C. Minocha, *University of New Hampshire*
L. Maynard Moe, *California State University, Bakersfield*
Joanna H. Norris, *University of Rhode Island*
Jeanette C. Oliver, *Flathead Valley Community College*
A.D. Owings, *Southeastern Louisiana University*
Julie M. Palmer, *University of Texas, Austin*
Richard A. Palmer, *Fresno City College*
Carolyn Peters, *Spoon River College*
Jerry L. Pickering, *Indiana University of Pennsylvania*
Wayne S. Pierce, *California State University, Stanislaus*
Mary Ann Polasek, *Cardinal Stritch University*
Margene M. Ranieri, *Bob Jones University*
Linda Mary Reeves, *San Juan College*
Dennis F. Ringling, *Pennsylvania College of Technology*
Darryl Ritter, *Okalossa-Walton Community College*
Manfred Ruddat, *University of Chicago*
Robert M. Rupp, *Ohio State University Agricultural Technical Inst.*
Dennis J. Russell, *University of Alaska Southeast*
Connie Rye, *Bevill State Community College*
C. L. Sagers, *University of Arkansas*
F. Lee St. John, *Ohio State University, Newark*
A. Edwards Salgado, *Christian Brothers University*
Thomas Sasek, *Northeast Louisiana University*
Michael A. Savka, *University of West Florida*
Renee M. Schloupt, *Delaware Valley College*
Bruce S. Serlin, *DePauw University*
Wilbur J. Settle, *State University of New York, Oneonta*
Richard H. Shippee, *Vincennes University*
Shaukat M. Siddiqi, *Virginia State University*
Dilbagh Singh, *Blackburn College*
James Smith, *Boise State University*
Joanna M.K. Smith
Steven Smith, *University of Arizona*
Spencer S. Stober, *Alvernia College*
Marshall D. Sundberg, *Emporia State University*
Eric Sundell, *University of Arkansas, Monticello*
Max R. Terman, *Tabor College*
Stephen L. Timme, *Pittsburgh State University*
Leslie R. Towill, *Arizona State University*
Jun Tsuji, *Siena Heights College*
Gordon E. Uno, *University of Oklahoma*
Delmar Vander Zee, *Dordt College*
Leon Walker, *University of Findlay*
Betty J. Washington, *Albany State University*
Edgar E. Webber, *Keuka College*
Ingelia White, *Windward Community College*
Marvin Williams, *University of Nebraska, Kearney*
James A. Winsor, *The Pennsylvania State University*
Clarence C. Wolfe, *Northern Virginia Community College*
Richard J. Wright, *Valencia Community College*
Todd Christian Yetter, *Cumberland College*
Brenda Young, *Daemen College*
Rebecca Zamora, *South Plains College*

Additional persons who read parts of the manuscripts of various editions and made many helpful criticisms and suggestions include Robert I. Ediger, Richard S. Demaree, Jr., Robert B. McNairn, Donald T. Kowalski, Larry Hanne, Patricia Parker, and Robert A. Schlising. Others whose encouragement and contributions are deeply appreciated include Timothy Devine, W. T. Stearn, Lorraine Wiley, Isabella A. Abbott, Paul C. Silva, Donald E. Brink, Jr., William F. Derr, Beverly Marcum, Robert McNulty, the faculty 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.

**Kingsley R. Stern**
Chico, California

# Brief Contents

# Table of Contents

## 14 *Plant Propagation and Biotechnology* 237



## 15 *Evolution* 255



## 16 *Plant Names and Classification* 267



## 17 *Kingdom Monera and Viruses* 279



## 18 *Kingdom Protista* *304*

## Chapter Outline



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

# What is Plant Biology?

# 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.

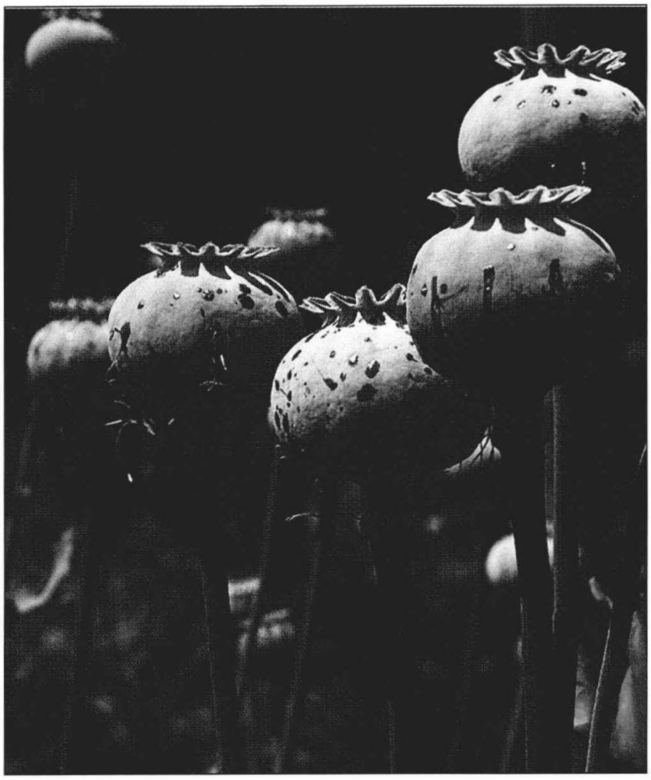

FIGURE 1.1 Immature opium poppy capsules that were gashed with a razor blade. Note the opium-containing latex oozing from the gashes.

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 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)?

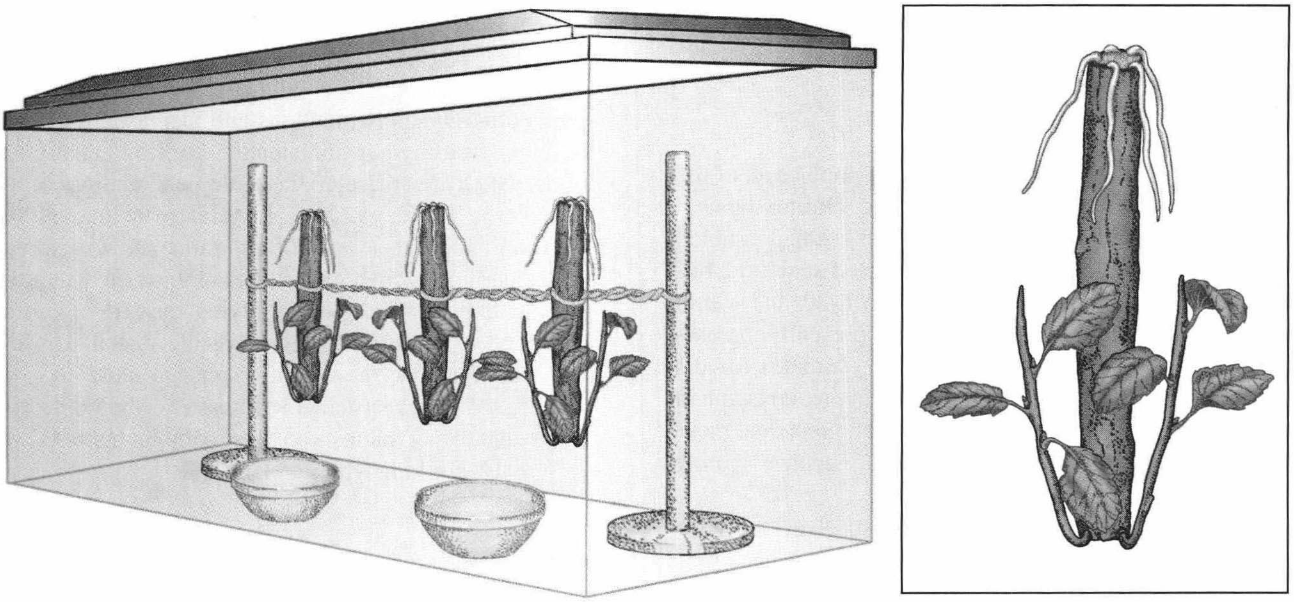

FIGURE 1.2 Cuttings (segments) of poplar twigs that were suspended upside down in a humid, lighted glass tank. New roots are growing down from the top ends and new shoots are growing up from the bottom.

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).

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 to mine for gold and for other human activities. 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 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, and 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.

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.

### *Ecological Review*

Expanding human populations and increasing intensity of human activity now threaten the earth's plant 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 reguire 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. ■

## 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 products that are so much a part of human society that we largely take them for granted. We know, of course, that rice, corn, potatoes, and other vegetables are plants (Fig. 1.4); but all foods, including meat, fish, poultry, eggs, cheese, and milk, to mention just a few, owe their existence to plants. Condiments such as spices (Fig. 1.5) and luxuries such as perfumes are produced by plants, as are some dyes, adhesives, digestible surgical stitching fiber, food stabilizers, beverages (Fig. 1.6), and emulsifiers.

Our houses are constructed with lumber from trees, which also furnish the cellulose for paper, cardboard, and synthetic fibers. Some of our clothing, camping equipment, bedding, draperies, and other textile goods are made from fibers of many different plant families (Fig. 1.7). Coal is fossilized plant material, and oil probably came from microscopic green organisms or animals that either directly or indirectly were plant consumers. All medicines and drugs at one time came from plants, fungi, or bacteria, and many important ones, including most of the antibiotics, still do (Fig. 1.8). Microscopic organisms play a vital role in recycling both plant and