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Animal Life



SN

Life

Beginnings of Life
Animal Life
Plant Life
Evolution of Life
Behavior and Ecology of Life

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Animal Biology, Behavior and Ecology

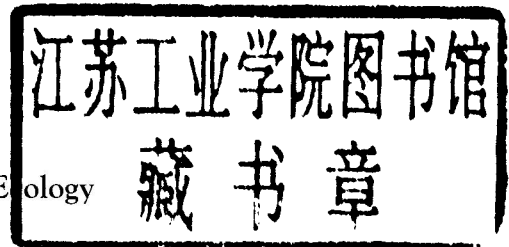
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Kevin Kane
Senior Editor
Biology

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The Life Learning System

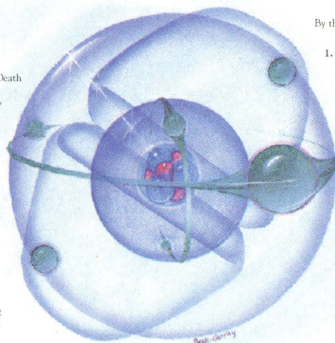
C H A P T E R

3

The Chemistry and Origin of Life

Chapter Outline

The Characteristics of Life
 Organization
 Metabolism
 Irritability and Adaptation
 Reading 3.1 The Definition of Death
 Reproduction
 What Is the Simplest Form of Life?
 Chemistry Basics
 The Atom
 Atoms Meeting Atoms
 Life's Chemical Components
 Characteristics of Water
 Water in the Human Body
 Organic Compounds of Life
 Inorganic Compounds in Life—Minerals
 The Origin of Life on Earth
 Spontaneous Generation
 Life from Space
 Common Ancestry
 Chemical Evolution
 Reading 3.2 Recipes for Starting Life—Simulating Early Earth Conditions



Learning Objectives

By the chapter's end, you should be able to answer these questions:

1. What characteristics distinguish living things from nonliving things?
2. What are the simplest forms of life?
3. What chemical components constitute living things?
4. What chemical compounds are important to human health?
5. How might living matter have evolved from nonliving chemicals?

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Key Concepts

At the ends of major sections within each chapter, summaries briefly highlight key concepts in the section, helping students focus their study efforts on the basics.

Dramatic Visuals Program

Colorful, informative photographs and illustrations enhance the learning program of the text as well as spark interest and discussion of important topics.

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Cell Biology

KEY CONCEPTS

The structural unit of an organism is the cell. Organisms are unicellular or multicellular. Complex cells contain specialized structures called organelles. All cells have structures in common to carry out basic life processes, but different numbers of organelles give cells distinct characteristics.

Viruses—Simpler Than Cells

The simplest form of life is a unicellular organism with no organelles, such as a bacterium. However, in chapter 3 we encountered several types of "infectious agents" that appear to be living while they are infecting cells but otherwise seem to be nonliving chemicals. Before describing how we examine cells and their contents, it is interesting to take a comparative look at the viruses, both to point out their noncellular organization and because they exert very noticeable effects on human health, causing such minor ills as colds and influenza and such deadly ones as AIDS. Reading 4.1 describes effects of the herpes simplex virus.

A virus consists of a nucleic acid (DNA or RNA) surrounded by protein. Figure 4.2 illustrates the human immunodeficiency virus (HIV), which causes AIDS. A virus must be within a cell to reproduce, and hence it is called an obligate parasite. Many viruses, such as HIV, cannot survive outside of a living cell. Some other viruses are afforded protection from the physical environment by their protein coverings. A virus reproduces by injecting its DNA or RNA into the host cell, where it situates itself within the host's DNA. In fact, viral DNA sequences can probably be found within your own chromosomes. (An RNA virus, such as HIV, is called a retrovirus and must first make a replica of its RNA in a DNA form.)

Once viral DNA integrates into the host's DNA, it can either remain there and be replicated along with the host's DNA whenever the cell divides, but not cause harm, or the viral DNA can actively take over the cell, leading eventually to the cell's death. To do this, some of the virus's genes direct the host cell to replicate viral DNA rather than the host DNA. As viral DNA accumulates in the cell, some of it is used to manufacture proteins. (Recall from chapter 3 that the function of DNA is to provide information from which the cell constructs proteins.)

Within hours or days, the

infected cell fills with viral DNA and protein. Some of the proteins wrap around the DNA to form new viral particles. Finally, a viral enzyme is produced that cuts through the host cell's outer membrane. The cell bursts, releasing new viruses.

Viruses are known to infect all kinds of organisms, including animals, plants, and bacteria. A particular type of virus, however, infects only certain species, which constitute its host range. (Refer back to figure 3.6 for an illustration of a tomato infected by the tomato bushy top virus.)

Figure 4.3 illustrates what happens to a moth infected by a type of virus called a baculovirus.

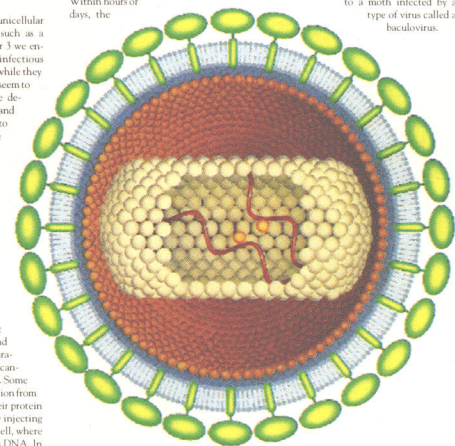


Figure 4.2

A virus is a nucleic acid coated with protein. The human immunodeficiency virus (HIV), which causes AIDS, consists of RNA surrounded by several layers of proteins. Once inside a human cell (usually a T cell, part of the immune system), the virus uses an enzyme to convert its RNA to DNA, which then inserts into the host DNA. HIV damages the human body's protection against disease by killing T cells and by using these cells to make more of itself. From "AIDS virus" (Janary 1987 cover painting), copyright © 1987, by Scientific American, Inc., George V. Kelnin, all rights reserved.

Chapter Outlines

Each chapter begins with an outline. These will allow students to tell at a glance how the chapter is organized and what major topics have been included in the chapter. The outlines include the first and second level heads for the chapter.

Learning Objectives

Each chapter begins with a list of concepts stressed in the chapter. This listing introduces the student to the chapter by organizing its content into a few meaningful sentences. The concepts provide a framework for the content of each chapter.

Reading 5.2 Liposomes—New Drug Delivers

In 1961, FLORENCE BANGHAM INVESTIGATED THE PROPERTIES OF LIPID BUBBLES AS PART OF HER RESEARCH ON MEMBRANE STRUCTURE. She was supposed to see that the lipid formed milk. Looking at the material under a microscope, Bangham saw that the phospholipid lipids had broken into thousands of tiny bubbles, each surrounding some of the water. The bubbles ranged in diameter from 150 Angstroms (Å) to several micrometers. They were named liposomes, meaning "bubbles of lipid."

What Bangham had discovered were microscopic spheres made of a simple lipid bilayer, identical to the structure that forms the basis of cell membranes. Some of the lipids even had more than one lipid bilayer coat, built a little like an onion skin. Throughout the 1960s, liposomes were used by cell biologists as models of cell membranes. In 1981, a young biologist named Marc Otter realized the potential of liposomes as drug carriers. Drugs that are soluble in water can be packaged in the watery interior of liposomes, drugs soluble in fat can be lodged within the lipid bilayer. The advantages of packaging a drug in a liposome are twofold—the drug can be released slowly from the liposome, and a way to direct the liposome to diseased cells can be found, drug delivery can be targeted. This would solve a major drawback of conventional drug treatment, that is, getting enough drug to the site of disease to be effective yet keeping it away from healthy cells, where it can cause side effects.

The natural reaction of the human immune system to liposomes provides a way to move them to sites of disease. Large scavenger cells of the immune system, called macrophages, are attracted to liposomes and rapidly engulf them. The

"swallowed" liposome is sent to a lysosome, where it is taken apart by enzymes. If the liposome contains a drug, some of it seeps into the cytoplasm and perhaps eventually out of the cell. The success of liposomes in carrying drugs lies in the function of macrophages, which normally congregate in spots of the liver, spleen, bone marrow, and lymph nodes and move to sites of inflammation or infection. Liposomes containing antibiotic drugs are engulfed by macrophages and transported to the infection site—precisely where they are needed. Liposomes harboring anti-inflammatory drugs are taken up by macrophages, so inflamed arthritic joints. Liposomes are also useful for delivering cancer drugs, which when given in "free" form cause severe side effects because they kill healthy cells as well as cancer cells. When such toxic drugs are encapsulated in

liposomes and injected, they accumulate in macrophage-laden places, where they leak out slowly and steadily enough to destroy the cancer cells but not the healthy ones. Liposomes are also used to treat infection, inflammation, and cancer are injected because they are not absorbed well into the digestive tract. The tiny bubbles are useful, however, in some topical applications. "Artificial tears," for example, are liposomes packed with tear components (water, salts, lipid, and a mucinlike substance) and sooth the irritating condition called dry eye. Another liposome-enclosed drug treats fungal infections in the female reproductive tract, and a hair growing drug treated in liposomes is used to treat pattern baldness. Because of their slow release, liposome-enclosed topical drugs are needed less often and are therefore less irritating.

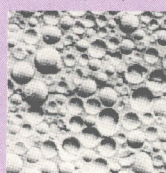


Figure 1 Liposomes are microscopic bubbles composed of lipid bilayers. They form spontaneously when certain concentrations of fatty molecules are mixed with water. The diameters of these liposomes are about 0.03 to 0.1 micrometers.

Membrane proteins and diverse. Some completely within the lipid bilayer, and others traverse it to extend out of one or both sides. In animal cells, membrane proteins are often held to the bilayer by hydrophobic molecules to form glycoproteins, which protrude from the membrane's outer surface (fig. 5.6). The proteins and glycoproteins

that jut from the cell membrane create the surface characteristics that are important to a cell's interactions with other cells. Proteins within the oily lipid sandwich can move about, like slow-moving ships at sea. The protein-lipid bilayer can also form a fluid mosaic because the proteins can move and are not regularly arranged, as are the

lipid molecules. A pigment protein found in the retina of a human eye, for example, moves to different depths within the lipid bilayer of the cell membrane depending upon the intensity of the incoming light. Figure 5.7 illustrates the membrane characteristics of another specialized cell, the red blood cell.

Readings

Throughout Life, selected readings both elaborate and entertain. Some describe experiments, some provide health information, and others are closer looks at specific topics. All readings are written by the author.

Unlike bacteria, cyanobacteria contain internal membranes that are outgrowths of the cell membrane. These membranes, however, are not extensive enough to subdivide the cell into compartments, as membranes do in more complex cells. The cyanobacterial membranes are studded with pigment molecules that absorb and extract energy from sunlight.

Cells require relatively large surface areas through which they can interact with the environment. Nutrients, water, oxygen, carbon dioxide, and waste products must enter or leave a cell through its surfaces. As a cell grows, its volume increases at a faster rate than does its surface area, a phenomenon that you can easily calculate (fig. 4.8).

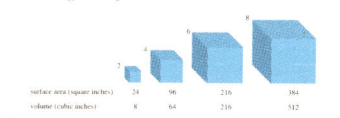


Figure 4.8 The important relationship between surface area and volume. As a cell grows larger, the amount of material inside it (its volume) increases faster than the area of the cell's surface. The surface of a cell is vital to its functioning because that is the site of communication between the cell's interior and the extracellular environment. The chemical reactions of life are more readily carried out when surface area is maximized. Imagine that a cell is a simple cube. Compare the surface area and volume of four increasingly larger cubes. (Surface area and volume of each face that multiplied by the number of faces; volume equals the length of a side cubed.) Can you see that volume increases faster than surface area?

Table 4.3 Comparison of Prokaryotic and Eukaryotic Cells. The table compares characteristics like cell size, DNA location, and membrane structure between prokaryotic and eukaryotic cells.

KEY CONCEPTS: Cells exhibit characteristics of life. Prokaryotes include the bacteria and cyanobacteria and are unicellular organisms. Eukaryotes include the plants, animals, and fungi. DNA is free of protein and located in the nuclear area. Ribosomes are present in all membranes derived from the plasma membrane.

The Eukaryotic Cell: Another cellular solution to the problem of increasing size is to divide into compartments, or organelles. Much as a growing store is subdivided into departments, organelles are established by biological membranes, which are themselves composed of lipids and proteins. Organelles have access to the environment outside the cell and to each other by networks of hollow tube-like structures called vesicles (or vacuoles) that bud off from the membranes. Cells that have organelles are termed eukaryotes. The typical eukaryotic cell, which is roughly 1,000 times the volume of a typical prokaryotic cell, would not be able to function efficiently were it not for the division of

Tables

Numerous strategically-placed tables list and summarize important information, making it readily accessible for efficient study.

Boldfaced Words

New terms appear in boldface print as they are introduced within the text and are immediately defined in context. If any of these terms are reintroduced in later chapters, they are italicized. Key terms are defined in the text glossary with appropriate page reference.

To Think About

Located at the end of each chapter, these questions are springboards for class discussions and term paper topics.

TO THINK ABOUT

Many of our discussions about the foods we eat, the medicines we take, and the activities we participate in are based, in part, upon health information. Some of this information comes from well-executed studies that adhere to the scientific method, but some comes from flawed investigations. For each of the following real-life examples, state whether or not the scientific method was followed. If it was not, indicate which of the following specific faults was present: a. Conclusions not supported by experimental evidence; b. Inadequate control; c. Biased sampling; d. Inappropriate extrapolation of the experimental group to the general population; e. Sample size too small; f. Other problem. 1. I ran 4 miles (approximately 6 kilometers) every morning when I was pregnant with my first child... 2. A large pipe in the small town of Love Canal, New York, was used for the disposal of industrial chemical wastes for several years... 3. A large pipe in the small town of Love Canal, New York, was used for the disposal of industrial chemical wastes for several years... 4. Each year, 50,000 American men join the 10 million who have already had a vasectomy, a simple sterilization procedure... 5. The National Cancer Institute (NCI) sponsors clinical trials at its Maryland headquarters and in several research centers around the country... 6. A former NCI researcher was bothered by the practice of turning down large numbers of cancer patients who wanted to participate in clinical trials...

There is a little bit of the scientist in each of us. We can all observe, form hypotheses, plan and carry out an experiment, and attempt to interpret and use the results. However, your observations and ideas concerning the living world will be more meaningful if you have more extensive experience and learning on which to build. This book and your biology course will provide you with that valuable background. With it, you will be better equipped to apply the systematic approach of the biologist to your own observations of the living world. Indeed, you will soon

SUMMARY

Understanding the unity and diversity of living things through the study of biology can help us to appreciate our position in the living world. Biologists study life by applying the scientific method, in which observation and reasoning are used to make an educated guess, or hypothesis. One or more experiments are conducted to test the validity of the hypothesis, including experimental controls to ensure that only one phenomenon is being examined at a time. The experiment is usually repeated to test its accuracy, and then conclusions are drawn. Conclusions add to knowledge, but they also usually lead to more questions, and then the cycle of scientific inquiry begins anew. Application of the scientific method does not always yield a complete answer to a question. A scientific investigation may be based on existing information, as in an epidemiological study, or it may be based on

QUESTIONS

- 1. Read the following passage and identify the steps of the scientific method. In 1953, a graduate student named Stanley Miller combined various chemicals in the presence of electrical sparks and heat, similar to conditions on earth before life existed. From the brew formed complex chemicals known to be important to the chemistry of living things. In 1981, geologists discovered openings in the ocean floor where the water is extremely hot compared to the surrounding water. They found simple chemicals there, which they knew from Miller's experiments could react to yield the chemical components of living things. Several researchers suggested that life could have originated at these deep sea vents, because the chemical building blocks of life were present, plus the ocean would have protected the delicate precursors to life from the damaging ultraviolet rays, and microbes that lurk there. In 1985, Stanley Miller, now a chemist at the University of California at San Diego, challenged the popular idea that life began in these oceans, but soon. Based on his knowledge of chemistry, Miller thought that the complex chemicals that might form under the suggested conditions would be unstable at the very high temperatures and decompose too rapidly to allow life to form. To test his idea, Miller conducted an experiment similar to what he had done as

information generated specifically for the investigation, as in studies using experimental organisms. Each method has its advantages and disadvantages. Many answers to scientific questions are unusual or unexpected, and some are stumbled upon accidentally. Overall, the scientific method provides a systematic approach to exploring the living world. In addition, we often practice the method in our everyday lives without being aware of it.

A chemical manufacturing plant closes down because a toxic substance, which was burnt on the plant property a decade earlier, is now leaking from its containers. To examine the effects of the contamination, a survey is distributed among workers and town residents, inquiring about their health problems and asking them whether or not they believe that they were exposed to the chemical. What can be learned from this type of study? What are its limitations?

- 4. Animal models often provide an effective means of testing substances and procedures that are not yet well enough understood to be used on humans. Many people object that pain is inflicted on the animals used for such purposes. However, in what has been called the "Bambi Factor," such objections raise the question of "cruel organisms, such as rabbits and dogs, rather than the fruit flies, leeches, rats, and other less appealing organisms that are also used experimentally. What limits, if any, do you think should be placed on animal experimentation? What technique mentioned briefly in the chapter might be considered a compromise? 5. Scientists traditionally report their research findings in journals. Go to your science library to consult a biology research journal, and try to find an article that you can follow well enough to identify the steps of the scientific method.

Chapter Summaries

At the end of each chapter is a summary. This should help students more easily identify important concepts and better facilitate their learning of chapter concepts

Questions

The end-of-chapter questions often continue the storytelling style of the chapter, using anecdotes and experiments from the chapter to illustrate and apply concepts.

SUGGESTED READINGS

- Dagen, Ron. November 12, 1984. In vitro methods may offer alternatives to animal testing. Chemical and Engineering News. Traditional product tests using live, whole animals are being replaced with tests using animal cells and tissue. Karpel, Robert. January/February 1987. Spectrum no. 1913. The Science: A 60's best life in the service of science—from its roots of war to its contemporary and increasingly straggling account of the use of animals in experiments. Larkin, Tim. June 1985. Evidence vs. anecdote: A guide to the scientific method. FDA Consumer. The scientific method is fine, in theory, in practice, it is sometimes difficult to implement. Lucas, Chris W. February 1985. Success stories: Methods may offer alternatives to animal testing. Chemical and Engineering News. Traditional product tests using live, whole animals are being replaced with tests using animal cells and tissue. Lewis, Robert. September 1984. Doxins danger? Doxins danger. Just how harmful to humans health is doxins, a chemical contaminant of the herbicide Agent Orange? Different types of studies give different answers. Segal, Martin. June 1990. Is it worth the risk? A strong risk. FDA Consumer. The scientific method is a major part of risk assessment. Thompson, Richard C. December 1986/January 1987. Footnote human genes. FDA Consumer. How people participate in testing new drugs or medical devices. Weseloh, Scott. May 23, 1987. AIDS vaccines: The problem of human testing. Science News. Testing a vaccine is always controversial because healthy people must be the recipients. In the case of deadly AIDS, the situation is even more serious. Young, Frank E. June 1987. Experimental dogs for the dangerously ill. FDA Consumer. The fumes from the FDA speak out on lowering the scientific method in cases of hopeless illness. Zamwalt, Elmo. III. June 1987. A war with hope. Health. An anecdotal look at the possible dangers to health of doxins vs. a Vietnam veteran suffering from several types of cancer.

Suggested Readings

A list of readings at the end of each chapter suggests references that can be used for further study of topics covered in the chapter. The items listed in this section were carefully chosen for readability and accessibility.

Preface

Life was written with the nonbiology major in mind, but contains enough information to be suitable for a majors' course too.

Diversity in Action

While human examples and applications are emphasized, *Life's* diversity is treated early in a separate chapter, later in an appendix on taxonomy, and is logically integrated into all chapters. The animal biology chapters, for example, explore a deep-sea shrimp's vision, an insect's exoskeleton, a cow's digestion, and much more. The behavior and ecology chapters are filled with glimpses into the lives of a variety of organisms, from aardwolves to fire ants to naked mole rats. The reader of *Life* will learn many new things, but also encounter familiar territory. The science of biology will not seem foreign—it will be fun and make sense.

Discovery and Evolution

Two conceptual threads weave their way through *Life*. The book opens with the first theme, discovery. The story of how the sweetener aspartame was discovered takes the student through the scientific method and experimental design, yet points out how the initial detection of the food additive was very much a surprise.

In chapter 2, "The Diversity of Life," taxonomy is alive and vibrant in the treetops of a Peruvian wildlife preserve, where biologists catalog the abundance of insect life; and in such an unlikely place as an urban fish market. A pair of children playing with spectacles led to the development of the compound microscope, as described in chapter 4. In chapter 6, "Biological Energy," the student can be the discoverer by using the reactions of photosynthesis to develop a photograph on a leaf. The inborn errors of

metabolism, PKU (chapter 15, "Genetic Disease: Diagnosis and Treatment") was discovered thanks to a mother's alertness of her infant's odd-smelling diapers. And a simple treatment for newborn jaundice (chapter 24, "The Digestive System") was discovered by an observant English nurse changing "nappies" in the sunlight. Chapter 15 also tells the story of how a seemingly drunken sailor and his 5,000 living descendants helped provide the first genetic marker.

Not all discovery is accidental. The look at "Molecular Genetics" in chapter 13 is liberally sprinkled with descriptions of the most elegant experiments ever performed. The scientific method is reviewed in chapter 36, "The Behavior of Individuals," as students at the University of Miami track singing birds, and in chapter 38 "Populations," through ecologists conducting wildlife surveys. The creation of an artificial mini-biosphere, described in chapter 39 "Ecosystems," is an exciting view of scientific investigation—whether it works or not.

The second conceptual thread, evolution, accustoms the reader to continually wonder, "How did all of this happen?" How did a duo of protein and nucleic acid join forces long ago to form the first cell? How could random mutations in those early cells build the metabolic pathways of today? How did eukaryotic cells come by their highly successful "bags within a bag" organization? How do species arise, change, become extinct? How have our ideas about evolution themselves evolved?

Humor, History, and Human Values

An occasional foray into humor can help students learn. Consider the example of epistasis in chapter 11, borrowed from the soap opera "Gen-

eral Hospital," or the opening to chapter 34 "The Forces of Evolutionary Change," a love story between a moose and a dairy cow.

Historical references add interest and chronicle the evolution of ideas. The confusing multiple phenotypes of the blood disorder porphyria, for example, may have led the "mad king" George III to provoke the American Revolution. The study of genetics begins with early agricultural efforts nearly 10,000 years ago. How different were Edward Jenner's problems with how best to test his smallpox vaccine (chapter 28, "Plants Through History") from today's scientists' attempts to test AIDS vaccines? The state of the American temperate forest today reflects pioneer activity over the past centuries. Recent history brings the ecology chapters alive, from Mt. St. Helens to the Yellowstone fires to the nuclear explosion at Chernobyl.

Examining human values teaches the student to develop informed opinions and judgments about biologically relevant issues—a skill that will last long after the steps of glycolysis or the parts of the cell are forgotten. Should a pregnant woman who smokes or drinks alcohol be responsible for the health effects on her fetus? Should an employer be told the results of an employee's genetic marker test for Alzheimer's disease? Should we take extraordinary measures to save extremely premature babies if they will be handicapped after (or by) the treatment? Should we even attempt to clean animals drenched in oil from tanker spills? Should we limit reproduction? These disturbing queries are most often found in the "To Think About" sections at the chapters' ends, both so that they will not distract from learning major facts and concepts and so that the student is left thinking.

Integrating Technology

Technology has given new, exciting meaning to some difficult subjects. Discussing the development of extraembryonic structures segues into a peek at chorionic villus sampling. Liposomes are but an extension of cell membrane structure and function. Teaching DNA replication is no longer a hurdle, now that we have the polymerase chain reaction to demonstrate elegantly the power of the process. Filling in the details of food webs no longer requires being on the scene of a meal, thanks to stable isotope tracing (chapter 39, "Ecosystems").

The chapters on plant anatomy and physiology are bracketed by two unique applications chapters—chapter 28, "Plants Through History," chronicles our harvesting of the major crop plants, and chapter 32, "Plant Biotechnology," looks at how molecular and cellular techniques are likely to continue that harvest, via the genetic alteration of plant life.

Finally, Appendix A, "Microscopy," provides a closer look at the technology that really breathed life into biology, from the first crude lenses to today's powerful confocal microscopes. Yet the very technology that has taught us so much and made our lives so comfortable can get out of control, upsetting the delicate balance of life. Chapter 40 "Environmental Concerns," describes these problems, but emphasizes natural resiliency, leaving the reader, ultimately, with a sense of hope and purpose:

"This book has shown you the wonder that is life, from its constituent chemicals, to its cells, tissues, and organs, and all the way up to the biosphere. Do nothing to harm life—and do whatever you can to preserve its precious diversity. For in diversity lies resiliency, and the future of life on earth."

Pedagogy

A great deal of creative energy has gone into the pedagogical aids, and some are quite different from those in the run-of-the-mill textbook. (For a visual walkthrough of these aids, examine the *Life Learning System* preview in this book's frontmatter.) The end-of-chapter "Questions" often continue the storytelling style of the chapter, using anecdotes and experiments from the literature to illustrate and apply concepts. The "To Think About" questions are springboards for class discussions and term paper topics. "Suggested Readings" go far beyond *Scientific American* and other textbooks, including sources such as *Science News*, *FDA Consumer* and the *New York Times*—sources that students are more likely to read, understand, and appreciate.

"Learning Objectives," which open the chapters, "Key Concepts" following major sections, and end-of-chapter summaries reinforce main points.

"Readings" throughout the chapters both elaborate and entertain. Some describe experiments: "Enticing Cells to Divide in the Laboratory," "Recipes for Starting Life—Simulating Early Earth Conditions," "Tracking Development in Different Organisms;" some provide health information, "Cardiovascular Spare Parts," "Jon and Linda—The Plight of an Infertile Couple," "Our Overdrugged Elderly," "Steroids and Athletes—An Unhealthy Combination," "The War on Cancer;" others are closer looks, "A Closer Look at an Organelle—The Lysosome," "Tumor Necrosis Factor," "Odd Human Traits," or "The Herpes Simplex Virus." Some are practical, "Nutrition and the Athlete," "Food Inhalation and the Heimlich Maneuver" and many highlight diversity "Falling Felines," "Rumbles, Roars, Screeches, and Squeals—Animal Communication," or "Sexual Seasons."

Ancillaries

Instructor's Manual/Test Item File

Prepared by Heather McKean and James Hanegan of Eastern Washington University, the instructor's manual offers helpful suggestions for course outlines and developing daily lectures. Each chapter provides key concepts, key terms, chapter outlines, learning objectives, answers to the text's end-of-chapter questions, and suggested audiovisual materials. There are also 25 to 50 objective questions in a *Test Item File* in the back of the manual. (ISBN 0-697-10181-9)

Laboratory Manual

Written by Alice Jacklet, a colleague of mine at SUNY-Albany, the *Laboratory Manual* strongly emphasizes and guides students through the process of scientific inquiry. Beautifully illustrated in full-color, it features 20 self-contained exercises that can easily be reorganized to suit individual course needs. (ISBN 0-697-05637-6)

Laboratory Resource Guide

This helpful prep guide offers instructions for assembling lab materials and preparing reagents, as well as suggestions for using the Lab Manual in different kinds of lab settings. (ISBN 0-697-10178-9)

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Readings in Biology

A compilation of original journal and magazine articles by Ricki Lewis is also available to students at a nominal price. The readings, which correlate closely with the sequence of topics in the text, present additional high-interest information on cell biology, genetics, reproduction, and animal biology. (ISBN 0-697-12059-7)

Student Study Guide

Also written by Heather McKean and James Hanegan, the study guide offers students a variety of exercises and keys for testing their comprehension of basic as well as difficult concepts. (ISBN 0-697-05636-8)

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by *Judith Getis*

This short, inexpensive supplement offers students practical guidelines for recycling, conserving energy, disposing of hazardous wastes, and other pollution controls. It can be shrink wrapped with the text, at minimal additional cost. (ISBN 0-697-13923-9)

How to Study Science

by *Fred Drewes, Suffolk County Community College*

This excellent new workbook offers students helpful suggestions for meeting the considerable challenges of a science course. It offers tips on how to take notes; how to get the most out of laboratories; as well as on how to overcome science anxiety. The book's unique design helps to stir critical thinking skills, while facilitating careful note-taking on the part of the student. (ISBN 0-697-14474-7)

The Life Science Lexicon

by *William N. Marchuk, Red Deer College*

This portable, inexpensive reference helps introductory-level students quickly master the vocabulary of the life sciences. Not a dictionary, it carefully explains the rules of word construction and derivation, while giving complete definitions of all important terms. (ISBN 0-697-12133-X)

Biology Study Cards

by *Kent Van De Graaff, R. Ward Rhees, and Christopher H. Creek, Brigham Young University*

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by *Tully Turney, Hampden-Sydney College*

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Acknowledgments

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