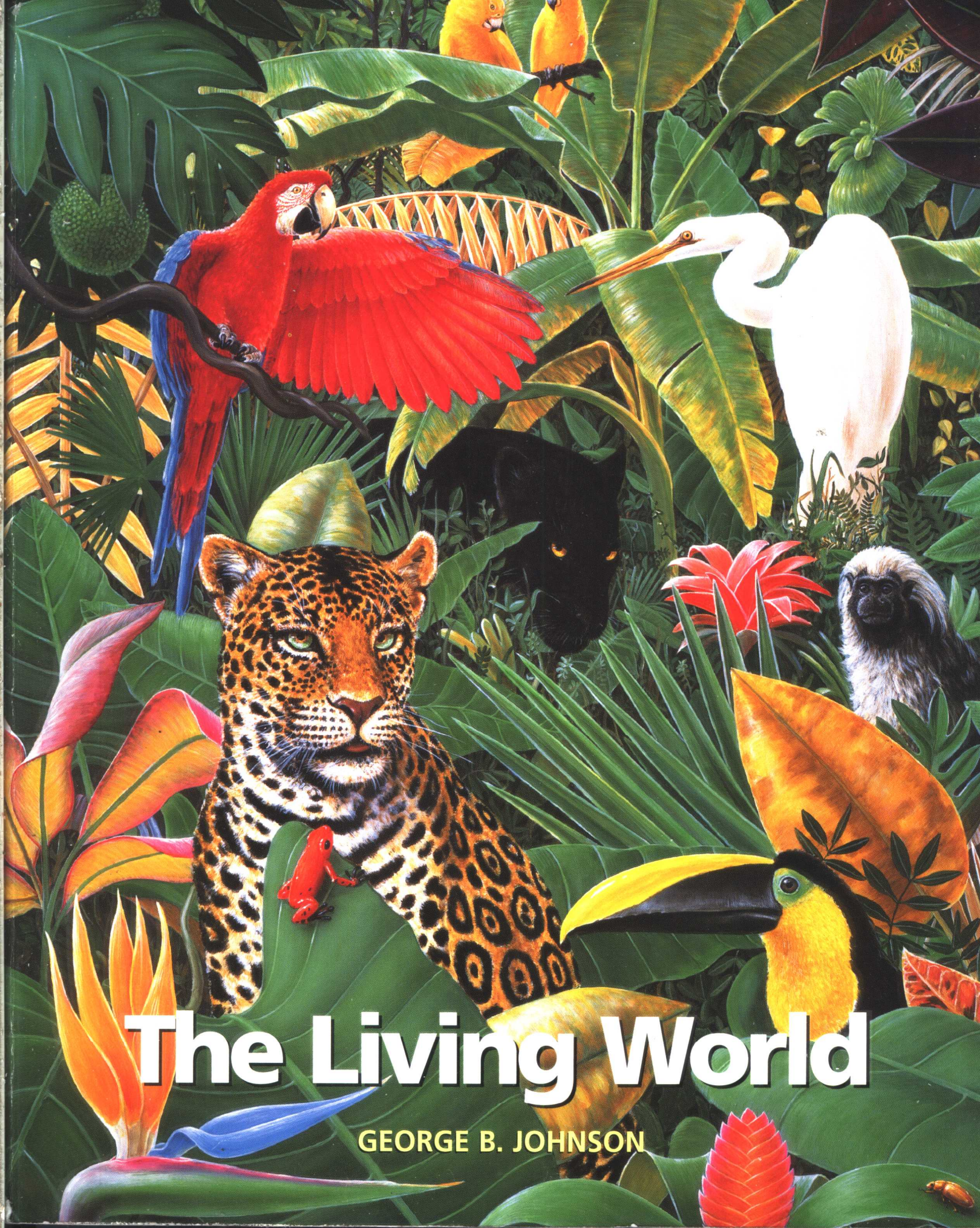

The Living World

GEORGE B. JOHNSON

The Living World

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Washington University
St. Louis, Missouri

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Boston, Massachusetts Burr Ridge, Illinios Dubuque, Iowa
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Preface

No one who teaches biology today can fail to appreciate how important a subject it has become for our modern world. As a teacher, I have stood in front of classrooms for over 25 years and attempted to explain biology to puzzled and sometimes uninterested students, an experience that has been both fun and frustrating: fun because biology is a joy to teach, rich in ideas and interesting concepts, and increasingly key to many important public issues; frustrating because in every biology class there are always some students who will not pay attention, who not only miss out on the fun but also fail to acquire a tool that will be essential to their futures.

This book, *The Living World,* is my attempt to address that problem. It is short enough to use in one semester, without a lot of added material to intimidate wary students. I have tried to write it in an informal, friendly way, to engage as well as to teach. The focus of the book is on the biology each student ought to know to live as an informed citizen in the twenty-first century. I have at every stage addressed ideas and concepts, rather than detailed information, trying to teach *how* things work and *why* things happen the way they do rather than merely naming parts or giving definitions.

My first step in creating this text was to attack the traditional table of contents (usually a formidable list of chapters covering every subject imaginable). The number of chapters in biology textbooks has grown over the years, until today the most widely used short texts have as many as 38 chapters. I have cut back ruthlessly on this overwhelming amount of information, reducing the number of chapters in *The Living World* to 28. I think it matches closely what is actually being taught in classrooms and, as you will see, all that is really important is preserved.

I have deliberately combined photosynthesis and cellular respiration into a single general chapter in *The Living World,* not because metabolism is unimportant but because the basic principles a student needs to understand are simple and easy to explain, while the details of chemical reactions only get in the way of many students' ability to see concepts. Details are sacrificed, but the basic concepts are presented clearly enough for nonmajors students to grasp.

Another key step in designing *The Living World* was to combine the teaching of evolution and diversity into a single story line. Traditionally, students are exposed to weeks of evolution before tackling animal diversity, struggling past the Hardy-Weinberg equilibrium and population growth equations (microevolution) and on through Darwin's discoveries (macroevolution). Then, when that is all done, they are dragged through a detailed tour of the phyla, followed by a long excursion into botany. In large measure, the three areas are presented as if unrelated to each other. In *The Living World* I have chosen instead to combine all three of these areas into one treatment, presenting biological diversity as an evolutionary journey. It is a lot more fun to teach this way, and I find that my students learn a great deal more, too.

I have also chosen to present ecology in a novel way. Rather than taking a levels-of-organization approach (that is, population ecology, community ecology, ecosystems, and biomes), I focus on the basic unit of ecology, the ecosystem—also the most relevant to the world's problems today. After describing what ecosystems are and how they function, I discuss how the architecture of ecosystems has been shaped by coevolution, how ecosystems respond to disruption, and what factors make some ecosystems more stable to disruption than others. Finally, I present a picture of the kinds of disruptions going on today. The approach throughout is positive and solution-oriented.

Forgive me if you find some favorite topic omitted or treated more lightly than you would wish—keeping this book brief and approachable has limited the amount of material that could be included. But I feel the benefit far outweighs the cost, for this is a book students can learn from.

As you page through the book, you will notice that major topics begin at the start of a page. This is no accident but rather the result of careful planning. Unlike most texts, the pages of *The Living World* were laid out by the author, so that I was able to create a very user-friendly organization of material.

In an effort to make the book more fun for students and at the same time increase its power as a learning tool, I have incorporated interactive CD-ROM *Explorations* into 16 of the chapters. The publisher has also opened a web site on the Internet for each chapter, which students can use to investigate further topics. Although students can use the text perfectly well without these new technological features, they add to the richness of the experience. I hope you will be tempted to try them with your class.

While it is not the first book I have written and probably will not be the last, *The Living World* has been one of the most challenging and rewarding. I hope that you like it—and that you find it an effective teaching tool.

Learning Aids

In the Text

Each chapter of *The Living World* provides the student with several features designed to facilitate study and learning.

Chapter Opener

A "Far Side" cartoon at the beginning of each chapter captures student interest and shows that science can be fun.

Chapter Outline

At the beginning of each chapter, an outline of the main chapter headings introduces the student to the topics about to be discussed.

End-of Chapter Highlights

This concise, visual summary highlights the main headings and key illustrations within the chapter. It recaps the concepts that relate to each main topic and links them to the most important key terms with page references.

Concept Review

Objective questions (multiple-choice and fill-in-the-blank) provide a built-in study guide, enabling students to quiz themselves on the material just read.

Challenge Yourself

Critical thinking questions challenge students to apply the concepts presented in the chapter.

For Further Reading

A list of sources points students and instructors toward additional related material and provides a brief overview of each book or article.

Technology Links

Icons indicate multimedia sources, including *The Living World's* own web site, where students can obtain supplementary material or practice applying the chapter concepts.

In addition, at the end of the book, students will find:

Appendix A: The Classification of Life

Illustrations and narrative explain the six-kingdom classification system used in *The Living World.*

Appendix B: Answers to Concept Reviews

Answers to the objective questions at the end of each chapter are provided so that students can get immediate reinforcement as they quiz themselves on the material.

Glossary of Key Terms and Concepts

This glossary contains definitions and derivations of the most important key terms used in biology and in *The Living World.*

Index

A comprehensive index is provided.

Ancillaries

Instructor's Manual/Test Item File

Prepared by Jennifer Carr Burtwistle of Northeast Community College, the *Instructor's Manual* provides the following instructor aids for each chapter of *The Living World:* chapter overview, learning objectives, student activities, discussion ideas, and a list of audiovisual materials. The test item file offers approximately 35 questions per chapter (multiple-choice, fill-in-the-blank, and essay) as well as answers for all.

Computerized Testing Software

The test item file is also available on disk with a test generator program in either Macintosh or Windows.

Transparencies

Two hundred full-color illustrations from the book are available as transparency acetates and provided free to adopters.

Student Study Guide

The *Student Study Guide,* by Lisa Shimeld of Crafton Hills College, contains chapter concepts, objective questions (multiple-choice, completion, and matching), drawings for students to label, key word searches, crossword puzzles, and a list of related web sites. An appendix provides the answers to all questions and activities.

How to Study Science

How to Study Science, second edition, by Fred Drewes of Suffolk County Community College, contains helpful tips and practical exercises to help students achieve success in biology and other science courses.

Basic Chemistry for Biology

Basic Chemistry for Biology, by Carolyn Chapman of Suffolk County Community College, is a self-paced book that leads students through basic concepts of inorganic chemistry.

How Scientists Think

How Scientists Think, by *The Living World* author George Johnson, is a paperbound text describing 21 experiments that have shaped our understanding of genetics and molecular biology. It fosters critical thinking and reinforces the scientific method.

Biology Study Cards

This boxed set of 300 two-sided study cards provides a quick yet thorough visual synopsis of all key biological terms and concepts in the general biology curriculum. Each card features a masterful illustration pronunciation guide, definition, and description in context.

The Internet Primer: Getting Started on Internet

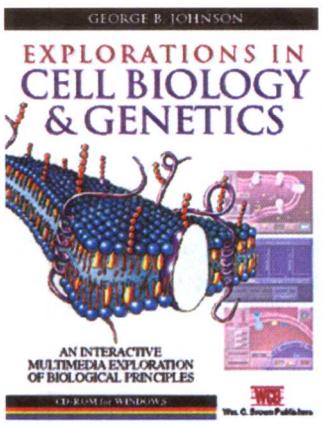
This primer, by Fritz J. Erickson and John A. Vonk, gives you just enough knowledge for getting started on the Internet, including the basics of how to access and use some of the Internet's most common features.

Multimedia Learning Aids

It is an exciting time for learning, as technology presents us with new tools that are both powerful and fun. The following multimedia products can be used with *The Living World:*

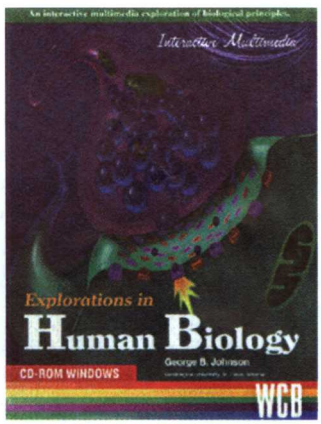
Explorations in Cell Biology & Genetics CD-ROM

*Keyed to the text



Explorations in Human Biology CD-ROM

*Keyed to the text

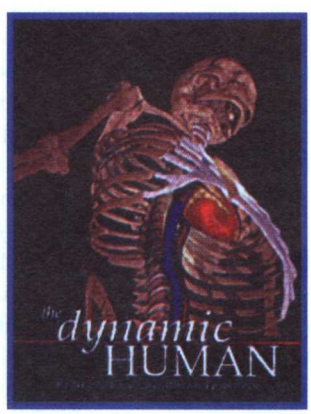


Developed by *The Living World* author George Johnson, these two CDs contain a total of 33 full-color, interactive exercises covering key biological concepts. Screen captures from appropriate modules are used as illustrations in selected chapters of *The Living World,* and the modules are also referenced at the ends of the chapters. *Explorations* can be used by students to enhance learning or by an instructor in lecture and/or a lab or resource center. They operate on either Macintosh or Windows platforms.

The Dynamic Human CD-ROM and Videodisc

*Keyed to the text

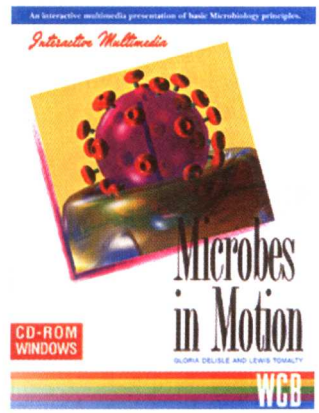
This guide to anatomy and physiology interactively illustrates the complex relationships between anatomical structures and their functions in the human body. Realistic, three-dimensional visuals are the premier feature of this learning tool. The program covers every body system, demonstrating to the viewer the anatomy, physiology, histology, and clinical applications of each.



Microbes in Motion CD-ROM

*Keyed to the text

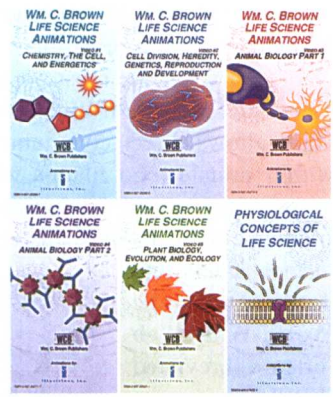
Microbiological topics come to life in this easy-to-use Windows tutorial by Gloria Delisle and Lewis Tomalty. The CD features interactive screens, animations, video, audio, and hyperlinked questions.



Life Science Animations Videotapes

*Keyed to the text

Sixty-six animations of key physiological processes are available on this set of six videotapes:



Video 1 *Chemistry, the Cell, and Energetics*
Video 2 *Cell Division/ Heredity/Genetics/ Reproduction and Development*
Video 3 *Animal Biology 1*
Video 4 *Animal Biology 2*
Video 5 *Plant Biology/Evolution/Ecology*
Video 6 *Physiological Concepts of Life Science*

A Life Science Living Lexicon CD-ROM

A Life Science Living Lexicon CD-ROM, by William Marchuk of Red Deer College, contains a comprehensive collection of life science terms, including definitions of their roots, prefixes, and suffixes as well as audio pronunciations and illustrations. The *Lexicon* is student-interactive, providing quizzing and notetaking capabilities. It contains 4,500 terms, which can be broken down for study into the following categories: anatomy and physiology, botany, cell and molecular biology, genetics, ecology and evolution, and zoology.

BioSource Videodisc

BioSource Videodisc, by Wm. C. Brown Publishers and Sandpiper Multimedia, Inc., features 20 minutes of animations and nearly 10,000 full-color illustrations and photos, many from leading WCB biology textbooks.

Biology Startup

Biology Startup, by Myles Robinson and Kathleen Pace of Grays Harbor College, is a five-disk Macintosh tutorial that helps nonmajors students master challenging biological concepts such as basic chemistry, photosynthesis, and cellular respiration.

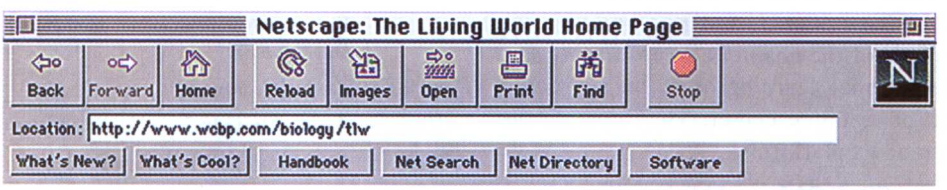
Technology and *The Living World*

Two new technology tools play an integral part in your exploration of biology with this text: the Internet and interactive CD-ROMs.

What Is the Internet?

Few innovations have had as dramatic an impact on our lives as the Internet. Starting in the late 1960s, a significant number of scientists began to link their computers for the purposes of sharing data. In the late 1980s, universities and government agencies started joining this network of networks. Soon, average people of all ages, backgrounds, and occupations began to connect as well until by 1995, 5 million different computers were linked to the Internet worldwide. By means of telephone lines, direct wires, fiber optics, and satellite links, the Internet allows instantaneous communication between individuals and gives them unrestricted access to vast amounts of information.

Two of the most popular features of the Internet are e-mail and the World Wide Web. **E-mail** (short for electronic mail) allows direct communication via the Internet, usually within minutes, no matter what the actual distance. Businesses, educational institutions, and private individuals are finding e-mail an inexpensive and convenient way to send memos, letters, and documents. The **World Wide Web** (often abbreviated WWW) is a mega-network created in 1992 that is capable of transferring text, graphics, audio, and video. Its information is presented in the form of a **home page,** also known as a **web site** or **web page.** Through WWW, you can access information as diverse as scientific data and other educational material, your daily newspaper, your favorite mail order catalog, interactive games, and the personal home pages of other Internet users.



Why is the Internet useful to instructors and students using *The Living World?* By visiting *The Living World's* home page, students and their instructors may access study questions specifically correlated to each chapter, the latest developments on topics covered in the text, other biologically relevant web sites, and even a message board where issues may be explored in depth with other students, instructors, and *The Living World* author.

How Does the Internet Work?

Communication within the Internet is possible because all the computers on the network use a common language, known as a **protocol.** The addressing system is very simple—an Internet address, called a **URL** for "uniform resource locator," identifies a specific computer linked to the Internet just as a street address identifies a specific house. For example, the Internet address for *The Living World* home page is:

http://www.wcbp.com/biology/tlw

The *http* stands for Hyper Text Transfer Protocol, the common language used to communicate between World Wide Web servers; *www* stands for World Wide Web; *wcbp.com* stands for Wm. C. Brown Publishers, a commercial organization; and *biology/tlw* specifically identifies *The Living World*'s directory structure and home page apart from those for other textbooks.

How Can I Access the Internet?

In order to use the Internet, you need a computer, a modem, and two kinds of software. The first type of software is an **interface,** a program that determines how the Internet looks to you. Provided by your host site (for example, a school or business) or by a commercial server such as America Online or CompuServe, these programs allow you to access the Internet with either a Windows or Macintosh computer. The second kind of software is called a **browser,** and it enables you to search for and view information. Many browsers are available, including Netscape, Mosaic, and those provided by commercial on-line services.

Once your system is installed, it is easy to access the home page for *The Living World.* Simply double click on the icon for Netscape (or whatever browser you use). When you arrive at a screen like the one shown at the left, type the home page address in the window provided after the words "Go to" or "Location." Then press the "enter" or "return" key on your keyboard. From that point, additional buttons will take you to chapter learning aids, related web sites, and other useful information. (Occasionally, you may not be able to get into Netscape because the lines are busy. If this happens, you will be instructed to try again.) To type in a different address, use your mouse to highlight the old address and then type the new one on top of it.

If you don't know a specific address but want to find out about a certain topic, you may use a **search engine.** One way to do this is by clicking on the button labeled "Net Search." A window will appear in which you may type a key word or phrase. Another way to find information on the Web is by using **hyperlinks.** These are words or phrases printed in color on the screen. Clicking on them can lead you deeper into the topic you are currently investigating or on to other related web sites. Navigating the Internet in this manner is known as **surfing.** Other buttons on the tool bar also help you get around on the Internet. For example, "back" and "forward" enable you to move back and forth among pages recently viewed, while "home" will take you back to your home page. With a little experimentation, you will quickly learn how to navigate the Internet.

Interactive CD-ROMs

As every teacher knows, hands-on experience is far and away the most effective way to learn anything. To teach art, let a student paint; to teach driving, let a student drive a car; to teach science, let a student do an experiment. Unfortunately, there is a limit to how much science can be taught "hands on" in a classroom. This is particularly true of biology, where students typically encounter a broad variety of concepts and organisms and can spend only a limited time in a laboratory—if any. Thus, it is with genuine excitement that we now present interactive CD-ROM *Explorations* in this text.

What do CD-ROM *Explorations* provide a classroom that slide collections and laser disc "multimedia" presentation managers don't? In a word, *interactivity*. Just as you cannot make a better painting simply by giving the artist more paint, so you cannot make a more hands-on experience simply by providing the student with more images. What is needed is a back-and-forth interaction, where true inquiry and analysis can take place. This is what a CD-ROM *Exploration* can provide and why CD-ROM technology plays such an important part in the learning experience provided by this text.

As an example, imagine introductory-level students learning in biology class about muscle contraction. Until now, their learning experience consisted of a text diagram illustrating actin and myosin filaments and the teacher's description of how the filaments interact. Using the CD-ROM *Exploration* described in figure 19.20 of *The Living World* (see the screen capture on this page), the class can watch the diagram "come alive," the filaments contracting in a dynamic animation. Then—and this is the key to the hands-on learning experience—the students can manipulate variables and see the effect on the animation. Altering ATP and Ca^{++} levels, the students can see the results of the changes they impose, collecting and analyzing data just as if they were in a laboratory. By exploring the effects of these variables, students learn for themselves how muscle contraction works, instead of simply being told. They gain a grasp of the key concepts far more effectively, and they have fun doing it—the whole interactive exercise need take up only a few minutes of class time.

Sixteen CD-ROM interactive investigations are integrated into *The Living World*, each in a chapter where the subject of the investigation plays a key role. The sixteen investigations have been selected from two CD-ROMs (*Explorations in Cell Biology & Genetics* and *Explorations in Human Biology*) that are part of an inexpensive student ancillary package. A list of all the topics covered appears at right; those printed in bold type are specially featured in certain chapters of *The Living World*. With the wide range of CD-ROM interactive *Explorations* employed in *The Living World*, hands-on learning in the classroom has finally become a practical goal.

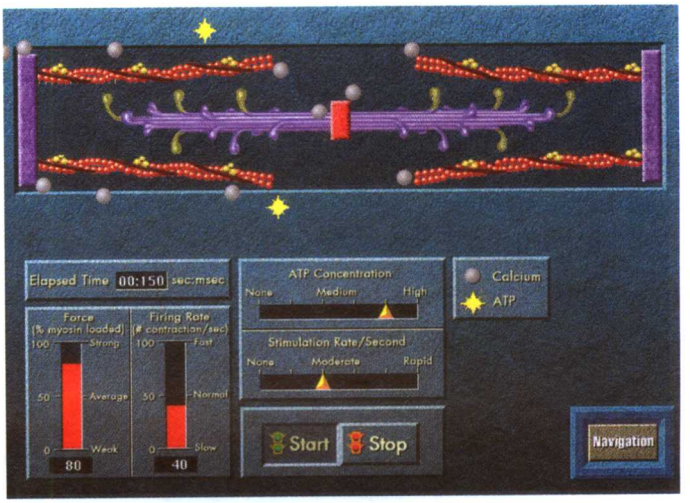


Figure 19.20 from *The Living World*. This is a screen capture from module 4, "Muscle Contraction," in *Explorations in Human Biology*.

Explorations in Cell Biology & Genetics CD-ROM

1. **Hemoglobin, chapter 2**
2. **Cell Size, chapter 3**
3. **Active Transport, chapter 4**
4. Cell-Cell Interactions
5. Mitosis
6. **Thermodynamics, chapter 5**
7. Kinetics
8. Oxidative Respiration
9. **Photosynthesis, chapter 15**
10. Meiosis: Down syndrome
11. Constructing a Genetic Map
12. **Heredity in Families, chapter 6**
13. Gene Segregation
14. **DNA Fingerprinting, chapter 8**
15. Reading DNA
16. **Gene Regulation, chapter 7**
17. Making a Restriction Map

Explorations in Human Biology CD-ROM

1. Cystic Fibrosis
2. **Active Transport, chapter 4**
3. Life Span and Life Style
4. **Muscle Contraction, chapter 19**
5. **Evolution of the Heart, chapter 20**
6. Smoking and Cancer
7. **Diet and Weight Loss, chapter 21**
8. Nerve Conduction
9. Synaptic Transmission
10. **Drug Addiction, chapter 23**
11. **Hormone Action, chapter 24**
12. **Immune Response, chapter 22**
13. **AIDS, chapter 25**
14. Constructing a Genetic Map
15. **Heredity in Families, chapter 6**
16. **Pollution of a Freshwater Lake, chapter 28**

Acknowledgments

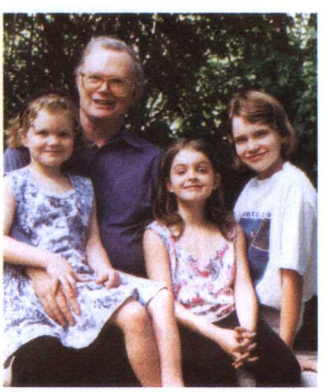
Every book has its own particular history. This one began with the appearance of "cut-down" versions of nonmajors biology texts several years ago. I went to my editors and said, "Wouldn't it be nice to write a short book from scratch, at a very approachable level, rather than just cutting the length of a longer, more difficult book?" *The Living World* is the result. For seeing its potential and turning me loose, I am in the debt of Kevin Kane, head of editorial at Wm. C. Brown Publishers. He solidly backed my efforts to develop the interactive CD-ROM software that I have integrated into this text and in many other ways lent support to the project. My editor, Michael Lange, was no less supportive, marshaling considerable resources as well as putting out the fires that I in my enthusiasm seem to forever ignite among editorial and production staff.

Dr. Thomas Emmel of the University of Florida offered significant encouragement to me at an early stage of this project. Reviewing the first draft of the manuscript, he made many valuable suggestions, particularly concerning pedagogy.

Much of the pagemaking task was carried out day-to-day by Megan Jackman, an on-site developmental editor who worked in an office next to mine for a year, hacking and hewing at the manuscript until it "fit." Her intelligence, perseverance, and ability to tolerate my crusty nature played a major role in the high quality of this book. The terrific appearance of the book reflects the efforts of Mark Christianson, who led Megan and me into PageMaker, held our hands as we learned, and also designed the clean, snappy look that helps make this book so approachable. Mark does not know how to say, "It can't be done."

I want to explicitly thank Gary Larson and Toni Carmichael for the use of "The Far Side" cartoons that grace each chapter opening. It has been their policy never to allow more than two of Gary's cartoons in any non-Larson publication, and I am very grateful that they made an exception for *The Living World* and let me use 28! In over 15 years of writing biology texts, few tasks have been more enjoyable than picking those 28 from the wealth of wildly funny cartoons Gary has produced.

As always, I have had the support of a wife and family who have had to live with a distracted daddy spending more hours at the computer than they would like. My girls—seven, ten, and twelve years old—are becoming old enough to appreciate not only the long hours, but also the joy of finally holding the new book in your hands, proud as if it were a new baby. They are quite a fan club.



Acknowledgments would not be complete without thanking the generations of students who have used the many editions of my college biology texts. They have taught me at least as much as I have them, and this book could not have been written without the temper of that experience.

Finally, I need to thank my reviewers. Every text owes a great deal to those faculty across the country who review it. Serving as sensitive antennae for errors and sounding boards for new approaches, reviewers are among the most valuable tools at an author's disposal. *The Living World* has been particularly fortunate in its panel of reviewers. Representing a very diverse array of institutions and interests, they have provided me with invaluable feedback. Many improvements are the direct result of their suggestions. Every one of them has my sincere thanks.

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Union College

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Westminster College

James A. Brenneman
University of Evansville

Cran Lucas
Louisiana State University–Shreveport

Vernon L. Wranosky
Colby Community College

Donald L. Terpening
Ulster County Community College

Lisa A. Shimeld
Crafton Hills College

H. Warrington Williams
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Allan J. Landwer
Hardin-Simmons University

Michael Gipson
Oklahoma Christian University

Quentin Reuer
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Rudolph Prins
Western Kentucky University

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Ohio University–Chillicothe Campus

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College of Southern Idaho

Edward R. Fliss
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Kenneth Nickell
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Brief Contents

PART ONE

The Study of Life

Chapter 1 The Science of Biology 2
Chapter 2 The Chemistry of Life 18
Chapter 3 Cells 44
Chapter 4 The Living Cell 66
Chapter 5 Energy and Life 84

PART TWO

The Continuity of Life

Chapter 6 Foundations of Genetics 110
Chapter 7 How Genes Work 136
Chapter 8 Gene Technology 154
Chapter 9 Evolution and Natural Selection 170

PART THREE

The Diversity of Life

Chapter 10 How We Name Living Things 200
Chapter 11 The First Single-Celled Creatures 214
Chapter 12 Advent of the Eukaryotes 230
Chapter 13 Evolution of Multicellular Life 248
Chapter 14 Rise of the Flowering Plants 264
Chapter 15 The Living Plant 288

PART FOUR

Animal Life

Chapter 16 Evolution of the Animal Phyla 320
Chapter 17 History of Terrestrial Vertebrates 354
Chapter 18 How Humans Evolved 388

PART FIVE

Human Life

Chapter 19 The Human Body 408
Chapter 20 Circulation and Respiration 432
Chapter 21 The Path of Food Through the Body 454
Chapter 22 How the Body Defends Itself 476
Chapter 23 The Nervous System 494
Chapter 24 Chemical Signaling Within the Body 520
Chapter 25 Human Reproduction and Development 536

PART SIX

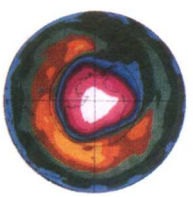
Our Living Environment

Chapter 26 Ecosystems 556
Chapter 27 Living in Ecosystems 582
Chapter 28 Planet Under Stress 606

Contents

Preface ix

PART ONE • THE STUDY OF LIFE

2 

1 The Science of Biology

From observation, scientists formulate sets of alternative hypotheses about how the physical world functions and attempt to disprove some of these hypotheses with controlled experiments.

1.1 The Scientific Process 4
1.2 Using Science to Make Decisions 8
1.3 Biological Principles 9

18 

2 The Chemistry of Life

Organisms are chemical machines, and in order to understand them, we need to learn a little chemistry. Life evolved in water, and much of the chemistry of living things is intimately tied to water.

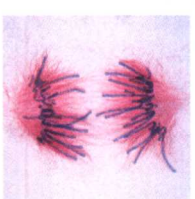
2.1 Some Simple Chemistry 20
2.2 Water: Cradle of Life 26
2.3 Macromolecules 30
2.4 Origin of the First Cells 38

44 

3 Cells

Cells are the basic units of life. Although most are too small to see with the naked eye, their inner workings are complex and highly organized.

3.1 The World of Cells 46
3.2 Exploring the Cell Surface 48
3.3 Bacteria Are the Simplest Cells 51
3.4 The Structure of Eukaryotic Cells 52

66 

4 The Living Cell

Every cell carries out the basic processes of living, gathering energy, and expending it to grow and divide. Cells can be remarkably clever in how they carry out these tasks.

4.1 How Cells Eat and Drink 68
4.2 How Cells Get Information 74
4.3 How Cells Divide 75

84 

5 Energy and Life

All of life's processes are driven by energy. Some cells obtain the energy they need from sunlight, using it to build molecules. Others harvest the energy in biomolecules.

5.1 Cells and Chemistry 86
5.2 How Cells Use Energy 90
5.3 Photosynthesis 92
5.4 Cellular Respiration 100

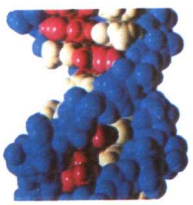
PART TWO • THE CONTINUITY OF LIFE

110 

6 **Foundations of Genetics**

Heredity, the passage of traits from one generation to the next, occurs because information specifying traits resides in chromosomes. The way chromosomes are transmitted determines the pattern of heredity.

6.1 Mendel 112
6.2 From Genotype to Phenotype 119
6.3 Meiosis 121
6.4 Patterns of Heredity in Humans 126

136 

7 **How Genes Work**

Genes are segments of DNA that encode proteins. Because the actions of proteins determine what we are like, genes are the ultimate units of heredity.

7.1 Genes Are Made of DNA 138
7.2 Transcription 143
7.3 Translation 145
7.4 Regulating Gene Expression 147

154 

8 **Gene Technology**

It is now possible to transfer specific genes from one organism to another. This technology is revolutionizing agriculture and medicine.

8.1 Genetic Engineering 156
8.2 Transforming Agriculture 161
8.3 Advances in Medicine 163

170 

9 **Evolution and Natural Selection**

The core theory upon which the science of biology is based is the proposition, advanced by Darwin, that changes in species are the result of natural selection.

9.1 Darwin 172
9.2 The Evidence for Evolution 175
9.3 How Populations Evolve 182
9.4 Adaptation: Evolution in Action 188
9.5 How Species Form 192

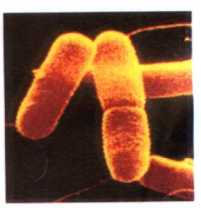
PART THREE • THE DIVERSITY OF LIFE

200 

10 **How We Name Living Things**

Naming organisms is very important in helping us deal with nature. Understanding how organisms are related to one another is not so simple.

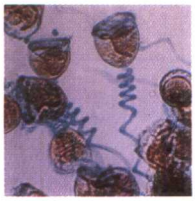
10.1 The Classification of Organisms 202
10.2 What Is a Species? 206
10.3 Inferring Phylogeny 208

214 

11 **The First Single-Celled Creatures**

The oldest organisms of which we have any knowledge are bacteria, the simplest, smallest, and most numerous creatures living on earth.

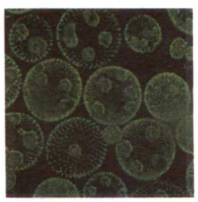
11.1 Bacteria 216
11.2 Kinds of Bacteria 218
11.3 Viruses 222

230 

12 Advent of the Eukaryotes

About 1.5 billion years ago, after 2 billion years in which bacteria had the world to themselves, a far more complex type of organism arose, the eukaryote.

12.1 Endosymbiosis 232
12.2 The Protists 234
12.3 The Evolution of Sex 236
12.4 Kinds of Protists 238

248 

13 Evolution of Multicellular Life

Multicellular life evolved among the protists several times. Fungi are perhaps the most unusual of all multicellular organisms, as their cells share cytoplasm and nuclei.

13.1 Colonial Protists 250
13.2 Multicellularity 251
13.3 Fungi 252
13.4 Fungal Associations 259

264 

14 Rise of the Flowering Plants

Plants successfully colonized the land in partnership with symbiotic fungi. The evolution of plants has been marked by the appearance first of vascular plants, then seeds, and finally flowers.

14.1 The Origin of Plants 266
14.2 General Features of Vascular Plants 272
14.3 The Advent of Seeds 276
14.4 The Evolution of Flowers 280

288 

15 The Living Plant

The plant body is basically a vertical tube that grows in length at its tips and, in trees, also in girth. Water is drawn up into the plant shoot from the soil when water vapor evaporates from the leaves.

15.1 The Structure and Function of Plant Tissues 290
15.2 Plant Nutrition and Transport 300
15.3 Flowering Plant Reproduction 310

PART FOUR • ANIMAL LIFE

320 

16 Evolution of the Animal Phyla

The evolution of the animal body plan has been marked by a series of innovations that are reflected in the characteristics of the major phyla.

16.1 Some General Features of Animals 322
16.2 The Simplest Animals 326
16.3 The Advent of Bilateral Symmetry 331
16.4 The Advent of a Body Cavity 334
16.5 Redesigning the Embryo 346

354 

17 History of Terrestrial Vertebrates

The evolution of terrestrial vertebrates has involved progressive changes in the lungs and heart to improve oxygen delivery to the tissues and reproductive changes to improve protection of young and parental care.

17.1 Overview of Vertebrate Evolution 356
17.2 The Parade of Vertebrates 362
17.3 Meeting the Challenge of Life on Land 374

388 

18 How Humans Evolved

Humans evolved from australopithecines in Africa only a few million years ago. The genus Homo *appears to have spread out from Africa several times.*

18.1 The Evolution of Primates 390
18.2 Evolutionary Origins of Humans 394
18.3 The First Humans 400
18.4 Our Own Species 402

PART FIVE • HUMAN LIFE

408 

19 **The Human Body**

The human body has the architecture of a crane, with jointed limbs attached to a central skeleton, within which is a protected cavity that contains the body's organs.

19.1 How the Body Is Organized 410
19.2 The Principal Tissues 414
19.3 The Human Skeleton 420
19.4 The Human Muscular System 424

432 

20 **Circulation and Respiration**

Humans circulate blood through the body by pumping it with the heart. The blood picks up oxygen in the lungs and delivers it to the tissues; from the tissues, it collects CO_2 and carries it back to the lungs.

20.1 The Circulatory System 434
20.2 Blood 438
20.3 The Heart and How It Works 440
20.4 The Respiratory System 443
20.5 Lung Cancer and Smoking 448

454 

21 **The Path of Food Through the Body**

The human digestive tract consists of a series of chambers that form a continuous tube. As food passes through this tube, large molecules in the diet are broken down into smaller bits the body can use.

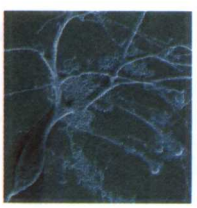
21.1 Diet 456
21.2 The Human Digestive System 460
21.3 Using the Products of Digestion 466
21.4 How the Body Eliminates Wastes 469
21.5 Water Balance 470

476 

22 **How the Body Defends Itself**

Several types of white blood cells protect the body from infection and eliminate cancer cells. These cells screen the surface of body cells for foreign proteins and eliminate any cells that contain "nonself" proteins.

22.1 Skin 478
22.2 Cellular Counterattack 480
22.3 The Immune System 483
22.4 Immune System Failure 488
22.5 AIDS 489

494 

23 **The Nervous System**

The nervous system regulates the body's activities and its internal condition, using special signaling cells called neurons to transmit information about the body's condition to the brain and to relay commands back.

23.1 Organization of the Nervous System 496
23.2 The Central Nervous System 497
23.3 The Motor Nervous System 501
23.4 How Nerves Work 503
23.5 The Sensory Nervous System 508

520 

24 **Chemical Signaling Within the Body**

The body uses chemical signals called hormones to control a wide variety of organs and processes. Many of these hormones are secreted by glands under the direct control of the brain.

24.1 The Neuroendocrine System 522
24.2 How Hormones Work 523
24.3 The Major Endocrine Glands 526

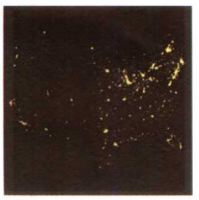
536 

25 **Human Reproduction and Development**

Human reproduction involves the fertilization of a female egg by a male sperm. Hormones regulate the development of the female's eggs and prepare the woman's body to nourish the developing embryo.

25.1 The Human Reproductive System 538
25.2 The Female Reproductive Cycle 542
25.3 Embryonic Development 544
25.4 Fetal Development 546
25.5 Birth Control 550

PART SIX • OUR LIVING ENVIRONMENT

556 

26 Ecosystems

Ecology is the study of the way organisms interact with one another and with their physical environment. A community of organisms, and the habitat in which they live, is called an ecological system, or ecosystem.

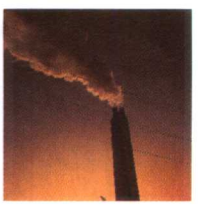
26.1 What Is an Ecosystem? 558
26.2 Energy Flows Through Ecosystems 559
26.3 Materials Cycle Within Ecosystems 562
26.4 Major Kinds of Ecosystems 567

582 

27 Living in Ecosystems

The species living in an ecosystem have evolved many accommodations to living together. This coevolution has made the members of ecosystems interdependent in many ways.

27.1 Population Dynamics 584
27.2 How Coevolution Shapes Ecosystems 588
27.3 How Ecosystems Develop Over Time 591
27.4 What Makes an Ecosystem Stable? 598
27.5 How Humans Disrupt Ecosystems 600

606 

28 Planet Under Stress

Our planet faces numerous problems that threaten its future existence, including chemical pollution on a global scale and nonsustainable use of the earth's nonrenewable resources.

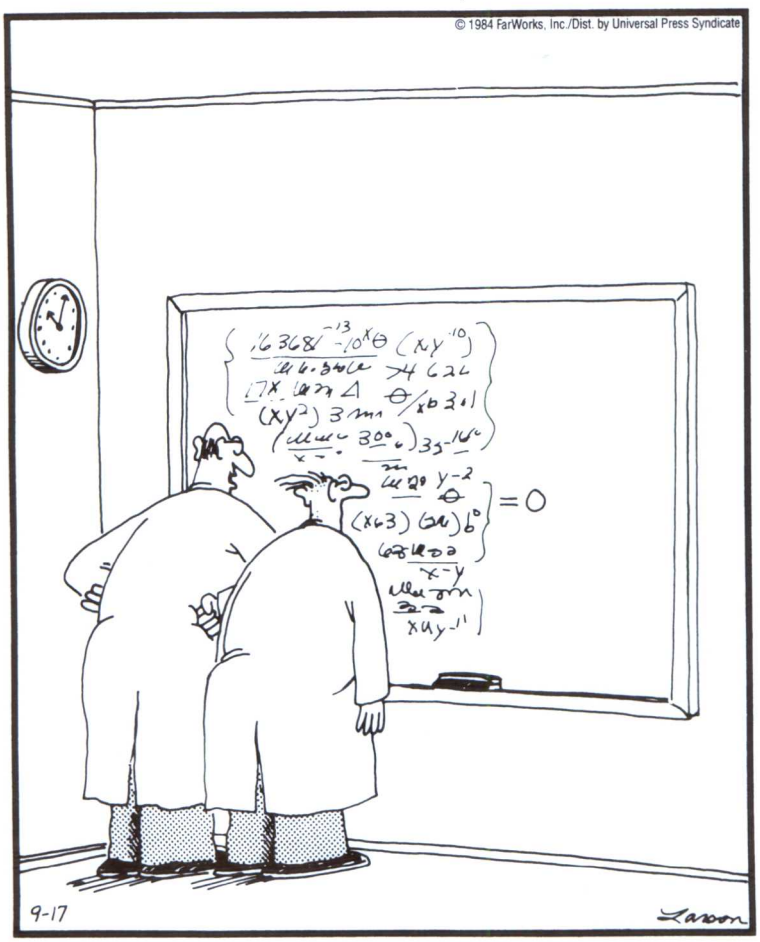
28.1 Global Change 608
28.2 Saving Our Environment 613
28.3 Solving Environmental Problems 620

Appendix A: Classification of Organisms 624
Appendix B: Answers to Concept Reviews 629
Glossary: Key Terms and Concepts 631
Credits 645
Index 648

1

The Science of Biology

THE FAR SIDE By GARY LARSON



"No doubt about it, Ellington—we've mathematically expressed the purpose of the universe. Gad, how I love the thrill of scientific discovery!"