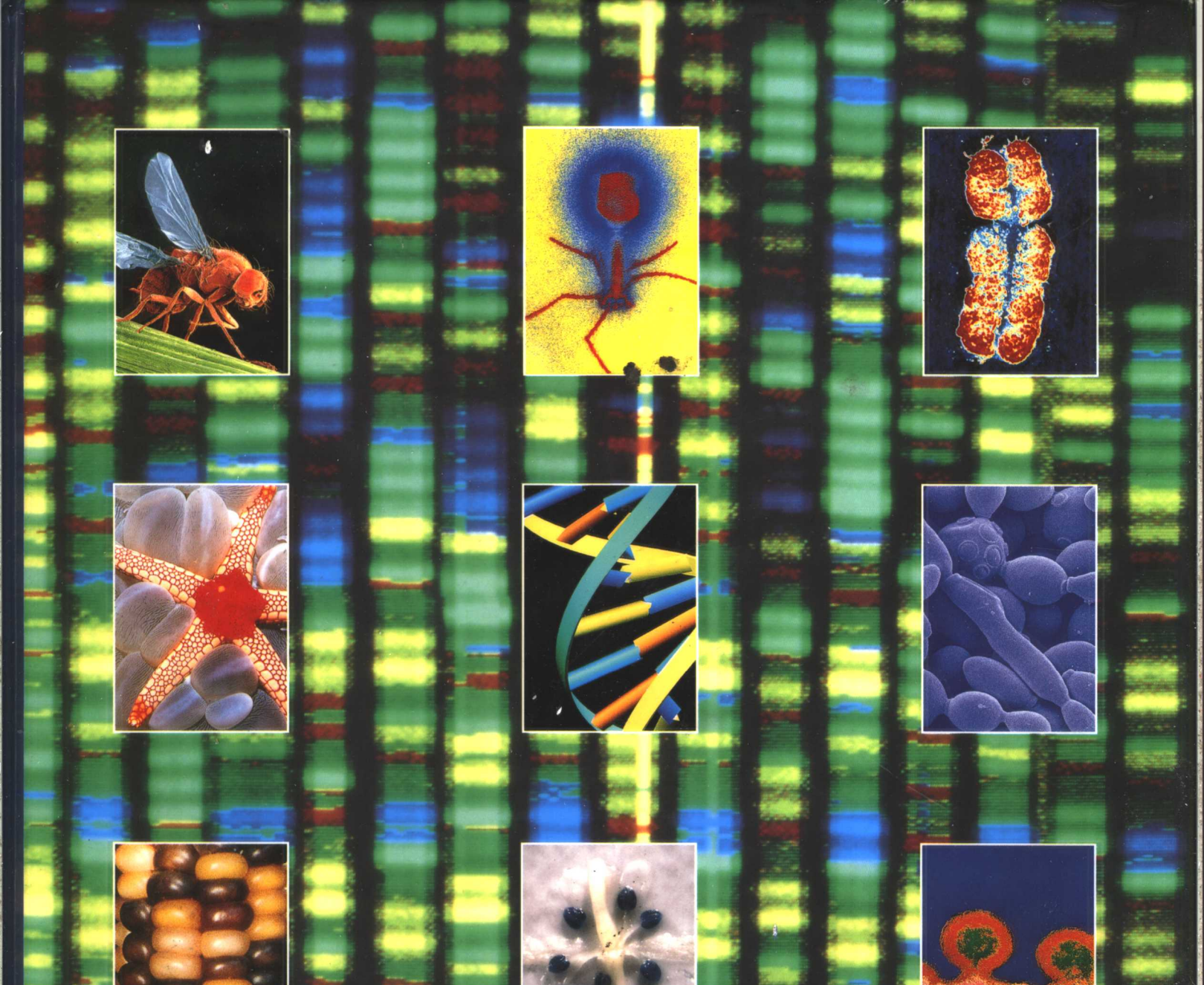

PRINCIPLES OF GENETICS

SNUSTAD • SIMMONS • JENKINS

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D. Peter Snustad
University of Minnesota

Michael J. Simmons
University of Minnesota

John B. Jenkins
Swarthmore College

Epilogue by James F. Crow

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About the Authors

D. Peter Snustad is a Professor in the Department of Genetics and Cell Biology at the University of Minnesota, Twin Cities. He received his B.S. degree in science specialization from the University of Minnesota and his M.S. and Ph.D. degrees in genetics from the University of California, Davis. During his 31 years as a member of the faculty at Minnesota, he has taught courses at all levels from general biology to advanced biochemical genetics. For 20 years, his research focused on bacteriophage T4 morphogenesis and the interaction between T4 and its host, *Escherichia coli*. For the past 11 years, his research group has studied the genetic control of the cytoskeleton in *Arabidopsis thaliana* and the glutamine synthetase gene family in *Zea mays*. He has served on the National Institutes of Health Molecular Cytology Study Section and as Program Chairperson for the Annual Meeting of the Genetics Society of America. His honors include the Morse-Amoco and Stanley Dagley Memorial teaching awards. A lifelong love of the Canadian wilderness has kept him in nearby Minnesota.

Michael J. Simmons is a Professor in the Department of Genetics and Cell Biology at the University of Minnesota, Twin Cities. He received his B.A. degree in biology from St. Vincent College in Latrobe, Pennsylvania, and his M.S. and Ph.D. degrees in genetics from the University of Wisconsin, Madison. Dr. Simmons has taught courses in general biology, genetics, population biology, population genetics, and molecular biology. His research activities are focused on the genetic significance of transposable genetic elements, especially those present in the genome of *Drosophila melanogaster*. He has served on advisory committees at the National Institutes of Health and is currently a member of the Editorial Board of *Genetics*, published by the Genetics Society of America. In 1986, Dr. Simmons received the Morse-Amoco teaching award from the University of Minnesota in recognition of his contributions to undergraduate education. One of his favorite activities, figure skating, is especially compatible with the Minnesota climate.

John B. Jenkins is a Professor in the Department of Biology at Swarthmore College, where he teaches genetics, human genetics, and evolution. He received his B.S. and M.S. degrees from Utah State University, where he studied with Eldon J. Gardner, and his Ph.D. from the University of California, Los Angeles, where he studied chemical mutagenesis with Elof Axel Carlson. Dr. Jenkins's research interests are in the areas of mutation, behavior genetics, cytogenetics, and Huntington's disease. He has authored textbooks on genetics and human genetics and has co-authored a collection of classic papers in genetics. He is a member of the Genetics Society of America, the American Society of Human Genetics, and other scientific societies. He has served on numerous committees and panels of the Genetics Society of America, American Society of Human Genetics, and the National Science Foundation. He has served on the Editorial Board of the Education Section of the *American Journal of Human Genetics* and the Board of Reviewers for the *Journal of Medical Genetics*. His love of fishing frequently takes him to the streams of Pennsylvania and the lakes of New Hampshire.

Dedications

To my son Eric, my best friend Judy, and my campfire buddies Jason and Oak. Thanks for sharing those special times.

D.P.S.

To my family, especially to Benjamin John.

M.J.S.

With much love to my extraordinary wife Dotti and to my wonderful children, John, Soraya, Jessica, and Charlotte, all of whom bring so much joy to my life.

J.B.J.

Preface

Although the science of genetics is only 130 years old, it has grown at an explosive rate during the last half of the twentieth century and now impacts virtually all aspects of our lives. What began with the simple and elegant experiments of Gregor Mendel has blossomed into a mature science that is the focus of research throughout the world. When we started teaching 30 years ago, genetics was considered by many biologists to be just one of several specialized disciplines in biology. Today, it is viewed as the core of biology. Genetic approaches to the dissection of biological processes have proven invaluable. The powerful tools of molecular genetics are now routinely used to investigate phenomena as diverse as photosynthesis, the immune response, memory, and evolution. In addition, numerous practical applications of genetics have been documented in fields such as medicine, agriculture, pharmaceutics, and forensics. Given the rapid growth of genetics during the last few decades, it follows that the teaching of genetics has also undergone major changes. *Principles of Genetics* is the culmination of our collective attempt to stay abreast of the exciting new developments in genetics without sacrificing rigor in the coverage of basic Mendelian genetics.

Our philosophy in teaching genetics—and in preparing this textbook—is that learning is best achieved by emphasizing basic principles, especially when these principles are introduced through the analysis of observations and experimental results. Not all genetics instructors will agree with all aspects of our approach to teaching genetics; however, we think that most of them will agree that an introductory course should not only convey concepts but also should demonstrate how genetics is done—how the results of genetic experiments lead to new knowledge.

Focus on the basic principles of genetics. Every week new and important discoveries in genetics are announced. Yet, all of these impressive accomplishments are rooted in basic principles that were elucidated by Mendel and his successors. This textbook strives to develop these principles carefully and thoroughly. We believe that an appreciation of current advances in genetics must be grounded on a foundation of basic principles. For example, the powerful tools of molecular genetics permit scientists to screen individuals for mutations that cause Huntington's disease (Chapter 20, Figure 20.11). However, only through an understanding of Mendelian genetics will students appreciate the 50 percent risk of Huntington's disease among the children of a parent with this disease (see *A Conversation with Nancy Wexler*).

Show how scientific concepts develop from observation and experimentation. No one should lose sight of the fact that genetics, like every science, is a human endeavor. What is known about genetics today is the result of considerable toil and effort. Thousands of geneticists have labored to discover the facts and develop the concepts that make up the science of genetics. Each discovery began with a rather tentative mix of ideas and observations. With careful scrutiny and experimental testing, these ideas and observations eventually gelled into something less tentative—a set of concepts supported by facts. Genetics is replete with examples of this process, many of which we present in this text to emphasize the central role of scientific experimentation in the evaluation of ideas and the importance of critical interpretation of experimental data in testing hypotheses. In addition, we have incorporated *Conversations* with eminent geneticists to emphasize the human component of the scientific process.

Incorporate human examples and show the relevance of genetics to societal issues. Experience has shown us that when we discuss human genetics, our students are more interested and pay closer attention. Because they are more attentive, students tend to comprehend complex concepts better when they are illustrated with human examples. For that reason, we have used human examples to illustrate genetic principles whenever possible. We have also included separate sections on the Human Genome Project, human gene mapping, human gene therapy, and human genetic disorders such as Huntington's disease, cystic fibrosis, and xeroderma pigmentosum. In addition, we have dedicated an entire chapter to behavior genetics (Chapter 26) in which we examine the effects of genes on traits such as intelligence, personality, and sexual orientation.

Genetics, perhaps more than any other science, has sparked numerous social, legal, and ethical debates, which is one reason why students find the subject so fascinating. Many of these controversial issues—genetic screening and its potential for misuse, DNA fingerprinting, genetic engineering, and gene therapy—are products of the Human Genome Project. Although some of these topics are controversial, we believe that it is important to involve students in an intelligent dialogue on these issues because society will increasingly be called upon to address such questions. Hopefully, this textbook will provide students with the background information needed to address these concerns in an informed manner.

Emphasize analytical thinking and problem solving. Genetics has always been a bit different from other disciplines in biology because of its heavy emphasis on analysis and problem solving. In this text, we have fleshed out the analytical nature of genetics in many ways—in the development of principles in classical genetics, in the discussion of experiments in molecular genetics, and in the presentation of calculations in population and quantitative genetics. We have provided special worked-out problems in the *Testing Your Knowledge* section at the end of each chapter to help students develop their analytical skills. For example, students usually master the concept of semiconservative DNA replication quite easily. However, when asked to properly package the parental and nascent DNA strands into chromatids and daughter chromosomes, they often are unable to do so. We have observed that when students work through *Testing Your Knowledge* problem 2 in Chapter 10, they develop an understanding of both semiconservative replication and the packaging of DNA into chromosomes.

AN ADAPTABLE ORGANIZATION

Our most difficult decisions in preparing this text related to organization and content. Should the text begin with Mendel and proceed roughly in chronological fashion? Should it begin with DNA and present classical transmission genetics afterward? Should population and quantitative genetics follow classical genetics, or should they be placed at the very end of the text? Should classical and molecular genetics be interwoven thoughout the text? Obviously, there is no single "correct" way to teach the basic principles of genetics. Thus our goal was to create a text that covers all the core topics and has an adaptable organization. We believe that this text can be adapted to a variety of class formats. For example, if an instructor prefers to discuss molecular genetics prior to classical genetics, she or he can cover Chapters 9–14 and then return to Chapters 3–8. Another goal was to keep the length of the text reasonable. As genetics has grown, so has the length of genetics textbooks. Without doubt, the most challenging choices that we made during the preparation of this text involved the omission of some of our favorite experiments, topics, and historical events. Genetics is a rich and diverse discipline, and we hope that we have made sensible decisions regarding what to include and exclude in this book.

The organization of the text is a mixture of traditional and unique. The organization is unique in that we have recognized the important contributions of viruses (Chapter 15) and bacteria (Chapter 16) to the basic concepts of genetics by covering each in a separate chapter. The genetic basis of cancer is covered in Chapter 22, which emphasizes the most important and recent research on this topic. It is also unique in dedicating an entire chapter (24) to immunogenetics, although this seems almost unavoidable given the impact of AIDS in our world. The organization is traditional in that we cover Mendelian genetics first (Chapters 3–8) and DNA, RNA, and proteins second (Chapters 9–14). The text contains 28 chapters and an epilogue. Chapters 1–2 provide an introduction to the science of genetics and the basic features of living organisms; Chapters 3–8 present the concepts of classical genetics; Chapters 9–14 present the core concepts of molecular genetics; Chapters 15–18 cover the genetics of viruses, bacteria, transposable elements and eukaryotic organelles; Chapters 19–24 contain more advanced topics in molecular genetics; and Chapters 25–28 contain topics on population, quantitative, evolutionary, and behavior genetics.

Finally, the epilogue, *Genetics: Yesterday, Today, and Tomorrow*, written by James F. Crow, an eminent geneticist and a leading contributor to genetics (and to the teaching of genetics), shares his personal views about the history and future prospects of this science. We do not believe that you can read his epilogue without feeling the excitement that has infected the people who have made genetics what it is. We thank Dr. Crow for providing a truly special ending to the text. His wit, charm, and wisdom are greatly appreciated; many thanks, Jim.

ART PROGRAM

Well-designed illustrations are an essential component of any science textbook. Stepped-out illustrations, showing each phase in a process, are an invaluable aid in communicating complex concepts. Thus we have worked very hard to make the illustrations in this text clear, attractive, and pedagogically effective. Approximately 700 figures and 200 photographs have been included to illustrate basic concepts, experimental procedures, and various genetic phenomena. Many complex figures are stepped-out and contain succinct labels to help students break down difficult processes into manageable parts. For example, in Chapter 12, the complex process of translation has been divided into chain initiation (Figure 12.15), chain elongation (Figure 12.17), and chain termination (Figure 12.19), with each component covered in a separate stepped-out illustration. In addition, in developing the illustrations, we have utilized the same color scheme throughout the text so that related items can be identified in different figures based on color.

CONVERSATIONS WITH GENETICISTS

During the writing of this book, one of our most enjoyable tasks was to have conversations with some truly

remarkable scientists. The book contains nine conversations with prominent geneticists. We are indebted to these people for sharing their insights about science and education, and we hope that you will find these conversations as fascinating as we have. We thank:

Thomas J. Bouchard, Jr.	University of Minnesota, Twin Cities
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James V. Neel	University of Michigan
Mary Lou Pardue	Massachusetts Institute of Technology
Nancy Wexler	Hereditary Disease Foundation, Santa Monica, California

We are grateful to each of these individuals for their willingness to contribute to this book.

PEDAGOGY

This text includes special features designed to emphasize the relevance of the topics discussed, to facilitate the comprehension of important concepts, and to assist students in evaluating their grasp of these concepts. However, we have tried to make sure that these features do not interfere with the flow of the scientific content of the text. The features include:

- ***Sidelights (Technical, Historical, Human Genetics).*** Throughout the text, special topics are presented in separate *Sidelight* sections: *Technical Sidelights* describe important experimental techniques; *Historical Sidelights* provide insights into the history of genetics; and *Human Genetics Sidelights* examine important aspects of human genetics.
- ***Chapter-Opening Vignettes.*** Each chapter opens with a vignette or brief story—usually related to human genetics or historical developments—that emphasizes the relevance of the topics discussed in the chapter.
- ***Key points.*** These learning aids are in-text summaries that appear at the end of each major section of the text. They are designed to help students review for exams and focus on the major concepts covered in each section.
- ***Testing Your Knowledge.*** At the end of each chapter, we have provided worked-out problems to help students hone their analytical and problem-solving skills. The answers walk the students step by step through the solutions to the problems.
- ***Questions and Problems.*** Each chapter ends with 20 to 35 questions and problems. The range of questions will provide students with the opportunity to enhance their understanding of the concepts covered in the chapter and to further develop their analytical skills.
- ***Answers.*** Answers to the odd-numbered problems are given at the back of the text, and answers to all problems are included in the *Instructor's Manual and Test Questions* supplement prepared by Robert Ivarie of the University of Georgia.

SUPPLEMENTS

The Problems Workbook and Study Guide, by H. J. Price of Texas A & M University, is a hands-on workbook designed to improve problem solving skills and to reinforce terminology and concepts from the text. Features included are important concepts, terms, and names; additional problems for self-test; key figures from the text; thought challenging exercises, answers to problems, and approaches to problem solving.

Instructor's Resources on CD-ROM, designed as a lecture enhancer and database of instructor's materials, is highly functional and easy to use. This cross-platform CD-ROM contains the following components and is free to adopters of the text: (1) A database of all the illustrations from the text from which the instructor can create presentations, download to the desktop, and/or print to acetates (2) *Instructor's Manual and Test Questions*, written by Bob Ivarie of the University of Georgia, which contains sample syllabi, lecture outlines, key concepts, teaching strategies for difficult material, and approximately 40 test questions per chapter. The complete set of answers to problems in the text are included here as well. The material can be printed from the CD or exported to word-processing programs for creation of handouts or lecture notes. The *Instructor's Manual and Test Questions* will also be available in a print format. (3) The *Transparency Set* which contains full-color figures from the text. (4) *World Wide Web.* Materials relevant to *Principles of Genetics* which are available to faculty and students.

GenLink, a new electronic supplement that integrates the Table of Contents to the vast resources of the World Wide Web, provides relevant links to genetic sites for you and your students. Linked sites include the latest research findings, forums, and simulations. We invite you to make comments and suggestions at the GenLink homepage so that we can make this program an even more effective learning tool. Please visit GenLink at http://www.wiley.com/genlink.

Of Related Interest: Drlica, *Understanding DNA & Gene Cloning: A Guide For the Curious*, 3/e, 1997.

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Manuscript Reviewers

Our gratitude also goes out to a host of reviewers whose criticisms and comments helped to shape the content of this book. These generous critics gave their time and expertise to correct errors and suggest ways in which the book could be improved; we deeply appreciate all their efforts. Of course, any errors that remain are solely our own responsibility. In particular, we acknowledge the constructive comments of the following reviewers:

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Lastly, we would like to encourage everyone—students, teaching assistants, instructors, and other readers—to send any comments on the text, corrections, or suggestions for improvements to D. Peter Snustad at John Wiley & Sons, Inc., 605 Third Avenue, New York, NY, 10158-0012, or PSnustad@Wiley.Com.

BRIEF CONTENTS

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