Preface to the First Edition

On April 25, 1953, American biologist James Watson and English chemist Francis Crick published a paper in the British journal *Nature* proposing a chemical structure for a family of chemical compounds known as deoxyribonucleic acid (DNA). The structure they suggested consisted of a long pair of chains twisted around each other, somewhat like a spiral staircase, with subunits called nitrogen bases paired with each other as steps on the staircase. At the conclusion of their paper, Watson and Crick noted, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for the genetic material." What Watson and Crick had discovered is that DNA molecules carry a "code" for genetic characteristics, such as hair and skin color, ear shape, color of eyes, height, and a host of other traits. This discovery solved a problem that had troubled scientists for decades: How does like produce like during the process of reproduction? How does a willow tree always produce other willow trees only, and never oak trees? How do redheaded children appear only in families with redheaded parents, grandparents, and/or great-grandparents, and never in families whose predecessors had only black or brown hair?

The very remarkable thing about the Watson and Crick discovery is that the answer to these and other biological questions was given in chemical terms. After Watson and Crick's paper, scientists were able to think about how hereditary traits

are transmitted in terms of atoms and molecules. And, since chemists already knew a great deal about manipulating atoms and molecules, the possibility presented itself that biologists might now be able to manipulate the characteristics of living organisms in much the same way: by moving around atoms and molecules.

Today, because of this discovery, biological studies are as much a function of chemical changes as are industrial processes, such as the production of paper, the manufacture of plastics, and the processing of metallic materials.

An even more profound consequence of the Watson and Crick discovery is that one can now say that, to a very considerable extent, it is possible to describe everything we know about the biological characteristics of a human being (or a chimpanzee or elephant or flea) by writing chemical formulas and chemical equations. To the average person, the following expression may just be a series of letters, or, to someone with an introductory course in chemistry, a series of nitrogen bases in a DNA molecule. But to a molecular biologist, that string of letters stands for some physical trait, such as hair color or a potential health problem, such as sickle-cell anemia.

-T-T-T-C-A-C-G-G-G-C-C-A-T-T-A-C-G-G-C-G-C-T-T-A-T-
-A-A-A-G-A-G-C-C-C-G-G-T-A-A-T-G-C-C-G-C-G-A-A-T-A-

This possibility was apparent to scientists from almost the moment that Watson and Crick published their 1953 paper. Researchers began to ask if it might be possible to alter the "genetic code" in an amoeba, or a fruit fly, or even a human being in order to change that organism's genetic composition and, therefore, its physical characteristics. Out of that line of thinking has come a whole new field of study that uses information about DNA structure to develop practical applications. This book reviews those applications in six fields:

forensic science, the development of transgenic organisms (organisms with genetic characteristics of two different species), genetic testing, gene therapy, molecular farming (also known as pharming), and cloning.

Perhaps the most remarkable feature of the history of DNA technology is the tempo at which progress has been made. Only 50 years after the Watson and Crick discovery, scientists are applying that knowledge to identifying genetic diseases in fetuses, altering tobacco plants so that they will produce useful drugs, identifying criminals accused of crimes with a certainty of one in a billion or better, treating (and, perhaps, curing) adults with life-threatening genetic disorders, and producing multiple copies (clones) of animals born outside the normal process of reproduction.

Chapter 1 provides a historical review of the development of these six DNA technologies, with an overview of the scientific principles fundamental to each technology. Chapter 2 reviews some social, ethical, political, and other issues that have arisen as a result of the development of these technologies. In many cases, the use of DNA technology has raised some fundamental philosophical and theological questions about what it means to be human, or what it means to be alive. One should not be surprised that these questions engender serious, and often heated, debates as to the conditions under which a particular technology should be used or, indeed, if it should ever be used at all. Chapter 3 focuses on the international aspects of the debates over DNA technology. Perhaps the most significant findings of this chapter are the enormous diversity in the use of DNA technologies in various parts of the world, the extent to which these technologies have stirred up controversy over their use, and the range of views that people from different parts of the world have about DNA technology.

Chapters 4 through 8 provide a variety of resources to help the reader continue a study of DNA technology. Chapter 4 offers a chronology of important events in the growth of scientific knowledge about the nature of DNA and its role in biological

processes, along with some important political, social, legal, and other events related to this growth of knowledge and its applications in everyday life. Chapter 5 provides brief biological sketches of some important figures in the development of DNA technology and its applications. Chapter 6 contains some political and legal documents that illustrate the way the United States and other countries around the world are attempting to assess, regulate, and control the applications of DNA technology in a variety of fields. Some relevant data about the growth of this field of study are also included. Chapter 7 provides a list of organizations interested in DNA technology, some whose primary responsibility is regulatory, some interested in advancing the development and use of DNA technology, and some working to moderate or stop the development of that field of research. Chapter 8 is an annotated bibliography of print and electronic resources for the six major types of DNA technology discussed in the book. The book concludes with a glossary of important terms used in the field of DNA technology.

Preface to the Second Edition

It is generally difficult to predict the precise direction of any particular subject in the sciences. Unexpected discoveries—such as the determination of the three-dimensional structure of the DNA molecule by Watson and Crick in 1953—may be both profound surprising and, at the same time, gateways to entirely new directions in the future of a scientific field. Such a statement is as true for the technology of DNA research as it is for any other field of science. The discovery of a mechanism for gene editing in a relatively simple and straightforward manner by Emmanuelle Charpentier and Jennifer Doudna in 2012 was both a startling breakthrough in the field of DNA technology and, at the same time, a tool for further developments in the field that researchers had only been able to hope for only a few years earlier.

For this reason, any book on the subject of DNA technology faces the challenge of continuously updating to stay up with changes in the field, new applications that have become available, and evolving or new social, economic, technological, political, economic, and other issues that may arise because of those breakthroughs. The second edition of *DNA Technology: A Reference Handbook* is our effort, then, to meet that challenge. The book attempts, in the first place, to lay out for readers some of the most important scientific and technical changes that have occurred since publication of the first edition, such as the discovery and use of gene-editing techniques such as

CRISPR-Cas9, zinc finger nucleases, and other types of gene-editing protocols, and the developing significance of low copy number DNA technology, along with the everyday challenges create by such technologies.

At the same time, this update is designed to keep readers up-to-date on developments in somewhat older technologies and issues, such as the development of genetically modified crops, animals, and foods, and the applications of DNA analysis in the forensic sciences. Topics such as these were discussed in some detail in the first edition of the book, but the debate as to how they are to be used and how society will be affected by them continues in actions such as the 2014 Vermont law on the labeling of genetically modified foods.

The backbone of the discussion of DNA technology presented in the first edition of the book, then, remains with this edition. But important changes that have occurred in the field are described and discussed both in the introductory chapters of the book and in the resources presented in Chapter 4 (Profiles), Chapter 5 (Data and Documents), Annotated Bibliography (Chapter 6), and Chronology (Chapter 7). In addition, a new Chapter 3, titled "Perspectives," provides interested individuals with an opportunity to discuss in greater detail some very specific issues within the general area of DNA technology.