

生命科学名著

GENES IX

BENJAMIN LEWIN

基因IX



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Benjamin Lewin



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About the cover: DNA transcription by mRNA. Colored transmission electron micrograph of DNA and messenger RNA (mRNA) molecules forming a feather-like, transcriptionally active structure. This DNA is from the nucleus of an amphibian egg. The backbone of the feather, running down the image, is a long strand of DNA coated with protein. Numerous mRNA molecules extend in clusters from the DNA strand. Transcription of genetic information begins at one end of the gene, with the mRNA molecules growing longer as they approach completion. Transcription is the first step in protein synthesis. Magnification: approximately $\times 30,000$.

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Preface

Science is a wonderfully resilient venture. There are new and interesting developments to report in each revision of this book, and this revision includes much updated material to account for new findings in molecular research. The general organization of material in this edition has been revised along the same lines as *Essential Genes*, making it easier to use the two books in conjunction. With increasing size becoming a problem, the content has been more sharply focused on genes and their expression by eliminating the chapters dealing with the consequences of gene expression for cell biology. Striking changes occur in the first part of the book, dealing with genomes, resulting from the success of many genome sequencing projects. The importance of RNA as a regulator has become increasingly evident and now can be seen to extend across all levels of gene expression in both prokaryotes and eukaryotes. Somewhat of a “missing link,” it casts further light on how the current apparatus for gene expression must have evolved from the early RNA world.

My policy in this book has been to cite research and review articles that I believe readers will reasonably be able to access. My preference is for articles that are free after six months; where that is not possible, the publication should be widely available.

I thank the following individuals who served as proof-readers and consultants for this revision:

Elliott Goldstein	University of Arizona, Tempe
Jocelyn Krebs	University of Alaska, Anchorage
Kathleen Matthews	Rice University, Houston

Benjamin Lewin
January 2007

Organization

The new organization of *GENES IX* allows instructors and students to focus more sharply on genes and their expression with expanded coverage of key topics. The number of chapters and the order of topic coverage remains the same; however, several chapters were expanded into two or more chapters. These changes are as follows:

Chapter 1 in *GENES VIII*, Genes are DNA, is expanded to two chapters in *GENES IX*. Basic information on DNA structure, replication, and mutation remains in Chapter 1, whereas the discussion of the gene’s function as the unit of heredity appears in the new Chapter 2, Genes Code for Proteins.

Chapter 3 in *GENES VIII*, The Content of the Genome, becomes two chapters in *GENES IX*.

Chapter 4, The Content of the Genome, includes information on DNA sequences, genome mapping, and DNA in organelles.

Chapter 5, Genome Sequences and Gene Numbers, now contains genome size and expression information for a number of organisms, as well as new material on genes in the Y chromosome.

The new Chapter 12, The Operon, comprises *GENES VIII* Chapter 10, as well information on regulation of transcription and translation from *GENES VIII* Chapter 11, Regulatory Circuits. Material on regulatory RNA is now found in Chapter 13.

The material in *GENES VIII* Chapter 13, The Replicon, is expanded in three chapters in *GENES IX*. Chapter 15, The Replicon, covers the structure and function of the replicon, as well as replication origins. Chapter 16, Extrachromosomal Replicons, contains material on terminal proteins, rolling circle replication, plasmids, and T-DNA. Information on how bacterial replication is connected to the cell cycle is found in Chapter 17.

Recombination and Repair, Chapter 15 in *GENES VIII*, is now covered in two chapters in *GENES IX*. Chapter 19 covers homologous and site-specific recombination, and Chapter 20 covers the repair systems, including new information on excision-repair pathways in mammalian cells.

Chapter 23, Controlling Chromatin Structure, in *GENES VIII* is now Chapter 30, discussing the relation between chromatin structure and gene expression.

Chapter 31, Epigenetic Effects are Inherited, details the causes and mechanisms of epigenetic inheritance.

Art Program and Design

GENES IX has a new, contemporary look. Both the design and art program for this edition were updated and revised to facilitate student learning. In addition, the style and design for *GENES IX* intentionally matches that of Lewin's new cell biology text, *CELLS*, which allows students and instructors to easily utilize both texts.

Supplements to the Text

For the Student

The web site developed exclusively for the ninth edition of this text, <http://biology.jbpub.com/book/genes/>, offers a variety of resources to enhance understanding of molecular biology.

Laboratory Investigations in Molecular Biology, by Williams, Slatko, and McCarrey, presents well-tested protocols in molecular biology that are commonly used in active re-

search labs. The experiments are designed to guide students through realistic research projects conducted in modern research laboratories.

For the Instructor

Compatible with Windows and Macintosh platforms, the Instructor's ToolKit—CD-ROM provides instructors with the following traditional ancillaries:

- The *Test Bank* is available as straight text files.
- The *PowerPoint® Lecture Outline Slides* presentation package provides lecture notes, and images for each chapter of *GENES IX*. Instructors with the Microsoft PowerPoint® software can customize the outlines, art, and order of presentation.
- The *Image Bank* provides the critical art and tables in the text to which Jones and Bartlett Publishers holds the copyright or has digital reprint rights. The image library enables instructors to project images from the text in the classroom, insert images into PowerPoint® presentations, or print overhead acetates.

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Genes Are DNA

CHAPTER OUTLINE

1.1 Introduction

1.2 DNA Is the Genetic Material of Bacteria

- Bacterial transformation provided the first proof that DNA is the genetic material of bacteria. Genetic properties can be transferred from one bacterial strain to another by extracting DNA from the first strain and adding it to the second strain.

1.3 DNA Is the Genetic Material of Viruses

- Phage infection proved that DNA is the genetic material of viruses. When the DNA and protein components of bacteriophages are labeled with different radioactive isotopes, only the DNA is transmitted to the progeny phages produced by infecting bacteria.

1.4 DNA Is the Genetic Material of Animal Cells

- DNA can be used to introduce new genetic features into animal cells or whole animals.
- In some viruses, the genetic material is RNA.

1.5 Polynucleotide Chains Have Nitrogenous Bases Linked to a Sugar–Phosphate Backbone

- A nucleoside consists of a purine or pyrimidine base linked to position 1 of a pentose sugar.
- Positions on the ribose ring are described with a prime (') to distinguish them.
- The difference between DNA and RNA is in the group at the 2' position of the sugar. DNA has a deoxyribose sugar (2'–H); RNA has a ribose sugar (2'–OH).
- A nucleotide consists of a nucleoside linked to a phosphate group on either the 5' or 3' position of the (deoxy)ribose.
- Successive (deoxy)ribose residues of a polynucleotide chain are joined by a phosphate group between the 3' position of one sugar and the 5' position of the next sugar.
- One end of the chain (conventionally the left) has a free 5' end and the other end has a free 3' end.
- DNA contains the four bases adenine, guanine, cytosine, and thymine; RNA has uracil instead of thymine.

1.6 DNA Is a Double Helix

- The B-form of DNA is a double helix consisting of two polynucleotide chains that run antiparallel.
- The nitrogenous bases of each chain are flat purine or pyrimidine rings that face inward and pair with one another by hydrogen bonding to form A-T or G-C pairs only.

- The diameter of the double helix is 20 Å, and there is a complete turn every 34 Å, with ten base pairs per turn.
- The double helix forms a major (wide) groove and a minor (narrow) groove.

1.7 DNA Replication Is Semiconservative

- The Meselson–Stahl experiment used density labeling to prove that the single polynucleotide strand is the unit of DNA that is conserved during replication.
- Each strand of a DNA duplex acts as a template to synthesize a daughter strand.
- The sequences of the daughter strands are determined by complementary base pairing with the separated parental strands.

1.8 DNA Strands Separate at the Replication Fork

- Replication of DNA is undertaken by a complex of enzymes that separate the parental strands and synthesize the daughter strands.
- The replication fork is the point at which the parental strands are separated.
- The enzymes that synthesize DNA are called DNA polymerases; the enzymes that synthesize RNA are called RNA polymerases.
- Nucleases are enzymes that degrade nucleic acids; they include DNAases and RNAases and can be divided into endonucleases and exonucleases.

1.9 Genetic Information Can Be Provided by DNA or RNA

- Cellular genes are DNA, but viruses and viroids may have genomes of RNA.
- DNA is converted into RNA by transcription, and RNA may be converted into DNA by reverse transcription.
- The translation of RNA into protein is unidirectional.

1.10 Nucleic Acids Hybridize by Base Pairing

- Heating causes the two strands of a DNA duplex to separate.
- The T_m is the midpoint of the temperature range for denaturation.
- Complementary single strands can renature when the temperature is reduced.
- Denaturation and renaturation/hybridization can occur with DNA–DNA, DNA–RNA, or RNA–RNA combinations and can be intermolecular or intramolecular.

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