PREFACE

OVERVIEW OF THE TEXT

It is now more than forty years since the mysteries of DNA were first unravelled, and in that time genetics has become one of the most exciting and groundbreaking of the sciences. A continual flood of discoveries not only expands our understanding about heredity but affects our daily lives in areas ranging from disease therapy to courtroom evidence.

Genetics, Fifth Edition, reflects this dynamic nature of the field. It has been extensively updated to include many significant advances made since the last edition, particularly those advances resulting from the use of molecular experimental approaches. Like previous editions, this new edition emphasizes an experimental, inquiry-based approach, with solid treatment of many research experiments that have contributed to our knowledge of genetics. In this way, students are exposed to the "process of science," learning about the formulation and study of scientific questions in a way that will be of value in their study of genetics and in all areas of science.

A consistent effort has been made to present the important experiments without including excessive facts and detail that could obscure the central concepts of genetics. *Genetics*, Fifth Edition, is ideally suited for students who have had some background in biology and chemistry and who are interested in learning the concepts of genetics from a research-oriented perspective. Great care has been taken to keep the text accessible to students by making it easy to read, with a consistent level of coverage and a logical progression of ideas. In addition, increased attention to editorial development in this edition ensures a high degree of accuracy throughout the text.

Genetics, Fifth Edition, retains the overall approach, organization, and pedagogical features (such as Principal Points, Keynotes, Summaries, and Analytical Approaches for Solving Genetics Problems) that have made previous editions valued learning tools for students of genetics. As in the past, problem solving is a major feature of the book, and this edition includes more and updated end-of-chapter Questions and Problems, which have been consistently praised by reviewers of all editions. It also retains a format that allows instructors to use the chapters out of sequence to accommodate various teaching approaches.

The fifth edition includes the following improvements:

- A new chapter, Genetics of Cancer (Chapter 18), discusses the relationship of the cell cycle to cancer, mutational models for cancer, genes and cancer, the multistep nature of cancer, and chemicals and radiation as carcinogens. Cancer is of obvious importance to the human population, and this chapter imparts important knowledge to students about the nature of the disease and the various roles that genes play in its development.
- All the molecular aspects of genetics are updated, so that the book continues to reflect our current understanding of genes at the molecular level. New material is presented, for example, on the structure of eukaryotic chromosomes (Chapter 11), the control of the cell cycle by cyclins and cyclin-dependent DNA kinases (Chapter 12), the use of mutations to define telomerase function (Chapter 12), promoter elements and initiation of transcription in eukaryotes (Chapter 13), 3' end generation and polyadenylation in eukaryotes (Chapter 13), alternative splicing in the production of mRNAs (Chapter 17), control of mRNA degradation (Chapter 17), modern molecular screens for the isolation of mutants (Chapter 19), and investigation of genetic relationships by mitochondrial DNA analysis (Chapter 21).
- Human examples continue to be used extensively throughout the text, and they have been updated particularly with regard to new molecular understandings of various human genetic diseases.
- The coverage of mapping genes in human chromosomes (Chapter 6) now involves a modern presentation of constructing physical and genetic maps of the human genome.
- The coverage of recombinant DNA technology has been updated and expanded to reflect the rapid developments in that area. New material is presented, for example, on the use of PCR (polymerase chain reaction) in the analysis of diseases, the current status of the human genome project, techniques for transforming genes into plants,

and the use of transposable elements for transforming *Drosophila*.

- The coverage of developmental genetics has been updated to include current information on *Drosophila* development and on the relationship between homeotic genes of *Drosophila* and mammals. The recent experiment demonstrating that the nucleus of an adult sheep cell could direct the development of a normal lamb from an enucleated egg cell is described.
- Approximately 100 new questions and problems have been added throughout the book. Many test the ability of students to think in an investigative way, and a number integrate concepts presented in more than one chapter.
- Many new references have been added to the Suggested Readings for each chapter.

ORGANIZATION AND COVERAGE

The three major areas of genetics—transmission genetics, molecular genetics, and population and quantitative genetics—are covered in 23 chapters. Chapter 1 is an introductory chapter designed to summarize the main branches of genetics, to explain what geneticists do and what their areas of research encompass, and to introduce the main properties of genes and the main experimental approaches used in genetics research today. The next seven chapters deal with transmission of the genetic material. Chapters 2 and 3 present the basic principles of genetics in relation to Mendel's laws. Chapter 2 is focused on Mendel's contributions to our understanding of the principles of heredity, while Chapter 3 covers mitosis and meiosis in the context of both animal and plant life cycles, the experimental evidence for the relationship between genes and chromosomes, and methods of sex determination. Mendelian genetics in humans is introduced in Chapter 2 with a focus on pedigree analysis and autosomal traits. The topic is continued in Chapter 3 with respect to sex-linked genes.

The exceptions to and extensions of Mendelian analysis (such as the existence of multiple alleles, the modification of dominance relationships, gene interactions and modified Mendelian ratios, essential genes and lethal alleles, and the relationship between genotype and phenotype) are described in Chapter 4. In Chapters 5 and 6, genetic mapping in eukaryotes is presented. In Chapter 5, we describe how the order of and distance between the genes on eukaryotic chromosomes are determined in genetic experiments designed to quantify the crossovers that occur during meiosis. Chapter 6 focuses on tetrad analysis, primarily in fungal systems; on mapping eukaryotic genes through mitotic analysis; and on the construction of genetic and physical maps in humans. With the understanding of the relationship between genes and chromosomes obtained from Chapters 2 through 6, chromosomal mutations—changes in normal chromosome structure or chromosome number—are discussed in Chapter 7. Chromosomal mutations in eukaryotes and human disease syndromes that result from chromosomal mutations, including triplet repeat mutations, are emphasized. In Chapter 8, we discuss the ways of mapping genes in bacteriophages and in bacteria, which take advantage of the processes of transformation, conjugation, and transduction. Fine structure analysis of bacteriophage genes concludes this chapter.

Chapters 9 through 15 comprise the "molecular core" of *Genetics*, Fifth Edition, detailing the current level of our knowledge about the molecular aspects of genetics. In Chapter 9, we examine some aspects of gene function, such as the genetic control of the structure and function of proteins and enzymes, and the role of genes in directing and controlling biochemical pathways. A number of examples of human genetic diseases that result from enzyme deficiencies are described to reinforce the concepts. The discussion of gene function in Chapter 9 enables students to understand the important concept that genes specify proteins and enzymes, setting them up for the following chapters in which gene structure and expression is discussed.

In Chapter 10, we cover the structure of DNA, presenting the classical experiments that revealed DNA and RNA to be genetic material and that established the double helix model as the structure of DNA. The details of DNA structure and organization in prokaryotic and eukaryotic chromosomes are set out in Chapter 11. We cover DNA replication in prokaryotes and eukaryotes, and recombination between DNA molecules in Chapter 12.

After thoroughly explaining the nature of the gene and its relationship to chromosome structure, in Chapter 13, we discuss the first step in the expression of a gene—transcription. First, we describe the general process of transcription and then present the currently understood details of the transcription of messenger RNA, transfer RNA, and ribosomal RNA genes, and the processing of the initial transcripts to the mature RNAs for both prokaryotes and eukaryotes. In Chapter 14, we describe the structure of proteins, the evidence for the nature of the genetic code, and a detailed expression of our current knowledge of trans-

lation in both prokaryotes and eukaryotes. A brief discussion of how eukaryotic proteins are sorted to the compartments in which they function is also included in Chapter 14. In Chapter 15, we discuss recombinant DNA technology and other molecular techniques that are now essential tools of most areas of modern genetics. There are descriptions of the use of recombinant DNA technology to clone and characterize genes and to manipulate DNA, followed by a discussion of the applications of recombinant DNA technology in the analysis of biological processes, the diagnosis of human diseases, the isolation of human genes, the Human Genome Project (with the goal of mapping and sequencing the complete genomes of humans and other selected organisms), forensics (DNA typing), gene therapy, the development of commercial products, and the genetic engineering of plants.

The next two chapters focus on regulation of gene expression in prokaryotes (Chapter 16) and eukaryotes (Chapter 17). In Chapter 16, we discuss the operon as a unit of gene regulation, the current molecular details in the regulation of gene expression in bacterial operons, and regulation of genes in bacteriophages. In Chapter 17, we explain how eukaryotic gene expression is regulated, stressing molecular changes that accompany gene regulation, short-term gene regulation in simple and complex eukaryotes, gene regulation in development and differentiation, and immunogenetics.

Next, in Chapter 18—the new chapter on the genetics of cancer—we discuss the relationship of the cell cycle to cancer, and the various types of genes which, when mutated, play a role in the development of cancer. We also discuss the fact that cancer usually requires a number of independent mutational events in order for it to develop. Lastly, we consider the induction of cancer by chemicals and radiation (carcinogens).

In Chapters 19 and 20, we describe some of the ways in which genetic material can change or be changed. Chapter 19 covers the processes of gene mutation, the procedures that screen for potential mutagens and carcinogens (the Ames test), some of the mechanisms that repair damage to DNA, and some of the procedures that are used to screen for particular types of mutants. Chapter 20 presents the structures and movements of transposable genetic elements in prokaryotes and eukaryotes.

In Chapter 21, we address the organization and genetics of extranuclear genomes of mitochondria and chloroplasts. We cover the current molecular information about the organization of genes within the extranuclear genomes, and the classical genetic experiments that are used to study the inheritance of extranuclear genes. New to this chapter are discussions of RNA editing and genomic imprinting.

In Chapters 22 and 23, we describe the genetics of populations and quantitative genetics, respectively. In Chapter 22, "Population Genetics," we present the basic principles in population genetics, extending our studies of heredity from the individual organism to a population of organisms. This chapter includes an integrated discussion of the developing area of conservation genetics. In Chapter 23, "Quantitative Genetics," we consider the heredity of traits in groups of individuals that are determined by many genes simultaneously. In this chapter we also discuss heritability: the relative extent to which a characteristic is determined by genes or by the environment. Both Chapters 22 and 23 include discussions of the application of molecular tools to these areas of genetics. Chapter 22, for example, includes a section on measuring genetic variation with RFLPs and DNA sequencing, and a discussion of molecular evolution.

PEDAGOGICAL FEATURES

Because the field of genetics is complex, making the study of it potentially difficult, we have incorporated a number of special pedagogical features to assist students and to enhance their understanding and appreciation of genetic principles. These features have proved to be very effective in previous editions of this text:

- Each chapter opens with an outline of its contents and a section called "Principal Points." Principal Points are short summaries that alert students to the key concepts they will encounter in the material to come.
- Throughout each chapter, strategically placed "Keynote" summaries emphasize important ideas and critical points.
- Important terms and concepts—highlighted in bold—are clearly defined where they are introduced in the text. For easy reference, they are also compiled in a Glossary at the back of the book.
- Some chapters include boxes covering special topics related to chapter coverage. Some of these boxed topics are: *Genetic Terminology* (Chapter 2); *Equilibrium Density Gradient Centrifugation* (Chapter 12); *Labeling of DNA* (Chapter 15); *Hardy, Weinberg, and the History of Their Contribution to Population Genetics* (Chapter 22); and *Analysis of Genetic Variation with Protein Electrophoresis* (Chapter 22).

- Chapter summaries close each chapter, further reinforcing the major points that have been discussed.
- With the exception of the introductory Chapter 1, all chapters conclude with a section entitled "Analytical Approaches for Solving Genetics Problems." Genetics principles have always been best taught with a problem-solving approach. However, beginning students often do not acquire the necessary experience with basic concepts that would enable them to attack assigned problems methodically. In the "analytical approaches" sections (pioneered in earlier editions of this text), typical genetic problems are talked through in step-by-step detail to help students understand how to tackle a genetics problem by applying fundamental principles.
- The problem sets that close the chapters include approximately 650 questions and problems designed to give students further practice in solving genetics problems. The problems for each chapter represent a range of topics and difficulty. The answers to questions indicated by an asterisk (*) can be found at the back of the book, and answers to all questions are available in a separate supplement, the *Study Guide and Solutions Manual*.
- Comprehensive and up-to-date suggested readings for each chapter are listed at the back of the book.
- Special care has been taken to provide the most useful Index—extensive, accurate, and well cross-referenced.

SUPPLEMENTS

A *Study Guide and Solutions Manual* to accompany this text has been prepared by Bruce Chase of the University of Nebraska. In addition to detailed solutions for all the problems in the text, the *Guide* contains the following features for each chapter: a review of important terms and concepts; an "Analytical Approaches for Solving Genetics Problems" section, which provides guidance and tips on solving problems and avoiding common pitfalls; and additional questions for practice and review.

The study guide includes a variety of essays, multiple choice and matching questions, Key Terms and Concepts, Chapter Outline, Approach to Analytical Thinking and Comprehensive Solutions.

The printed Test Bank, prepared by Holly Ahern of Adirondack Community College, includes approximately 900 multiple-choice, fill-in-the-blanks, and short-answer questions. The entire set of questions is also available in Macintosh and Windows test-generating software.

A set of 146 full-color transparencies complements the text.

The full complement of supplemental teaching materials is available to qualified instructors.

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