

# Preface

***Those ignorant of the historical development of science are not likely ever to understand fully the nature of science and scientific research.***

—Hans Krebs, Nobel laureate

Every biological fact has a story behind it. The story helps us understand how the fact is justified. It also tells us how science is done. If we do not know this, we remain ignorant of how scientists work and how important scientific discoveries have been made. Krebs's own discovery of the metabolic cycle that bears his name is an excellent example of scientific problem solving. It illustrates the creative processes by which our knowledge of the living world is generated, and the critical processes by which scientific claims are evaluated. Like many other case studies, the discovery of the Krebs cycle is also a compelling story of personal triumph over adversity.

Without understanding the background of discoveries we have little to justify our scientific beliefs. We must rely on the authority of scientists themselves. Authorities are often wrong, however. A stronger foundation for knowledge comes from examining its justification: the alternative explanations, the various forms of evidence, and the reasoning strategies used to draw conclusions. This allows us to think critically about both the process and content of science. We can analyze important questions dealing with scientific and social issues such as medicine, the environment, the teaching of evolution in public schools, the ethics of genetic research—and other debates that will arise in the future. This understanding cannot be gained simply by learning currently accepted facts and theories. We must also understand how biologists *do biology*.

We have adopted a historical perspective, but this book is not really about history. Our objective is to look at the past to better understand biology today. All our case studies deal with or touch upon biological topics included in a typical introductory biology course. Although some of the scientists may be unfamiliar, their discoveries are not.

Historical perspectives are not new. Indeed, biology textbooks often celebrate discoveries from the distant past: van Leeuwenhoek's pioneering microscopic investigations, for example, or van Helmont's intriguing experiments on plant growth. We have omitted these early examples of biology because we find them fraught with problems of interpretation. The scientific issues facing van Helmont and the culture of which he was

a part were very different from today's. To really understand van Helmont's science, we would have to immerse ourselves in the ideas of the seventeenth century and regard seriously some concepts that today seem wildly implausible and *unscientific*. Were we to discuss his experiments in our present terms, however, we would capture only a shadow of van Helmont's actual achievement. By making early biologists appear more modern than they really were, we distort both history and the process of scientific discovery. For this reason, we have focused on episodes from the past century.

Still, even recent scientific discoveries look different now than they did in their original historical context. The solution to a problem appeared less obvious to the biologists who originally struggled with it than it does to us today. To show how someone made the transition to our current state of knowledge, we have reconstructed how biologists viewed the world *before* a discovery was made.

Taking this historical perspective is a useful approach to teaching because early scientific theories are often quite similar to the ideas of students who are struggling with a modern concept for the first time. In recreating historical moments of uncertainty and discovery, we hope to convey a sense of "science-in-the-making." We trust that teachers, too, will find it useful to place themselves in the shoes of famous biologists and to face historically significant problems and original data, forsaking the privilege of already knowing the answer. How did renowned biologists reach certain conclusions with the intellectual and technical resources available to them at the time of the discovery? In answering these questions, we hope to faithfully portray how scientific knowledge develops.

Toward these ends, we have adopted a case study approach. We believe that science is complex and richly textured. Practicing biologists know that scientists do not all share a single "cookbook" approach to research. What is often referred to as "*the scientific method*" is really a diverse "toolbox" of methods, including simple observation, indirect observation with instruments, inferences from historical evidence, controlled experiments, demonstrations, modeling and simulation, correlation studies, and reasoning by analogy. Each of these methods has unique strengths and limitations. Through case studies, we hope to highlight the diversity of approaches used by biologists in different fields.

The case study method is also particularly appropriate for presenting the human character of science. Most chapters focus on individual biologists. We hope to show how biologists' personalities and styles of investigation shaped the outcome of their biological research. We also wish to underscore biologists' deep commitment to research and to convey some of the excitement of *doing biology*. At the same time, we do not want to idealize or romanticize accounts of scientific discovery. Without dwelling unduly on character flaws, we present biologists as people with emotions, ambitions, and theoretical biases. After all, biologists are human, and these human characteristics also influence *doing biology*.

While focusing on individuals, we should always keep in mind that science is a social activity. Scientists both collaborate and compete within scientific communities. They are also influenced by the broader society of which they are members. We have placed each of our cases within a broader historical context, although this is not the central focus of the book. We encourage those readers interested in the

cultural dimension of biology to explore the rich literature on this topic produced by social historians and sociologists.

In our selected case studies, we offer a wide cross-section for understanding science as an intellectual, practical, and social process. We do not intend to present encyclopedic coverage of the history of biology. Too many cases would simply make this book unwieldy. We chose historical episodes that are closely tied to topics in introductory biology courses, that exemplify important characteristics of scientific practice, and that are less familiar than those found in most textbooks.

We have also tried to strike a balance in the length of individual chapters. Textbooks often include short historical sketches that can be read in a minute or two. Such vignettes are valuable for introducing biological topics but are too superficial to show the creative process of discovery. We hope our accounts more fully reveal how biology is done but still remain short enough to read in one sitting. For those interested in greater depth of coverage, we provide a "Suggested Reading" list at the end of each chapter.

This volume will be a useful companion to any introductory biology text. Our problem-solving approach is designed to engage students in *doing biology*, not just reading about its conclusions. Each chapter provides an occasion for discussion—during recitation sessions, laboratory, or lecture. Alternatively, chapters may be assigned as supplementary reading. We have embedded problems within the text and "Questions and Activities" at the end of each chapter to serve as points of departure.

Ultimately, this book addresses a need expressed in several recent proposals for reforming science teaching. We have not written an alternative textbook, nor do we offer a new curriculum. We aim to complement existing teaching resources and to fill an obvious void. Textbooks teach biological content. We hope this volume goes a significant step further by helping students to learn about *doing biology*.

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