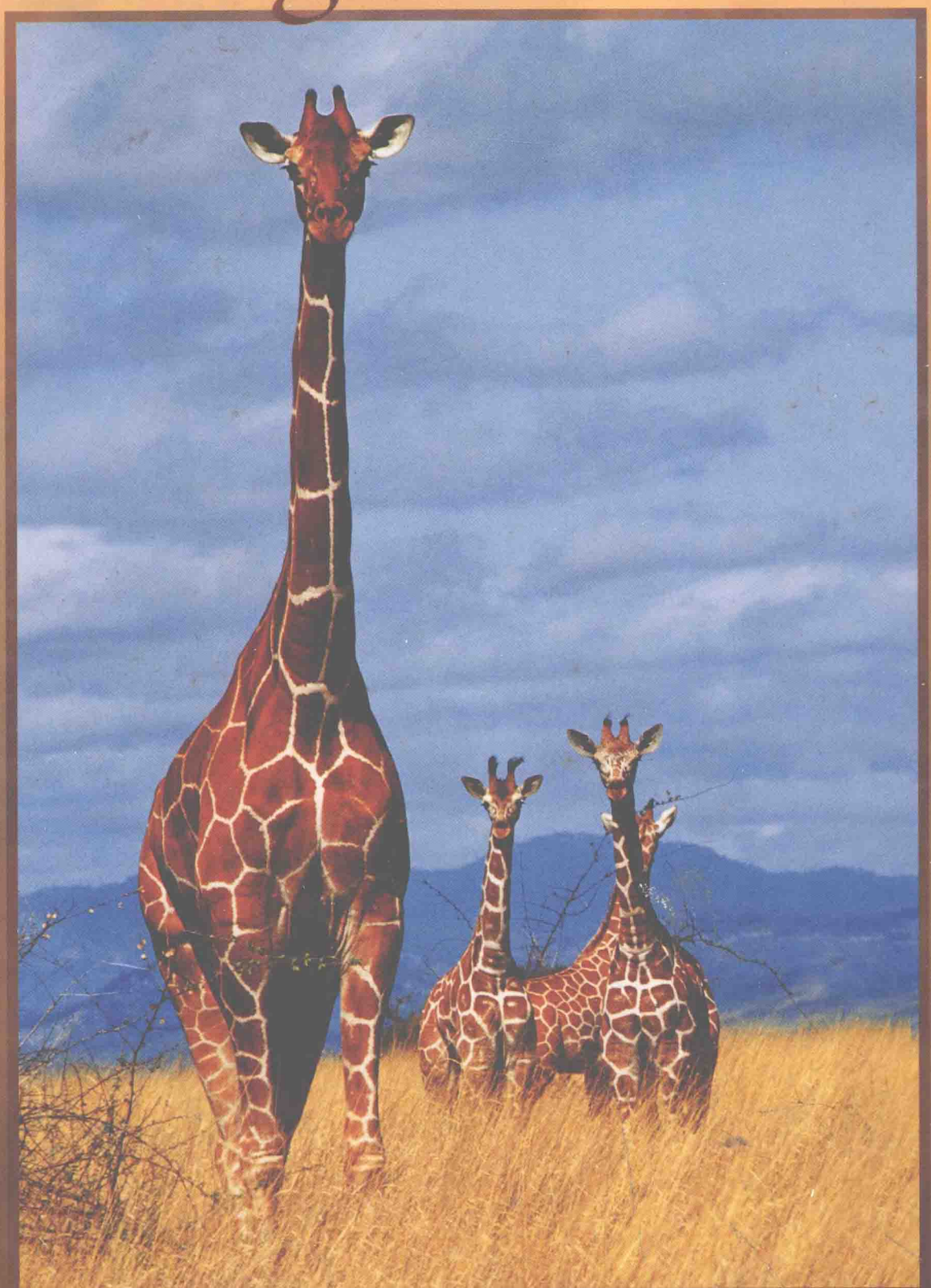
Asking About Life



TOBIN & DUSHECK

Asking About Life

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ABOUT THE COVER

Like humans, many animals are curious about the world around them. These giraffes are obviously intrigued by the activities of the photographer and seem to be studying the reader. Three hang back hesitantly, but the fourth has moved forward, fearless and determined to find out what's up. That attitude typifies the best science and exemplifies the questioning theme of *Asking About Life*.

The giraffes also remind us of Lamarck's theory of evolution and how human is the scientific enterprise. Like many modern scientists, Lamarck suffered humiliating rejection by his peers. Charles Darwin's efforts to avoid a similar fate inspired him to build an irrefutable and monolithic theory of evolution that modern biologists accept nearly as Darwin wrote it. (*Mitch Reardon/Tony Stone Images*)

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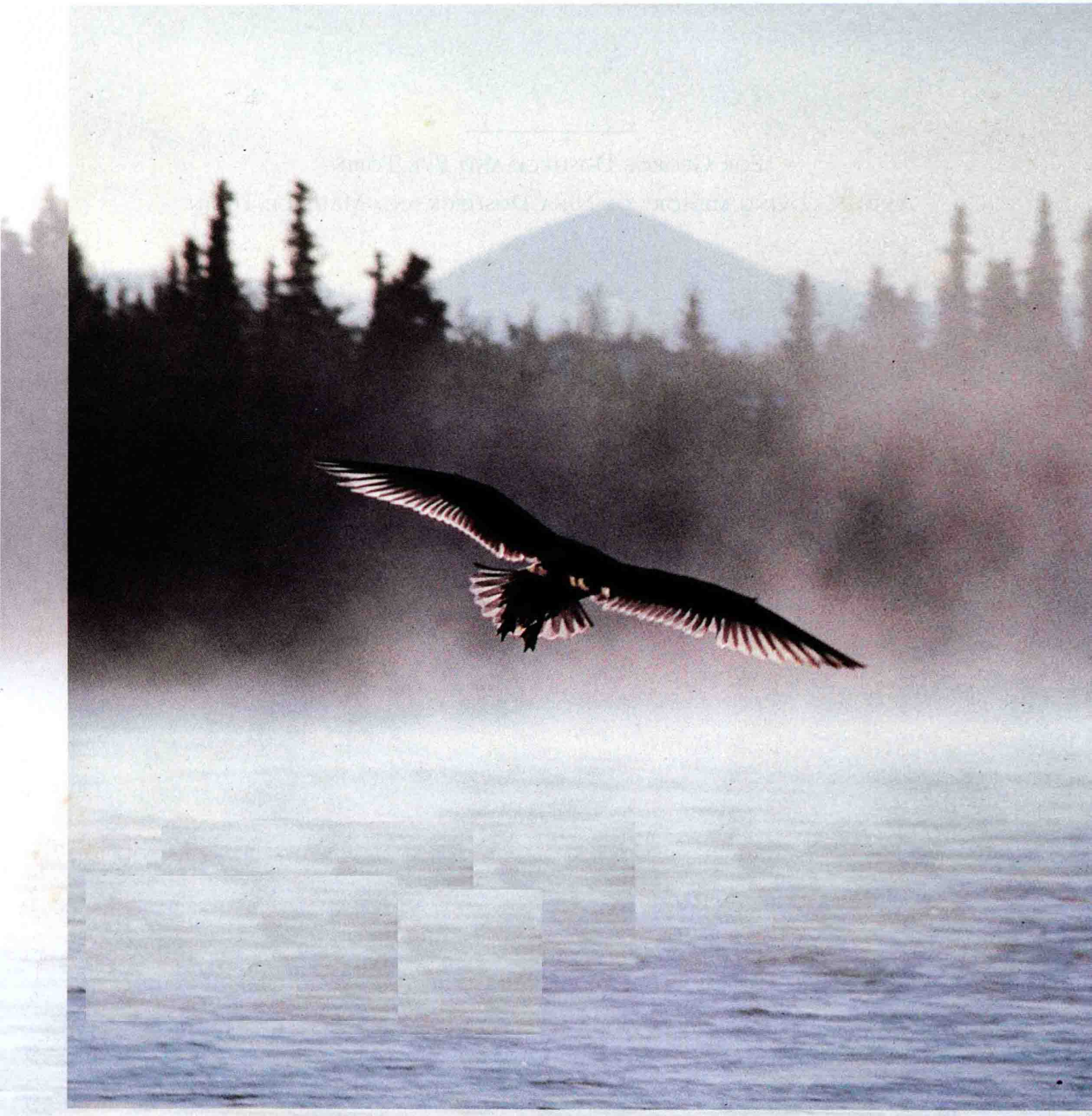
For George Dusheck and Eve Tobin

And in loving memory of Nina Dusheck and Maurice Tobin



PREFACE

When Charles Darwin published *The Origin of Species* in 1859, the first edition sold out overnight. His revolutionary theory of evolution was of interest not only to his fellow scientists, but to great numbers of ordinary people, who avidly read *The Origin* and argued over the details of the theory.

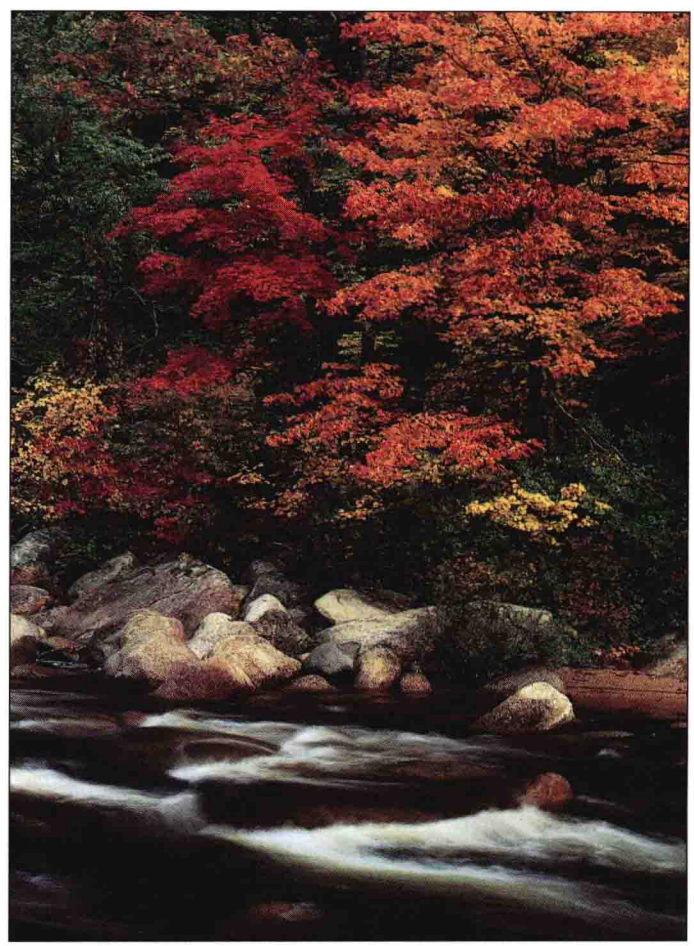
Today, public interest in biology is even greater. When a previously unknown Scottish biologist cloned the first mammal, a sheep, in February of 1997, the story made front-page headlines all over the world and sharply increased the value of biotechnology stocks overnight.

Biology is a discipline in full flower. Biologists now have the capacity to understand the workings and the interactions of organisms and—at the cellular level—to alter them, almost at will. Biologists have bred new crops, discovered the frailties and strengths of precious ecosystems, developed new treatments for diseases, and begun to solve many puzzles of the human mind.

Spectacular as these developments are, they are a mixed blessing for instructors and their students. The sheer numbers of facts can be overwhelming. How, for example, can we remember the difference between a missense mutation and a nonsense mutation? Between a plasmodial slime mold and a cellular slime mold? And why should we care?

Yet, to make the simplest decisions in the 21st century, you will need to understand how science works and, at least, the basics of biology. If you are sick, should you take an antibiotic? If one of your parents has a genetic disease, should you be tested for the disease-causing allele? If the vacant lot down the road is to be turned into a playing field, should the creek that runs through it be preserved? Is there any harm in running the creek through an underground, concrete culvert? The answers to all of these questions and hundreds of others depend on the ability to understand and evaluate scientific arguments.

The greatest barrier to understanding science is the common perception that science is inaccessible to ordinary folks. We know that it is accessible. It's about asking questions, getting a partial answer, then asking another question.



Stephen J. Krasemann/Photo Researchers

What Is *Asking About Life* About?

Asking About Life is about curiosity. Our very title stresses our conviction that questions are what drive the process of science. The history of science reveals that while the answers to questions change over time, the questions themselves, if they are good ones, remain the same. One good question has been "How do new species form?" Biologists have been trying to answer this question for 150 years. But it is a question with many answers. And the answers that seemed correct in 1880 or 1960 continue to be refined, expanded, or even overthrown.

Asking About Life consistently emphasizes the importance of questions and the process of finding answers. To remind ourselves and our readers of this, headings and subheadings are more often questions than statements.

The task of student and scientist alike is to ask questions as insistently as possible and to answer them as cleverly as possible. While we understand that the "facts" of biology are important, science progresses only by discovering new relationships of facts to questions: the difference between a nonsense mutation and a missense mutation takes on pressing significance if a relative has a disease caused by a genetic mutation. Suddenly, we find it much easier to remember why a missense mutation often does no harm, while a nonsense mutation nearly always does harm. Just hearing a story about someone with a genetic disease would help us remember why this distinction is important. In learning, story and context (whether emotional or historical) are everything.

Throughout our book, we have emphasized the story behind scientific discoveries. *Asking About Life* illustrates the passion of the scientific enterprise by beginning each chapter with a story about a piece of research. Each story illustrates how an individual biologist pursued a scientific question, often in the face of intellectual or social adversity—how, for example, Barry Marshall convinced first himself and then others that bacteria, not stress, cause ulcers; and how Rosalind Franklin struggled in deep social isolation to elucidate the structure of DNA. Our anecdotes are about real people—their triumphs, their frustrations, their genius, and their persistence.

The story of how biologists came to ask a question and how they went about answering that question helps us remember not just one fact, but all the facts and ideas associated with that question. All the stories illustrate that science is both an intellectual endeavor and a social one. Scientists must not only ask and answer questions, they must also persuade their colleagues that their answers are correct and interesting. The most successful scientists are often the most sociable ones—though not always.

We have tried to make our stories lively and engaging. Asking and answering questions about life is a job for the most lively and engaged of humans. Biology is not a mysterious activity performed by those who are remote, calculating, or cold. It is an exquisitely human endeavor in which enthusiastic beginning students can participate as fully as veteran scientists. In fact, the fresh view of the engaged beginner sometimes unlocks puzzles that have stumped seasoned scientists for years, as illustrated in the story about Walter Sutton in Chapter 9.

The flowering of biology in the late 20th century has already produced new seeds for the 21st. It is our hope that student readers of *Asking About Life* will be able to nurture and appreciate the growth of new ideas that we feel will dominate the intellectual and economic landscape of the next generation.

What Is the Philosophy Behind *Asking About Life?*

In some respects, the philosophy of our text runs counter to current trends in textbook construction. Many textbooks now break information up into self-contained units. Each bit of information is presented as if unrelated to the information in the rest of the book. Much information is tucked into separate illustrations, with no text to weave disparate facts together. The rationale for this is that today's students belong to the "visual-information" generation and are incapable of sustained reading.

We have more faith in students. We know they can read, and even enjoy reading, provided the reading is interesting and rewarding. Our philosophy is that biology is a story, and, as such, it must be presented as continuously as possible. Each section of the book includes background information, usually historical, that provides a context for current research.

For example, in the introductory chapter to the section on Diversity, where we discuss different systems of classification, we show students that biologists have been arguing about the definition of a species for nearly 200 years. In the previous section, we have emphasized Darwin's frustration in defining species of barnacles when he could see that many species blended one into the next. In that context, the opening story in the Diversity section about the current and highly politicized debate over whether the red wolf is a species or a hybrid makes sense. At the same time, the red wolf story brings to life what would otherwise be an abstract discussion of classification.

In this context of questions and process, we naturally emphasize the experimental nature of science. Relying on headings that are phrased as questions, we lead students from one critical experiment to the next. Students learn not only the results of experiments, but why biologists asked certain questions and how they discovered the answers. In Chapter 10, for example, we do not content ourselves with describing the structure of DNA, but lay out for the student all the clues that Rosalind Franklin, James Watson, and Francis Crick used to deduce DNA's structure. The reader thus experiences anew the excitement of the original discovery.

Throughout the book we emphasize current research wherever appropriate. As a result, instructors have the opportunity to discuss with their students topics appearing in the daily news. The chapter on human genetics, for example, focuses heavily on current debates about policy and ethics in the application of genetic techniques to human disease and reproduction.

Naturally, we also try to minimize abstract discussions through the use of metaphors and analogies. For example, in our discussion of the movements of chromosomes during mitosis and meiosis, we compare the pairs of chromosomes to pairs of socks going through the laundry. In our discussion of osmosis, we compare the swelling of cells in a hypotonic solution to the swelling of raisins in a pot of water. And in Chapter 3, we compare functional groups—the small chemical groups that give molecules their characteristic chemistries—to the different parts of a Swiss Army knife.

More than in other texts, the art program in *Asking About Life* makes such metaphors visual—leaving the student with memorable and often amusing images. Vivid illustrations help fix otherwise abstract ideas in our minds in the same way a

mordant fixes a dye. For example, many books compare the structure of tRNA to a clover leaf. Only *Asking About Life* actually shows the clover leaf—complete with stem and leaflets—folded into the classic "L" shape. In the same chapter, Chapter 11, the ribosome is depicted as a sewing machine that stitches together amino acids to form polypeptides.

In Chapter 34, a drawing of a mouse with an 8-inch fur coat helps students remember that the metabolic rates of small animals must be much higher than those of large ones. Wherever possible, we have used visual metaphors and other striking images that act as icons for ideas.

Each chapter begins with an image, either a photograph or drawing, that was chosen to complement the opening story or to sum up a theme of the chapter. These are not captioned and are intended to be brain-teasers for the reader, who may find it fun and interesting to guess the connection being made.

For instance, the opening image for Chapter 1—the dinosaur in the egg—represents evolution and the continuity of life. The dinosaur, not unlike a modern barnyard chick, illustrates how life continues from generation to generation. Life changes and yet stays the same.

In Chapter 3, the thousands of Lego™ pieces in the Legoland elephant symbolize the building blocks of life. Similarly, just a few molecules combine to make the large molecules that make up all organisms.

In Chapter 5, the rusting car symbolizes entropy, the concept that ordered systems and structures tend to become disordered over time.

The chapter-opening images for all 44 chapters are identified and their significance is explained in the Teaching Suggestions section of each chapter in the *Instructor's Manual*.

We regard illustration as a teaching tool in its own right, not just a backup for the text. In this, we have been privileged to work closely with two outstanding illustrators—Elizabeth Morales and Elizabeth McClelland—whose skill, attention, and insight have contributed not only to the art manuscript but to the text as well. Morales, the book's art developmental editor, created a friendly style that perfectly complements our informal text. Her clean designs and simple illustrations greatly clarify sometimes difficult material. In addition, Elizabeth McClelland contributed dozens of beautifully rendered illustrations of animals and plants, as well as many excellent diagrams throughout the book.

What Kinds of Pedagogy Does *Asking About Life* Employ?

Asking About Life has a variety of features designed to engage the reader and to aid student learning:

Each chapter begins with a story about a piece of research that draws students into the subject of the chapter and also introduces the key questions and ideas that are discussed.

Within or after each chapter story, readers will find a list of **Key Concepts**, which are some of the most important and basic ideas covered in the chapter.

Headings are often posed in the form of questions throughout each chapter. These question headings focus the reader's attention on the most significant question to be explored in that section.

Subsections are followed by **Summary Statements**—brief summaries of the take-home message. These provide students with a reality check. If the student doesn't understand the summary statement, that is a cue to study the preceding material more closely.

Drawings and photographs support concepts covered in the text and help students visualize the structures of objects as diverse as molecules and ecological communities. Photographs of structures that are too small to be seen with the naked eye are accompanied by size bars to give a sense of scale.

Figure legends are designed to stand alone, so that even a student flipping through the chapter for the first time, glancing at the diagrams and reading the captions, will come away with some important information.

Visual metaphors in the illustrations drive home key points introduced in the text.

Boldface terms throughout the text help students to locate key terms and their definitions.

Tables and **graphs** summarize key facts and additional material.

Most chapters feature one or more **Boxes**, which discuss some topics in greater depth or bring into sharper focus a piece of especially important research. In Chapter 12, which focuses on viruses and jumping genes, a box discusses current interest in the old idea of using bacteriophages as a therapeutic treatment for bacterial infections in humans. Chapter 26, on ecological succession, features a box on forensic ecology—the technique by which coroners determine when a person died by using the stages of development of different insect larvae found on a corpse.

The end of each chapter features a **Study Outline with Key Terms.** All of the boldface terms found in the chapter are used again in a highly compressed summary. This provides students with another opportunity to check their understanding of the chapter. If they encounter terms they don't remember or ideas that seem unfamiliar, they can return to the main text and illustrations.

The Study Outline is followed by a set of **Review and Thought Questions**. Our Thought Questions are especially engaging, frequently bringing ideas in the chapter into the everyday world.

Selected Readings emphasize readings in science that are accessible to a general audience and available in any good library. The majority of the readings are books, most of which the authors of *Asking About Life* have themselves enjoyed. The readings are intended as thought-provoking pleasure reading, not as grist for term papers. Class papers can always be researched in the conventional way—at the library, or increasingly, online.

An appendix on standard weights and measures is provided for student reference (Appendix B).

A **Glossary** provides a complete list of Key Terms and their definitions.

Supplements

To further facilitate learning and teaching, a supplements package has been carefully designed for the student and instructor.

The **Study Guide** by Lori Garrett of Danville Area Community College includes Chapter Objectives that restate the Key Concepts of the text as material to be mastered, Key Concepts, an Extended Chapter Outline that gives an overview of the most important topics covered in the chapter, Vocabulary Building exercises, and Chapter Tests. Each Chapter Test has five parts: Multiple Choice; True/False; Matching; Short Answer; and Essay/Thought Questions. All answers are provided, with the exeption of the Essay/Thought Questions.

The **Instructor's Manual** by Michael Ulrich of Elon College includes an introductory section of classroom teaching suggestions, research paper grading criteria, and evaluation procedures. Each chapter has Lecture Outlines; all the answers to the Review and Thought Questions from the text; and Teaching Suggestions, which include how to use the opening stories to motivate student interest and the significance of the chapter-opening images.

The **Test Bank** by Frederick Peabody of University of South Dakota comprises 2000 questions of assorted type (multiple choice, fill-in-the-blank, and short-answer essay questions) that are organized by the main chapter headings as well as keyed to the Key Concepts as they appear at the start of chapters. The **Computerized Test Bank** is available for Windows™ and Macintosh platforms.

Other important components of the supplements package for *Asking About Life* include a set of 200 **Overhead Transparencies** based on the drawings from the book and **Bio-Art**, which is a set of 100 black-and-white unlabeled line drawings from the text.

Thinking Toward Solutions: Problem-Based Learning Activities in General Biology by Deborah Allen and Barbara Duch, of the University of Delaware, presents complex, open-ended problems for introductory biology covering all aspects of the discipline from cells to the environment. Problems address real-world applications of biology to questions of ethics, economy, and daily living. Problems foster critical thinking, cooperative learning, and problem-solving skills. A detailed Instructor's Manual provides practical suggestions on how to use the problems in any size course and in a variety of teaching styles. *Thinking Toward Solutions* also has an Internet component, which provides links to resources to aid students in solving each problem.

The Process of Science: Discovering Biology™ CD-ROM has been developed to reflect the spirit of inquiry that characterizes *Asking About Life*. It allows students to explore the discoveries of some of the most important concepts in biology. In the *Interactive Investigations,* students retrace the steps of scientists' experiments and discoveries using the scientific process as their road map. An *Investigator's Notepad* allows the students to track their progress through each investigation, to pose new questions for themselves to pursue, or to initiate a discussion with the instructor or other students via an Internet connection. *Concept Tutorials* provide students with essential background information in general biology for the course and the investigations. The CD will be available for use with classes in the fall of 1998; a demonstration disk on the topic of transmission genetics will be available to preview in January 1998.

The **Biology Survival Kit CD-ROM** is available for both IBM and Macintosh formats. The Biology Survivial Kit includes **BioXL+™** and **Biology A_2Z™ The Dynamic Glossary.** The BioXL+™ CD-ROM program presents a series of interactive animations that illustrate essential biological concepts. These simulations ensure a better retention of important concepts because students are actively engaged in a visual and dynamic way. BioXL+™ focuses on the basics, while guiding students through the concepts and providing real-world applications. Biology A_2Z™ The Dynamic Glossary CD-ROM provides text definitions, audio pronunciations, graphics, and animations for approximately 800 key terms traditionally presented in introductory biology courses. In addition to the definitions and audio, terms are supported by the text explanations, figures, and animations that put the key term in a conceptual context. Students will access the audio glossary from an extensive table of contents organized by concepts.

Biology MediaActive, Version III (Version III 1998). The CD-ROM Biology Media Bank contains imagery from Tobin/Dusheck: *Asking About Life,* Goodenough/Wallace/McGuire: *Human Biology*, Karleskint: *Marine Biology,* and Raven/Berg/Johnson: *Environment,* Second Edition. This CD-ROM is available as a presentation tool to be used in conjunction with commercial presentation packages, such as PowerPoint™ and Persuasion™, and will be available on the Biology MediaActive CD-ROM. Available for both Windows and Macintosh platforms.

Please visit our *Asking About Life* **Website** at

http://www.saunderscollege.com/lifesci/

Click on Tobin/Dusheck: *Asking About Life.* It offers an on-line study section for students and a continually updated resource for instructor materials.

A Textbook Is Born

Our developmental editor, Lee Marcott, has been a true midwife to this book, and both authors are extremely grateful to her. In addition to editing the manuscript and choosing excellent reviewers, artists, and photo researcher, Lee has also tactfully managed the two authors—pushing us to meet deadlines, calming us down when we panicked, organizing us, and giving us pep talks.

We also thank photo researcher Amy Ellis Dunleavy, who consistently found just the right photo, or had it shot, and project editor Beth Ahrens, who managed the endless details during the production of this first-edition book. We deeply appreciate, as well, the work of all the other people at Saunders College Publishing who made this book happen—including Donald Jackson, Michael Brown, and Edward Murphy, who

nursed the manuscript in its infancy; and Elizabeth Widdicombe, Julie Levin Alexander, Edith Beard Brady, and Emily Barrosse, who supported and nurtured this project as it developed.

We are also grateful to the art and production people at Saunders College Publishing: Beth Ahrens, of course, and Carol Bleistine, Joanne Cassetti, Ruth Hoover, Sue Kinney, Sally Kusch, Caroline McGowan, and Charlene Squibb, to name only some of the dozens of people who helped to shepherd this book into being. We thank Erik Fahlgren for his enthusiastic support of the book and his creative marketing strategy. We also thank our copy editors, Toni Wrighton and Sue Nelson; proofreader, Beth Morel; layout artists, Claudia Durrell and Julie Anderson; and indexer, Kathi Unger. We thank Don Lovett for calculating the scale bars found throughout the book and for fact checking many of our captions. Special thanks also to Leslie Sweeney, Jonathan Knight, Mari Jensen, Nili Kirschner, Don Ellis, Lydia Okelberry, and Chelsea Forbes.

We thank all the reviewers who took the time to read and comment on this manuscript—correcting our errors, asking thought-provoking questions, and suggesting examples, alternative wordings, or new ways of thinking. Although we never met any of our reviewers in person, working with them has been a rewarding intellectual experience. Both the process of writing this book and the resulting book itself would not have been the same without the reviewers.

Finally, we thank the following individuals, who took the time to talk to us or to answer our letters: Seymour Benzer, of Caltech; Harry Greene, of UC Berkeley; Ross Koning, of Eastern Connecticut State University; Gail Martin, of UC San Francisco; James Patton, of UC Berkeley; Peter Radetsky, of UC Santa Cruz; Gunther Stent, of UC Berkeley; and Robert Wayne, of UCLA.

We dedicate this book to our mentors in the art of communicating: Janet Hadda, David Tobin, Adam Tobin, and Eve Tobin; and to our mentors in the art of communicating science: Nina Dusheck, George Dusheck, John Dobson, and John Wilkes.

Allan J. Tobin
Jennie Dusheck
November 1997

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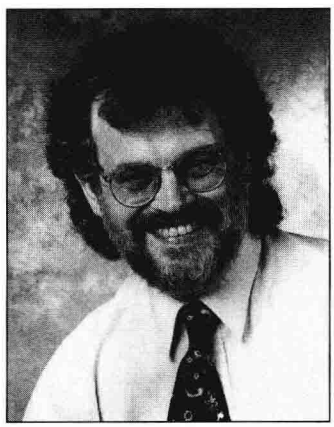

is Director of the UCLA Brain Research Institute. He holds the Eleanor Leslie Chair in Neuroscience at UCLA, where he is both Professor of Neurology and Professor of Physiological Science. Tobin is also Scientific Director of the Hereditary Disease Foundation (HDF), where he helped organize the consortium that identified the gene responsible for Huntington's disease. Both at UCLA and at HDF, he has encouraged the application of cell biology and molecular genetics to disorders of the brain.

Tobin's undergraduate degree is in literature and biology (MIT, 1963), and his doctoral degree is in biophysics, with an emphasis on physical biochemistry (Harvard, 1969). Tobin did postdoctoral work at the Weizmann Institute of Science, in Israel, and at MIT. At UCLA, his active research laboratory studies the production and action of GABA, the major inhibitory signal in the brain. These studies may eventually lead to new therapeutic approaches to epilepsy, Huntington's disease, and juvenile diabetes. Tobin is the recipient of a Jacob Javits Neuroscience Investigator Award from the National Institute of Neurological Disorders and Stroke.

For more than 25 years, Tobin has taught introductory courses in cell biology, molecular biology, developmental biology, and neuroscience. He is the recipient of a Faculty Teaching and Service Award and is regarded as an excellent and highly interactive teacher.

Jennie Dusheck

is a writer living in Santa Cruz, California, and a member of the National Association of Science Writers. Her undergraduate degree is in zoology (University of California, Berkeley, 1978) and her master's degree (by thesis) is in zoology (UC Davis, 1983). She also holds a certificate in science writing from UC Santa Cruz (1985).

Dusheck has done field and laboratory research on bird song; social behavior in field mice; food preferences of deer, cattle, and skipper butterflies (the subject of her thesis research at UC Davis); as well as axis formation in *Xenopus laevis*. While working for the Department of Molecular Biology at UC Berkeley, under a contract with NASA, she designed and wrote a protocol for an experiment that sent live frog embryos into space on the Fall 1992 Space Shuttle flight. She has taught university lab classes in introductory zoology, embryology, and comparative anatomy.

Dusheck has written for *Science News*, *Science* magazine, and other publications. From 1985 to 1993, she worked as a Principal Editor at the University of California, Santa Cruz. She has received several national awards, including the Gold Medal for Best-in-Category from the National Council for the Advancement and Support of Education.

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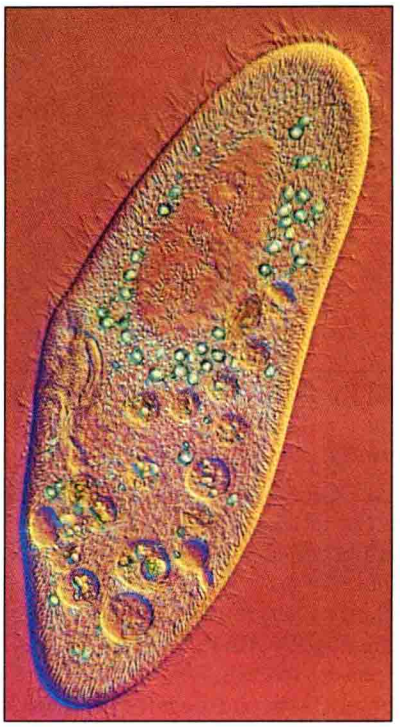

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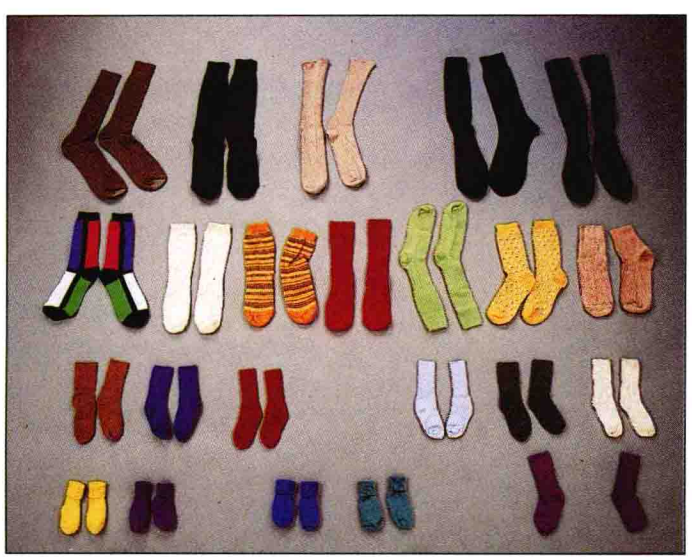

Paraskevas Photography