



**STERN**

**INTRODUCTORY  
PLANT BIOLOGY**

Tenth  
Edition

McGraw-Hill International Edition



# *Introductory*



# Plant Biology

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*with Contributions by*

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INTRODUCTORY PLANT BIOLOGY, TENTH EDITION

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# Preface

Recently a botanical colleague of mine was contacted by the police to see if she could help them solve a crime. A young woman had disappeared and there was reason to suspect foul play involving a male acquaintance of hers. The police had found tiny bits of plant material in the man's car, and asked if my colleague could identify them. She was able not only to identify two or three different plants, but also knew where that particular association of plants grew. She took the police to the area, and within 20 minutes they found the woman's body. The man was subsequently charged with and convicted of murder.

The field of forensics sometimes uses microscopic bits of plant material to help solve crimes, but in addition to forensics, botany today plays a special role in many interests of both major and nonmajor students. For example, in this text topics such as global warming, ozone layer depletion, acid rain, genetic engineering, organic gardening, Native American and pioneer uses of plants, pollution and recycling, houseplants, backyard vegetable gardening, natural dye plants, poisonous and hallucinogenic plants, nutritional values of edible plants, and many other topics are discussed. To intelligently pursue such topics one needs to understand how plants are constructed, and how they function. To this end the text assumes little prior knowledge of the sciences on the part of the student, but covers basic botany, without excessively resorting to technical terms. The coverage, however, includes sufficient depth to prepare students to go farther in the field, should they choose to do so.

The text is arranged so that certain sections can be omitted in shorter courses. Such sections may include topics such as, "Soils," "Molecular Genetics," Phylum Psilophyta," etc. Because botany instructors vary greatly in their opinions about the depth of coverage needed for photosynthesis and respiration in an introductory botany course open to both majors and nonmajors, the topics are presented at three different levels. Some instructors will find one or two levels sufficient, whereas others will want to include all three.

I have found that both majors in botany and nonmajors who may initially be disinterested in the subject matter of a required course, frequently become engrossed if the material is related repeatedly to their popular interests. This is reflected, as intimated above, in the considerable amount of ecology and ethnobotany included with traditional botany throughout the book.

*"I am currently using Stern, and I believe it is far and away the best Introductory Plant Biology text on the market. Stern covers the necessary information in a clear and concise manner. . . I am very happy with the Stern text."*

Del William Smith, Modesto Junior College

## ORGANIZATION OF THE TEXT

A relatively conventional sequence of botanical subjects is followed. 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 deals with 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 other information of general interest pertaining to sixteen major plant families or groups of families. Chapters 25 and 26 present an overview of the vast topic of ecology, although ecological topics and applied botany are included in the preceding chapters as well. Some of these topics are broached in anecdotes that introduce the chapters, while others are mentioned in the ecological review summaries, in the human and ecological review sections, and in the extensive appendices.

## 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. Although scientific names are given in some instances, their use has been minimized throughout the text. However, a list of the scientific names of all organisms mentioned throughout the text is given in Appendix 1. Appendix 2 deals with biological controls and companion planting. Appendix 3 includes wild edible plants, poisonous plants, medicinal plants, hallucinogenic plants, spices, tropical fruits, and natural dye plants. Appendix 4 gives horticultural information on houseplants, along with brief discussions on how to cultivate vegetables. Nutritional values of the vegetables are included. Appendix 5 covers metric equivalents and conversion tables.

## NEW TO THIS EDITION

In addition to updating the content throughout the chapters, the following major changes have been incorporated into the tenth edition:

- ✿ The first major change in this edition has been the development of a new art program. Our goal has been to



maintain the detail and accuracy of the illustrations crafted over many editions, while creating new art that is colorful and dynamic. The new renderings feature shading, dimension, and color that give students a true-to-life representation of plant structures. An added benefit are the electronic versions of the new art available on the Digital Content Manager, which allow you to incorporate and manipulate the figures for lecture presentations and exams.

*"The improvements are . . . significant, and taken together present a more appealing presentation. I agree with the artistic changes, which make the text more appealing and in some cases, more clear."*

Roger del Moral, University of Washington

✿ In Chapter 3, Cells, the section on modern microscopes has been updated to include phase-contrast, fluorescence, and confocal microscopy. The section on plastids has been reorganized to discuss thylakoids prior to stroma, since light reactions precede dark reactions. This sequence of topics is also consistent with the presentation of photosynthesis reactions in Chapter 10, Plant Metabolism.

✿ The revisions to Chapter 10, Plant Metabolism, include the rewriting of the water-splitting (photolysis) and photophosphorylation sections to reflect current scientific understanding and to make the sections easier to read. The description of electron transport has been expanded to better clarify how chemiosmosis leads to the production of ATP.

✿ Chapter 13, Genetics, has been updated to include a section on the role of nonprotein-coding DNA in gene expression.

✿ Chapter 25, Ecology, has been reorganized by first discussing individual plants, then plant populations and plant communities, followed by the impact of humans on plant communities at the global level, and finally at the regional level.

✿ Appendix 4, House Plants and Home Gardening, has been augmented to include discussions on pruning and grafting.

*"I would give the Stern text a grade of 'A' as a nonmajors botany text based on its many strengths including writing style, readability, attractiveness, and excellent visual aids."*

Patricia Rugaber, Coastal Georgia Community College

## ACKNOWLEDGEMENTS

The valuable contributions of Dr. James Enderby Bidlack and Dr. Shelley H. Jansky, who rewrote Chapters 3, Cells, and 10, Plant Metabolism, and Chapters 13, Genetics, and 14, Plant Breeding and Propagation, respectively, for the previous edition and updated them for this edition, are gratefully acknowledged. Dr. Daniel Scheirer, who contributed

most of the "Awareness" boxed readings, and Dr. Manuel Molles, who provided highlighted ecological summaries for each chapter, both enhanced the text with what they wrote. Dr. Gordon Uno reorganized Chapter 25, Ecology, by introducing major ecological concepts prior to discussing the impact of humans. The help of all these gifted individuals has been much appreciated.

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

Finally I would like to extend thanks to the following reviewers who provided feedback on the text and the new illustrations. Their help has been invaluable in shaping the tenth edition of *Introductory Plant Biology*. Upon reaching this milestone tenth edition, I would also like to once again extend my gratitude to the reviewers of previous editions, who have provided considerable comments and suggestions. Although too numerous to include here, their contributions have been much appreciated.

Susan C. Barber, *Oklahoma City University*

Roger Del Moral, *University of Washington*

William Eisinger, *Santa Clara University*

Thomas E. Elthon, *University of Nebraska - Lincoln*

Jorge F. S. Ferreira, *Southern Illinois University - Carbondale*

David L. Gorchov, *Miami University - Oxford*

Timothy C. Hall, *Texas A & M University*

L. Michael Hill, *Bridgewater College*

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David W. Kramer, *Ohio State University - Mansfield*

Marshall D. Sundberg, *Emporia State University*

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Donald L. Williams, *Sterling College*

# Teaching and Learning Supplements

## DIGITAL CONTENT MANAGER 2.0

This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and/or quizzes, dynamic course web site content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped within the following easy-to-use folders:

- ✱ **Art Library.** Full-color digital files of all illustrations in this edition of the book, as well as the previous edition's illustrations.
- ✱ **Photo Library.** Hundreds of discipline-appropriate photos in digital files.
- ✱ **Table Library.** Every table that appears in the text is provided in electronic form.
- ✱ **PowerPoint Lecture Outline.** Ready-made presentations combine art from the text with customized lecture notes covering all 26 chapters.
- ✱ **Active Art.** These special art pieces consist of key images that are converted to a format that allows instructors to break the art down into core elements and then group the various pieces and create customized images. This is especially helpful with difficult concepts; they can be presented step by step.
- ✱ **TextEdit Art.** The newly rendered illustrations in this edition have also been specially prepared in PowerPoint format, which allows labels to be revised, moved, or deleted for use in customized presentations, quizzes, and exams.
- ✱ **Animations Library.** Numerous full-color animations illustrating many different concepts covered in the study of botany are provided. The visual impact of motion will enhance classroom presentations and increase comprehension.

## THE AMAZING LIVES OF PLANTS: THE REPRODUCTIVE LIVES OF MOSSES, PINES, FERNS, FLOWERS, AND LEAVES

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CD-ROM (ISBN 0-07-266394-X)

DVD (ISBN 0-07-294339-4)

## TRANSPARENCIES

A set of 100 Transparencies is available to users of the text. These acetates include key figures from the text, including new art from this edition. (ISBN 0-07-286568-7)

## INSTRUCTOR'S TESTING AND RESOURCE CD-ROM

McGraw-Hill's EZ Test is a flexible and easy-to-use electronic testing program. The program allows instructors to create tests from book specific items. It accommodates a wide range of question types and instructors may add their own questions. Multiple versions of the test can be created and any test can be exported for use with course management systems such as WebCT, BlackBoard or PageOut. The program is available for Windows and Macintosh environments. (ISBN 0-07-286566-0)

## INTRODUCTORY PLANT BIOLOGY LAB MANUAL

The laboratory manual that accompanies *Introductory Plant Biology* has been revised and updated. 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. They are written to allow for maximum flexibility in sequencing. (ISBN 0-07-252841-9)

# ONLINE LEARNING CENTER

The Online Learning Center that accompanies this text provides abundant resources for both instructor and student.

**For each chapter of the textbook, students will have access to:**

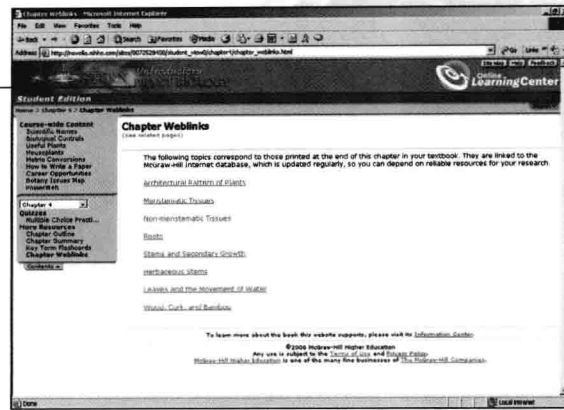
- ✱ **Chapter Summaries**
- ✱ **Chapter Web links** Correlated to each chapter of the tenth edition, these regularly updated URLs provide additional learning opportunities for research, writing papers, or tutorial purposes.
- ✱ **Practice Quizzing** Designed as a study aid, these chapter-by-chapter quizzes help students review text material and prepare for upcoming exams.
- ✱ **Key Term Flash Cards** Yet another great study tool that tests students' knowledge of important botany terms.

**Additional resources available to students include:**

- ✱ **Global Botany Issues World Map** A world map is tagged with hot points that link to case studies and articles complete with photos, references back to the text, and additional links to appropriate Internet sites.
- ✱ **Guide to Electronic Research**
- ✱ **Metric Equivalents and Conversions Tables**
- ✱ **Career Opportunities**
- ✱ **Animations**
- ✱ **How to Write a Paper**
- ✱ **Scientific Names of Organisms**
- ✱ **Biological Controls**
- ✱ **Useful Plants and Poisonous Plants**
- ✱ **House Plants and Home Gardening**

**As an instructor you'll receive complete access to all of the above plus:**

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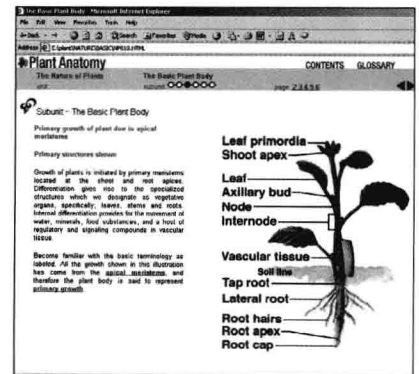
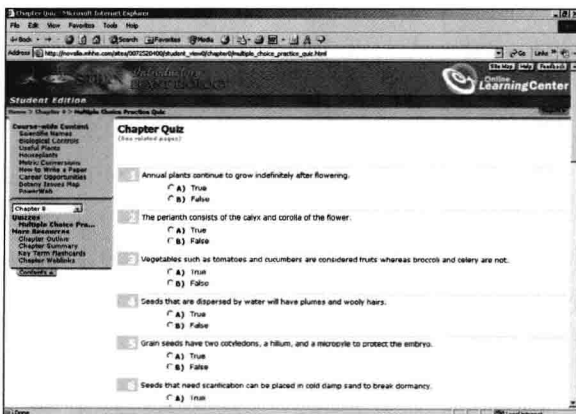
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## ELECTRONIC PLANT ANATOMY CD-ROM

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(ISBN 0-07-251084-6)



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# 1

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Learning Online

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




# 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.



While in high school in southern Africa, I was once invited to a friend's farm during the spring break. One day as I was returning to the farmhouse from a walk around the farm, I heard groaning coming from within. I learned that my friend's father had been clearing cactuslike *Euphorbia* plants from some land. The plants produce a poisonous milky latex, which the father had taken great care to wash thoroughly from his hands. Absent minded, however, he had splashed some of the water in his face, and traces of the poison had gotten into his eyes, causing great pain. Another member of the household immediately ran to the nearby barn and obtained some colostrum milk from a cow that had just given birth. The eyes were bathed in the milk, which contains an antidote for that particular poison, and the pain subsided. I was told that if the milk had not been quickly available, the man would have been blind within half an hour. In Venezuela and Brazil, however, cow trees (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 *Euphorbia* species 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?



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

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?

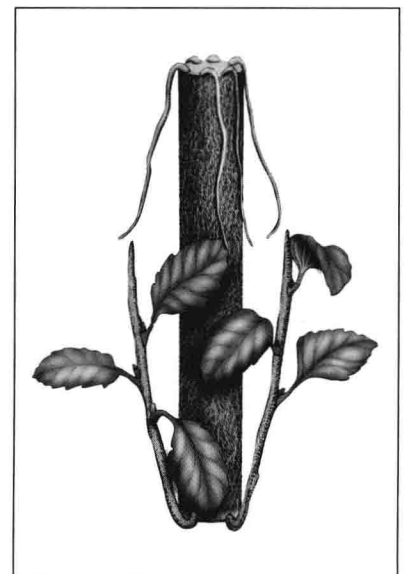
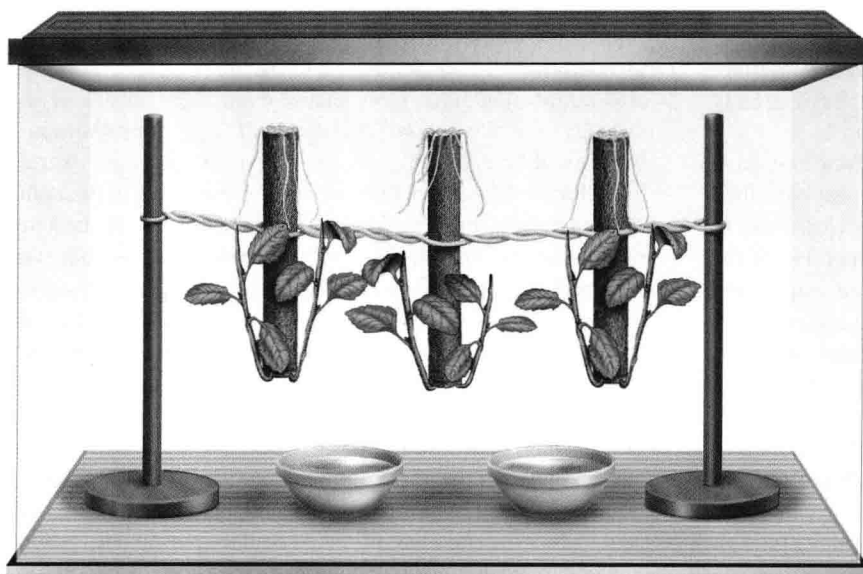
California's huge coastal redwoods and Tasmania's giant gum trees can grow to heights of 60 to 90 or more meters (200 to 300 or more feet). When these giant trees are cut down, there is no evidence of pumps of any kind within them. How then does water get from the roots below ground to the tops of these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

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?



**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).



**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.

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 80 million annually, and estimates for the year 2004 are 6.5 billion. By 2010 it is believed the world's population will exceed 6.8 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 5% 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



## 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.

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 the ozone shield, major global climatic changes, loss of biodiversity in general, and loss of tropical rain forests in particular, gained widespread publicity.