The cover features a central illustration of a large, textured, orange-yellow bacterium. A bacteriophage is shown attached to the bacterium's surface, with its tail fibers and head visible. A red DNA double helix is shown extending from the bacterium. Below the bacterium, a blue DNA double helix is shown being cut by a pair of scissors. The background is a dark blue gradient with a pattern of small, light blue dots.

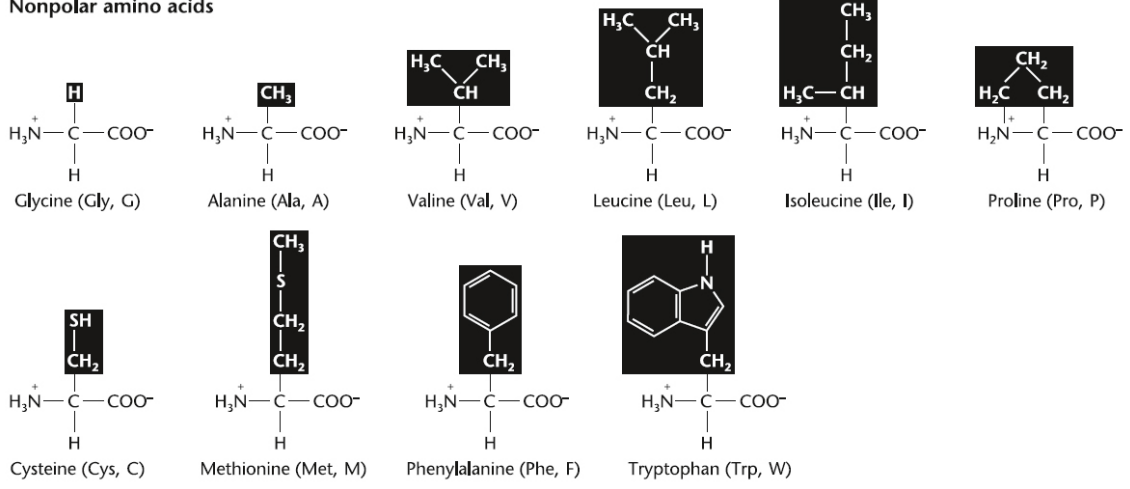
Snyder & Champness
**Molecular
Genetics
of Bacteria**

FIFTH EDITION

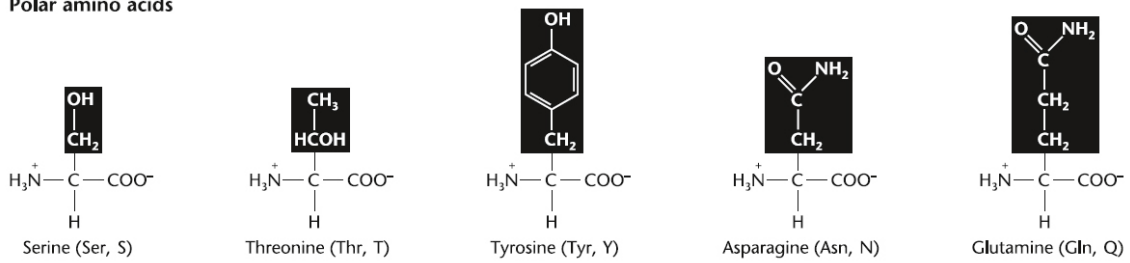
Tina M. Henkin
and Joseph E. Peters

The Amino Acids

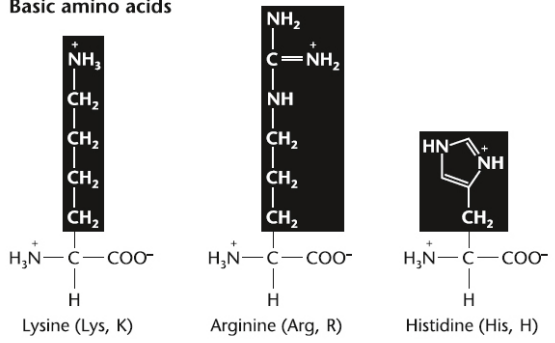
Nonpolar amino acids



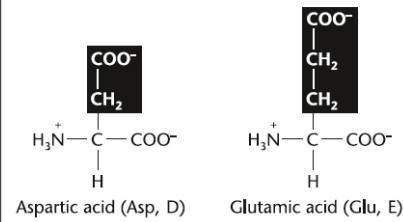
Polar amino acids



Basic amino acids

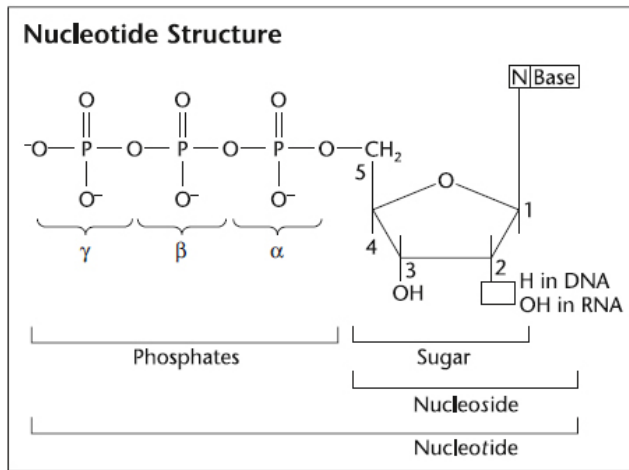


Acidic amino acids



The Genetic Code

First position	Second position				Third position
	U	C	A	G	
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	Stop	Stop	A
	Leu	Ser	Stop	Trp	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G



Names of Nucleic Acid Subunits

Base	Nucleoside	Nucleotide	Abbreviation	
			RNA	DNA
Adenine	Adenosine	Adenosine triphosphate	ATP	dATP
Guanine	Guanosine	Guanosine triphosphate	GTP	dGTP
Cytosine	Cytidine	Cytidine triphosphate	CTP	dCTP
Thymine	Thymidine	Thymidine triphosphate		dTTP
Uracil	Uridine	Uridine triphosphate	UTP	

Table of Contents

[Cover](#)

[Table of Contents](#)

[About the Companion Website](#)

[Title Page](#)

[Preface](#)

[Acknowledgments](#)

[About the Authors](#)

[Introduction](#)

[The Biological Universe](#)

[What Is Genetics?](#)

[Bacterial Genetics](#)

[Phage Genetics](#)

[A Brief History of Bacterial Molecular Genetics](#)

[What Is Ahead](#)

[1 The Bacterial Chromosome: DNA Structure, Replication, and Segregation](#)

[DNA Structure](#)

[The Mechanism of DNA Replication](#)

[Replication Errors](#)

[Impediments to DNA Replication](#)

[Replication of the Bacterial Chromosome and Cell Division](#)

[The Bacterial Nucleoid](#)

[The Bacterial Genome](#)

[2 Bacterial Gene Expression: Transcription, Translation, Protein Folding, and Localization](#)

[Overview](#)

[The Structure and Function of RNA](#)

[Transcription](#)

[RNA Degradation](#)

[The Structure and Function of Proteins](#)

[Translation](#)

[Protein Folding and Degradation](#)

[Protein Localization](#)

[Protein Secretion and Export](#)

[Regulation of Gene Expression](#)

[What You Need To Know](#)

[3 Bacterial Genetic Analysis: Fundamentals and Current Approaches](#)

[Definitions](#)

[Inheritance in Bacteria](#)

[Mutation Rates](#)

[Types of Mutations](#)

[Reversion versus Suppression](#)

[Genetic Analysis in Bacteria](#)

[Perspective](#)

[4 Plasmids](#)

[What Is a Plasmid?](#)

[Properties of Plasmids](#)

[5 Conjugation](#)

[Overview](#)

[Mechanism of DNA Transfer during Conjugation in *Proteobacteria*](#)

[Chromosome Transfer by Plasmids](#)

[Diversity in Transfer Systems](#)

Integrating Conjugative Elements

6 Transformation

Natural Transformation

Artificially Induced Competence

7 Bacteriophages and Transduction

Lytic Development

Lysogenic Development

Genetic Analysis of Phages

Phage-Mediated Genetic Transfer

Host Defenses Against Phage Infection

Phages as Tools

8 Transposition, Site-Specific Recombination, and Families of Recombinases

Transposition

Mechanisms of Transposition

General Properties of Transposons

Transposon Mutagenesis

Site-Specific Recombination

Y and S Recombinases

Group II Mobile Introns: Elements that Move Using an RNA Intermediate

Importance of Transposition and Site-Specific Recombination in Bacterial Adaptation

9 Molecular Mechanisms of Homologous Recombination

Homologous Recombination and DNA Replication in Bacteria

The Molecular Basis for Recombination in *E. coli*

Recombination between Different DNAs in Bacteria

Recombineering: Gene Replacements in *E. coli* with Phage λ Recombination Functions

10 DNA Repair and Mutagenesis

Evidence for DNA Repair

Specific Repair Pathways

General Repair Mechanisms

DNA Damage Tolerance Mechanisms

Summary of Repair Pathways in *E. coli*

Bacteriophage Repair Pathways

11 Regulation of Gene Expression: Genes and Operons

Transcriptional Regulation in Bacteria

Negative Regulation of Transcription Initiation

Positive Regulation of Transcription Initiation

Regulation by Transcription Attenuation

Regulation of mRNA Degradation

Regulation of Translation

Posttranslational Regulation

Why Are There So Many Mechanisms of Gene Regulation?

12 Global Regulation: Regulons and Stimulons

Carbon Catabolite Regulation

Regulation of Nitrogen Assimilation

Regulation of Ribosome Components and tRNA Synthesis

Ribosomal Protein Gene Regulation

Stress Responses in Bacteria

Iron Regulation in *E. coli*

Regulation of Virulence Genes in Pathogenic Bacteria

[Developmental Regulation: Sporulation in *B. subtilis*](#)

[13 Genomes and Genomic Analysis](#)

[The Bacterial Genome](#)

[DNA Sequencing](#)

[Barriers to Horizontal Transfer: Genome](#)

[Gatekeepers and the Molecular Biologist's Toolkit](#)

[Glossary](#)

[End Papers](#)

[Index](#)

[End User License Agreement](#)

List of Illustrations

Introduction

[Figure 1 A molecular tree of life capturing diversity using ribosomal proteins...](#)

Chapter 1

[Figure 1.1 Schematic drawing of the Watson-Crick structure of DNA, showing the...](#)

[Figure 1.2 Chemical structures of deoxyribonucleotides, showing the bases and ...](#)

[Figure 1.3 \(A\) Schematic drawing of a DNA chain, showing the 3'-to-5' attachme...](#)

[Figure 1.4 The two complementary base pairs found in DNA. Two hydrogen bonds f...](#)

[Figure 1.5 The pathways for synthesis of deoxynucleotides from ribonucleotides...](#)

[Figure 1.6 Features of DNA. \(A\) Polymerization of the deoxynucleotides during ...](#)

[Figure 1.7 Functions of the primer and template in DNA replication. \(A\) The DN...](#)

[Figure 1.8 Discontinuous synthesis of one of the two strands of DNA during chr...](#)

[Figure 1.9 DNA polymerase I can remove an RNA primer by using strand displacem...](#)

[Figure 1.10 "Trombone" model for how both the leading strand and lagging stran...](#)

[Figure 1.11 Mistakes in base pairing can lead to changes in the DNA sequence c...](#)

[Figure 1.12 Editing function of DNA polymerase. \(A\) A G is mistakenly placed o...](#)

[Figure 1.13 Physical blocks on template DNAs. \(A\) When DNA polymerase III stal...](#)

[Figure 1.14 Structure of the origin of chromosomal replication \(*oriC*\) region o...](#)

[Figure 1.15 Initiation of replication at the *Escherichia coli* origin \(*oriC*\) re...](#)

[Figure 1.16 Termination of chromosome replication in *Escherichia coli*. \(A\) The...](#)

[Figure 1.17 Model of the way in which chromosome translocation by FtsK coordin...](#)

[Figure 1.18 Model of the way in which unwinding of the template DNA strands ca...](#)

[Figure 1.19 Model of the way in which chromosome decatenation by topoisomerase...](#)

[Figure 1.20 Model of how an origin region containing *parS* sites bound by the P...](#)

[Figure 1.21 The *E. coli* chromosome has four structured regions called macrodom...](#)

[Figure 1.22 The MinCDE and nucleoid occlusion systems control placement of the...](#)

[Figure 1.23 Timing of DNA replication during the cell cycle, with two differen...](#)

[Figure 1.24 Replication creates hemimethylated DNA. \(A\) The A in the sequence ...](#)

[Figure 1.25 Model showing the possible functional consequences of SeqA binding...](#)

[Figure 1.26 \(A\) Supercoiled DNA. \(B\) Twisting of the ends in opposite directio...](#)

[Figure 1.27 Action of the two types of topoisomerases. The type I topoisomerases...](#)

Chapter 2

[Figure 2.1 RNA precursors. \(A\) A ribonucleoside triphosphate \(rNTP\) \(the form ...](#)

[Figure 2.2 Secondary structure in an RNA. \(A\) The RNA folds back on itself to ...](#)

[Figure 2.3 The structure of bacterial RNA polymerase. The core enzyme is compo...](#)

[Figure 2.4 Crystal structure of bacterial RNA polymerase and \$\sigma\$ interact...](#)

[Figure 2.5 RNA transcription. \(A\) The polymerization reaction, in whi...](#)

[Figure 2.6 \(A\) Typical structure of a \$\sigma^{70}\$ bacterial...](#)

[Figure 2.7 Transcription begins at a promoter and ends at a transcription te...](#)

[Figure 2.8 Overview of transcription. \(A\) The transcription cycle. Ea...](#)

[Figure 2.9 Transcription initiation. \(A\) Binding of \$\sigma\$ to RNA p...](#)

[Figure 2.10 Interactions between RNA polymerase subunits and promoter elements...](#)

[Figure 2.11 Abortive transcription and RNA polymerase escape from the promoter...](#)

[Figure 2.12 The transcription elongation complex \(TEC\). During elongation, nuc...](#)

[Figure 2.13 Backtracked transcription elongation complex \(TEC\). Backward movem...](#)

[Figure 2.14 Transcription termination at a factor-independent termination site...](#)

[Figure 2.15 Model for factor-dependent transcription termination at a ...](#)

[Figure 2.16 Precursor of rRNA. The precursor transcript \(top\) contains ...](#)

[Figure 2.17 Structure of mature tRNAs. \(A\) Standard clover leaf ...](#)

[Figure 2.18 Pathways for RNA degradation. RNA transcripts that are gene...](#)

[Figure 2.19 Two amino acids joined by a peptide bond. The bond connects...](#)

[Figure 2.20 Primary, secondary, tertiary, and quaternary structures of ...](#)

[Figure 2.21 The composition of a bacterial ribosome containing one copy...](#)

[Figure 2.22 Crystal structures of a tRNA and the ribosome. \(A\) ...](#)

[Figure 2.23 Overview of translation. \(A\) The ribosomal A \(amino...](#)

[Figure 2.24 Aminoacylation of a tRNA by its cognate aminoacyl-tRNA syn...](#)

[Figure 2.25 Complementary pairing between a tRNA anticodon and an mRNA...](#)

[Figure 2.26 Conversion of methionine \(Met\) to *N*-formyl-methionin...](#)

[Figure 2.27 Structure of a typical bacterial translational initiation r...](#)

[Figure 2.28 Initiation of translation. **\(1\)** The IF3 factor binds ...](#)

[Figure 2.29 The peptidyltransferase reaction catalyzes dissociation of ...](#)

[Figure 2.30 Termination of translation at a nonsense codon. In the abse...](#)

[Figure 2.31 Removal of the N-terminal formyl group by peptide deformyla...](#)

[Figure 2.32 *trans*-Translation by transfer-messenger RNA \(tmRNA\)...](#)

[Figure 2.33 Wobble pairing between the anticodon on the tRNA and the ...](#)

[Figure 2.34 Structure of a polycistronic mRNA. **\(A\)** The coding ...](#)

[Figure 2.35 Model for translational coupling in a polycistronic mRNA...](#)

[Figure 2.36 Polarity in transcription of a polycistronic mRNA transcr...](#)

[Figure 2.37 Chaperonins. The GroEL \(Hsp60\)-type chaperonin multimers ...](#)

[Figure 2.38 Protein transport systems. **\(A\)** Cutaway view of the...](#)

[Figure 2.39 Schematic representation of the type I, II, III, and IV ...](#)

[Figure 2.40 Structure and function of a typical autotransporter. A ...](#)

[Figure 2.41 Comparison of the *Firmicute*-type injectosome ...](#)

[Figure 2.42 The sortase A pathway. \(A\) Typical sortase sub...](#)

[Figure 2.43 \(A\) The two general types of transcriptional r...](#)

[Figure 2.44 Relationship between gene structure in DNA and the co...](#)

[Figure 2.45 Transcriptional and translational fusions to express ...](#)

Chapter 3

[Figure 3.1 Detection of auxotrophic mutants. Cells were scraped with a loop fr...](#)

[Figure 3.2 The number of mutants in a culture is not proportional to the numbe...](#)

[Figure 3.3 The Luria and Delbrück experiment. In experiment 1, a single flask ...](#)

[Figure 3.4 Mutants are clonal. In experiment 1, cells were spread onto a plate...](#)

[Figure 3.5 The number of cell divisions \(7\) equals the total number of cells I...](#)

[Figure 3.6 The fraction of mutants increases as a culture multiplies, and the ...](#)

[Figure 3.7 Transitions versus transversions. The mutations are shown in gold s...](#)

Figure 3.8 (A) A mispairing during replication can lead to a base pair change ...

Figure 3.9 Removal of deaminated cytosine (uracil) from DNA. (A) Comparison of...

Figure 3.10 Missense mutation. A mutation that changes T to C in the DNA templ...

Figure 3.11 Nonsense mutation. Changing the CAA codon, encoding glutamine (Gln...

Figure 3.12 Frameshift mutation. The wild-type mRNA is translated as glutamine...

Figure 3.13 Slippage of DNA at a repeated sequence (for example, a series of A...

Figure 3.14 Ectopic recombination between directly repeated sequences can caus...

Figure 3.15 Formation of a long tandem-duplication mutation does not Inactivat...

Figure 3.16 Recombination between inverted repeats can cause inversion mutatio...

Figure 3.17 The pathway to galactose utilization in *E. coli* and most other org...

Figure 3.18 Formation of a nonsense suppressor tRNA. (A) Gene X (turquoise) an...

Figure 3.19 Selection of a His⁺ revertant. A sample of a His⁻ mutant cul...

Figure 3.20 Replica plating. (A) A few hundred bacteria are spread on a nonsele...

Figure 3.21 A simplified diagram of recombination between two genetic markers....

Figure 3.22 Different consequences of recombination between linear and circula...

[Figure 3.23 Using recombination to introduce an antibiotic resistance cassette...](#)

[Figure 3.24 Using marker rescue to locate a mutation In the physical map of th...](#)

[Figure 3.25 Complementation tests for allelism. Four mutations, *hisA1*, *hisA2*, ...](#)

[Figure 3.26 *E. coli lacZ* \$\alpha\$ intragenic complementation. \(A\) The *lacZ* \$\Delta\$ M15 deleti...](#)

[Figure 3.27 Identification of clones of the *thyA* gene of *E. coli* by complement...](#)

[Figure 3.28 Use of marker rescue to identify a clone containing at least part ...](#)

[Figure 3.29 Selected versus unselected markers In a bacterial cross. Replaceme...](#)

[Figure 3.30 Example of generalized transduction. A phage Infects a Trp⁺ bacter...](#)

[Figure 3.31 Cotransduction of bacterial genetic markers. \(A\) Two-factor cross....](#)

[Figure 3.32 Generic test for reversion versus suppression. \(A\) The mutation ha...](#)

[Figure 3.33 Using transduction to distinguish reversion from suppression. If t...](#)

[Figure 3.34 Transfer of chromosomal DNA by an Integrated plasmid. Formation of...](#)

[Figure 3.35 Partial genetic linkage map of *E. coli* showing the positions \(blac...](#)

[Figure 3.36 Mapping by Hfr crosses. The phenotypes and positions of the marker...](#)

[Figure 3.37 Mapping by gradient of transfer during an Hfr cross. The ordinate ...](#)

Chapter 4

[Figure 4.1 Supercoiling of a covalently closed circular plasmid. \(A\) A break i...](#)

[Figure 4.2 Some common schemes of plasmid replication. \(A\) Unidirectional repl...](#)

[Figure 4.3 Coexistence of two plasmids from different Inc groups. \(A\) After di...](#)

[Figure 4.4 Genetic map of plasmid ColE1. The plasmid is 6,646 bp long. On the ...](#)

[Figure 4.5 Regulation of the replication of ColE1-derived plasmids. RNA II mus...](#)

[Figure 4.6 Pairing between an RNA and its antisense RNA. \(A\) An antisense RNA ...](#)

[Figure 4.7 Regulation of replication of the IncFII plasmid R1. \(A\) Locations o...](#)

[Figure 4.8 Regulation of plasmid ColIb-P9 copy number by antisense RNA inhibit...](#)

[Figure 4.9 Regulation of plasmid pT181 copy number by antisense RNA regulation...](#)

[Figure 4.10 The *ori* region of pSC101. R1, R2, and R3 are the three iteron sequ...](#)

[Figure 4.11 The “handcuffing” or “coupling” model for regulation of iteron pla...](#)

[Figure 4.12 The Xer functions of *E. coli* catalyze site-specific recombination ...](#)

[Figure 4.13 Model for partitioning of the R1 plasmid. \(A\) Structure of the *par*](#)

[Figure 4.14 Model for partitioning by *par* systems on P1, F, and RK2. \(A\) Struc...](#)

[Figure 4.15 Finding the origin of replication \(*ori*\) in a plasmid. Random piece...](#)

[Figure 4.16 pUC expression vector. A gene cloned into one of the restriction s...](#)

[Figure 4.17 pBAC cloning vector for cloning large pieces of DNA. The multiple ...](#)

[Figure 4.18 Shuttle plasmid YEp13. The plasmid contains origins of replication...](#)

Chapter 5

[Figure 5.1 A simplified view of conjugation by a self-transmissible plasmid, t...](#)

[Figure 5.2 Partial genetic map of the ~100-kilobase pair \(kbp\) self-transmissi...](#)

[Figure 5.3 Representation of the F transfer apparatus. The pilus is assembled ...](#)

[Figure 5.4 Mechanism of DNA transfer during conjugation, showing the Mpf funct...](#)

[Figure 5.5 Reactions performed by the relaxase. \(A\) The relaxase nicks the DNA...](#)

[Figure 5.6 Fertility Inhibition of the F plasmid. Only the relevant *tra* genes ...](#)

[Figure 5.7 Gene arrangements of type IV secretion loci. Genes with homologs in...](#)

[Figure 5.8 Mechanism of plasmid mobilization. The donor cell carries two plasm...](#)

[Figure 5.9 Integration of the F plasmid by recombination between IS2 elements ...](#)

[Figure 5.10 Generation of a prime factor by recombination. Recombination may o...](#)

[Figure 5.11 Self-transmissible and mobilizable elements are found with integra...](#)

[Figure 5.12 Fluorescence micrograph of *Bacillus subtilis* cells showing the loc...](#)

[Figure 5.13 Self-transmissible Integrating conjugative elements \(ICE\) can carr...](#)

[Figure 5.14 Genetic map and diagram of the integration and excision process of...](#)

Chapter 6

[Figure 6.1 The Griffith experiment. \(A\) Type R \(rough\) nonencapsulated bacteri...](#)

[Figure 6.2 Structure of DNA uptake competence systems. \(A\) *Firmicutes*. \(B\) *Pro...*](#)

[Figure 6.3 Visualization of DNA uptake using fluorescent labels. Competent *B. ...*](#)

[Figure 6.4 Sequence logos showing conservation of uptake sequences for natural...](#)

[Figure 6.5 Transformation by plasmid DNA. DNA is linearized outside the cell \(...\)](#)

[Figure 6.6 Import of multiple DNA fragments into a single cell by congression....](#)

[Figure 6.7 Regulation of competence development by quorum sensing. \(A\) In *Baci...*](#)

[Figure 6.8 Comparison of competence regulatory mechanisms. Green arrows indica...](#)

[Figure 6.9 Repair of DNA damage by transforming DNA. Thymine dimers \(T residue...](#)

Chapter 7

[Figure 7.1 Electron micrographs and plaques of some bacteriophages. \(A\) A phag...](#)

[Figure 7.2 A typical bacteriophage multiplication cycle. After the phage injec...](#)

[Figure 7.3 Transcriptional regulation by a regulatory cascade during developme...](#)

[Figure 7.4 Genetic map of phage T7. The genes for the RNA polymerase used for ...](#)

[Figure 7.5 Regulation of SP01 gene expression by a cascade of \$\sigma\$ factors. Early...](#)

[Figure 7.6 \(A\) Genomic map of phage T4. From Karam JD \(ed\), *Molecular Biology ...*](#)

[Figure 7.7 Sequence of T4 middle-mode and late promoters. Only the sequences i...](#)

[Figure 7.8 Model for T4 DNA replication and activation of a replication-couple...](#)

[Figure 7.9 Genetic map of \$\lambda\$ cyclized by pairing at the *cos* sites, shown at the...](#)

[Figure 7.10 Antitermination of transcription in phage \$\lambda\$. \(A\) Before the N prot...](#)

[Figure 7.11 Sequences of the *nutL* and *nutR* regions of bacteriophage \$\lambda\$. Box A, ...](#)

[Figure 7.12 Formation of the Q protein antitermination complex at the \$p_R'\$ prom...](#)

[Figure 7.13 Infection cycle of the single-stranded DNA phage \$\phi\$ 1. Steps 1 throu...](#)

[Figure 7.14 Schematic representation of the filamentous bacteriophage M13. The...](#)

[Figure 7.15 Replication of the circular single-stranded DNA phage M13. First, ...](#)

[Figure 7.16 Overview of replication of phage \$\lambda\$. See text for details.](#)

[Figure 7.17 Replication of phage T7 DNA. Replication is initiated bidirectiona...](#)

[Figure 7.18 Initiation of replication of phage T4 DNA. In stage 1, replication...](#)

[Figure 7.19 T4 DNA headful packaging. Packaging of DNA longer than a single ge...](#)

[Figure 7.20 Timing of phage lysis by activation of holins. The antiholin keeps...](#)

[Figure 7.21 Overview of the fate of \$\lambda\$ DNA in the lytic and lysogenic pathways....](#)

[Figure 7.22 Genetic map of phage \$\lambda\$. The locations of key genes and transcripts...](#)

[Figure 7.23 Formation of lysogens after \$\lambda\$ infection. \(A\) The *cII* and *cIII* gene...](#)

[Figure 7.24 Integration of \$\lambda\$ DNA into the chromosome of *E. coli*. \(A\) The *Int* p...](#)

[Figure 7.25 Regulation of repressor synthesis in the lysogenic state. The dumb...](#)

[Figure 7.26 Cro prevents repressor binding and synthesis by binding to the ope...](#)

[Figure 7.27 Induction of \$\lambda\$. Accumulation of single-stranded DNA \(ssDNA\) due to...](#)

[Figure 7.28 Retroregulation. \(A\) After infection, the *xis* and *int* genes cannot...](#)

[Figure 7.29 Competition determining whether phage will enter the lytic or lyso...](#)

[Figure 7.30 Recombination between two phage mutations. The two different mutan...](#)

[Figure 7.31 Tests of complementation between phage mutations. Phages with diff...](#)

[Figure 7.32 Generalized transduction. A phage infects one bacterium, and in th...](#)

[Figure 7.33 Formation of a \$\lambda\$ dg_{al} transducing particle. A rare mistake in recom...](#)

[Figure 7.34 Induction of the \$\lambda\$ dg_{al} phage from a dilyso_{gen} containing both \$\lambda\$ dga...](#)

[Figure 7.35 Lysogenic conversion. \(A\) Shiga toxins encoded by close relatives ...](#)

[Figure 7.36 Use of phage T7 for phage display. \(A\) A randomized protein-coding...](#)

Chapter 8

[Figure 8.1 Overview of transposition. See the text for details.](#)

[Figure 8.2 Steps in transposon excision. Inverted repeats \(IRs\) \(shown as oran...](#)

[Figure 8.3 Steps in transposon insertion. The transposon inserts into a target...](#)

[Figure 8.4 Structures of some composite transposons. The left \(L\) and right \(R...](#)

[Figure 8.5 Two insertion sequence \(IS\) elements can transpose any DNA between ...](#)

[Figure 8.6 R factors, or plasmids containing many resistance genes, may have b...](#)

[Figure 8.7 Some examples of noncomposite transposons. The positions of the tra...](#)

[Figure 8.8 Example of a mating-out assay for transposition. See the text for d...](#)

[Figure 8.9 The DDE transpose has been adapted in multiple ways for different f...](#)

[Figure 8.10 Replicative transposition of Tn3 \(orange\) and formation and resolu...](#)

[Figure 8.11 Model for single-strand DNA transposition with IS608. IS608 moves ...](#)

[Figure 8.12 Regulation of Tn5 transposition. Two similar IS50 elements flank t...](#)

[Figure 8.13 Transposition after DNA replication facilitates DNA repair. \(A and...](#)

[Figure 8.14 Transposon Tn7 uses an element-encoded heteromeric transposase and...](#)

[Figure 8.15 Random transposon Tn5 mutagenesis. Random transposon mutagenesis o...](#)

[Figure 8.16 Cloning genes mutated by insertion of a transposon. A transposon u...](#)

[Figure 8.17 Assembly of integrons. The primary transposon carries an integron ...](#)

[Figure 8.18 Example of a superintegron from *Vibrio cholerae*. More than 100 cas...](#)

[Figure 8.19 Regulation of *Salmonella* phase variation and some other members of...](#)

[Figure 8.20 Domain structure of tyrosine recombinases \(Cre, XerCD, etc.; \$\lambda\$ Int...](#)

[Figure 8.21 Model for the reaction promoted by the Cre tyrosine \(Y\) recombinas...](#)

[Figure 8.22 Structures of some sites recognized by tyrosine \(Y\) recombinases. ...](#)

[Figure 8.23 Domain structure of serine \(S\) recombinases. The conserved catalyt...](#)

[Figure 8.24 Model for the reaction promoted by the \$\gamma\delta\$ recombinase. \(A\) Four re...](#)

[Figure 8.25 How successive attacks by nucleophilic hydroxyl groups of serine \(...](#)

[Figure 8.26 Excision of a group II mobile intron from an mRNA. \(A\) After trans...](#)

[Figure 8.27 Integration of a group II mobile intron into double-stranded DNA b...](#)

Chapter 9

[Figure 9.1 Replication forks initiated at *oriC* can collapse when there are nic...](#)

[Figure 9.2 Model for promotion of recombination Initiation at a \$\chi\$ site by the ...](#)

[Figure 9.3 Model for how \$\chi\$ sites can help RecBCD load RecA to direct DNA repli...](#)

[Figure 9.4 Models for recombination Initiation by the RecF pathway on substrat...](#)

[Figure 9.5 Model for how DNA substrates with various types of DNA breaks are p...](#)

[Figure 9.6 Model for synapse formation and strand exchange between two homolog...](#)

[Figure 9.7 Holliday junctions can form through the action of RecA. The movemen...](#)

[Figure 9.8 Model for the mechanism of action of the Ruv proteins. \(1\) One or t...](#)

[Figure 9.9 A synthetic Holliday junction with four complementary strands. The ...](#)

[Figure 9.10 Model for how linear fragments are recombined Into the chromosome ...](#)

[Figure 9.11 Recombineering: *in vivo* DNA modification in *E. coli* using \$\lambda\$ phage-...](#)

[Figure 9.12 Migration of Holliday junctions. By breaking the hydrogen bonds ho...](#)

[Figure 9.13 Repair of a mismatch in a heteroduplex region formed during recomb...](#)

[Figure 9.14 Repair of mismatches can give rise to recombinant types between tw...](#)

Chapter 10

[Figure 10.1 Survival of cells as a function of the time or extent of treatment...](#)

[Figure 10.2 \(A\) Modified bases created by deaminating agents, such as nitrous ...](#)

[Figure 10.3 Repair of altered bases by DNA glycosylases. \(A\) The specific DNA ...](#)

[Figure 10.4 \(A\) Structure of 8-oxoG. \(B\) Mechanisms for avoiding mutagenesis d...](#)

[Figure 10.5 Alkylation of guanine to produce O⁶-methyiguanine. The altered bas...](#)

[Figure 10.6 \(A\) The adaptive response. \(B\) Regulation of the adaptive response...](#)

[Figure 10.7 Two common types of pyrimidine dimers caused by UV irradiation. In...](#)

[Figure 10.8 Photoreactivation. The photoreactivating enzyme \(photolyase\) binds...](#)

[Figure 10.9 Base analogs 2-aminopurine \(2-AP\) and 5-bromouracil \(5-BU\). The am...](#)

[Figure 10.10 Mutagenesis by incorporation of the adenine analog 2-AP into DNA....](#)

[Figure 10.11 Mutagenesis by a frameshift mutagen. Intercalation of a planar ac...](#)

[Figure 10.12 The methyl-directed mismatch repair system. The newly replicated ...](#)

[Figure 10.13 MutSLH DNA repair in *E. coli*. \(A\) One arm of a replication fork i...](#)

[Figure 10.14 Colonies due to *mut* mutants have more papillae. A *lacZ* mutant was...](#)

[Figure 10.15 Model for nucleotide excision repair by the UvrABC endonuclease. ...](#)

[Figure 10.16 Model for transcription-coupled nucleotide excision repair. Mfd-d...](#)

[Figure 10.17 Model for recombination-mediated bypass of DNA damage in the DNA ...](#)

[Figure 10.18 Fork regression model for recombination-mediated replicative bypa...](#)

[Figure 10.19 Models for how regressed replication forks can be repaired by mul...](#)

[Figure 10.20 Repair of a DNA interstrand cross-link through the combined actio...](#)

[Figure 10.21 Regulation of the SOS response regulon in *Escherichia coli*. About...](#)

[Figure 10.22 Detection of a mutant defective in mutagenic repair. Colonies of ...](#)

[Figure 10.23 Regulation of SOS mutagenesis in *E. coli*. \(A\) Before DNA damage o...](#)

Chapter 11

[Figure 11.1 Complementation of *lac* mutations. One mutation \(*m1*\) is in the chro...](#)

Figure 11.2 The p_{jac} mutations cannot be complemented and are *cis* acting. A *pl...*

Figure 11.3 Complementation with two types of constitutive mutations. (A) The

Figure 11.4 The Jacob and Monod model for negative regulation of the *lac* opero...

Figure 11.5 Locations of the three operators in the *lac* operon (A) and a model...

Figure 11.6 (A) DNA sequence of the promoter and operator regions of the *lac* o...

Figure 11.7 Three-dimensional structure of the LacI protein, showing regions d...

Figure 11.8 Structure of the galactose operon of *E. coli*. The *galE*, *galT*, and

Figure 11.9 Pathway for galactose utilization In *E. coli*.

Figure 11.10 Formation of the *gal* operon repressosome. (A) Structure of the *ga...*

Figure 11.11 Structure of the tryptophan biosynthetic (*trp*) operon of *E. coli*.

Figure 11.12 Negative regulation of the *trp* operon by the TrpR repressor. Bind...

Figure 11.13 Structure of the TrpR repressor and an illustration of how trypto...

Figure 11.14 (A) Structure and function of the L-arabinose operon of *E. coli*.

Figure 1 Figures 1-4 adapted from Dove SL, Hochschild A, in Higgins NP (ed), *T...*

Figure 2

[Figure 3](#)

[Figure 4](#)

[Figure 11.15 Recessiveness of *araC* mutations. The presence of a wild-type copy...](#)

[Figure 11.16 A model to explain how AraC can be a positive activator of the *ar...*](#)

[Figure 11.17 Face-of-the-helix dependence. \(A\) Molecules of AraC in the PI sta...](#)

[Figure 11.18 Regulation of fatty acid biosynthesis and degradation pathways. \(...\)](#)

[Figure 11.19 Transcription attenuation. \(A\) The presence of a transcription te...](#)

[Figure 11.20 Structure of the leader region of the *trp* operon. \(A\) Key feature...](#)

[Figure 11.21 Details of regulation by transcription attenuation In the *trp* ope...](#)

[Figure 11.22 TRAP regulation of the *trp* operon in *Bacillus subtilis*. \(A\) Model...](#)

[Figure 11.23 Regulation of the *bgl* operon by proteinmediated antltermnatlon.](#)

[Figure 11.24 The tRNA-responsive T box riboswitch system. The leader RNAs for ...](#)

[Figure 11.25 Metabolite-binding riboswitch regulation of transcription attenua...](#)

[Figure 11.26 Regulation by mRNA degradation. The *E. coli rne* gene, which encod...](#)

[Figure 11.27 Regulation of the *E. coli rpoH* gene by an RNA thermosensor. Trans...](#)

[Figure 11.28 Regulation by translational arrest in the ribosome. \(A\) Regulatio...](#)

[Figure 11.29 Regulated proteolysis of \$\sigma^S\$ by adaptors and antiadaptors. Under n...](#)

Chapter 12

[Figure 12.1 Diauxic growth of *E. coli* in a mixture of glucose and galactose. T...](#)

[Figure 12.2 Exogenous glucose inhibits both cAMP synthesis and the uptake of o...](#)

[Figure 12.3 Model for CAP activation at class I and class II CAP-dependent pro...](#)

[Figure 12.4 Summary of the RNA polymerase-promoter and activator-promoter inte...](#)

[Figure 12.5 Regulation of the *lac* operon by both glucose and the inducer lacto...](#)

[Figure 12.6 Mutations in the *lac* regulatory region that affect activation by c...](#)

[Figure 12.7 Carbon catabolite regulation in *B. subtilis*. \(A\) The CcpA regulato...](#)

[Figure 12.8 Pathways for nitrogen assimilation in *E. coli* and other enteric ba...](#)

[Figure 12.9 Regulation of nitrogen assimilation genes by a signal transduction...](#)

[Figure 1 Modified from Dhiman A, Schleif R, *J. Bacteriol* **182**:5076-5081, 2000.](#)

[Figure 2](#)

[Figure 12.10 Sequence comparison of promoters recognized by the RNA polymerase...](#)

[Figure 12.11 Model for the activation of the \$p_2\$ promoter by phosphorylated Ntr...](#)

[Figure 12.12 Translational autoregulation of ribosomal protein gene expression...](#)

[Figure 12.13 Model for synthesis of ppGpp after amino acid starvation. Cells a...](#)

[Figure 12.14 Regulation of SpoT activity. SpoT has both \(p\)ppGpp synthetase a...](#)

[Figure 12.15 Induction of the heat shock response in *E. coli*. The *rpoH* mRNA is...](#)

[Figure 12.16 Repression and activation by the DsrA sRNA. \(A\) Domain 1 of the D...](#)

[Figure 12.17 Two envelope stress responses in *E. coli* respond to different str...](#)

[Figure 12.18 Regulation of operons in the Fur regulon. \(Left\) Negative regulat...](#)

[Figure 12.19 Regulation of the *C. diphtheriae tox* gene of prophage \$\beta\$. The DtxR...](#)

[Figure 12.20 Regulatory cascade for *V. cholerae* virulence factors. The ToxR-To...](#)

[Figure 12.21 Quorum sensing. In systems regulated by quorum sensing, expressio...](#)

[Figure 12.22 Quorum sensing in *Photobacterium harveyi* and *Vibrio cholerae*. \(A\)](#)

[Figure 12.23 Stages of sporulation. The left side of each panel shows an elect...](#)

[Figure 12.24 The phosphorelay activation of the transcription factor Spo0A. Th...](#)

[Figure 12.25 Phosphate transfer through the sporulation phosphorelay. Unlike m...](#)

[Figure 12.26 Compartmentalization of sigma factors and temporal regulation of ...](#)

[Figure 12.27 Sequential and compartmentalized activation of the *B. subtilis* sp...](#)

[Figure 12.28 Model for the regulation of \$\sigma^E\$ activity. SpoIIAB holds \$\sigma^E\$ in an I...](#)

[Figure 12.29 Model for activation of \$\sigma^E\$ in the mother cell compartment....](#)

[Figure 12.30 Model for regulation of Pro- \$\sigma^K\$ processing. Proteolytic cleavage o...](#)

Chapter 13

[Figure 13.1 Bacterial strains from within the same species can be significantl...](#)

[Figure 1](#)

[Figure 2 Modified from Gill SR, Fouts DE, Archer GL, et al, *J Bacteriol* **187**:24...](#)

[Figure 1](#)

[Figure 2](#)

[Figure 13.2 Popular DNA-sequencing strategies involve fragmenting the DNA subs...](#)

[Figure 13.3 Steps in PCR. In the first cycle, the template is denatured by hea...](#)

[Figure 13.4 Multiple types of restriction endonucleases exist where the DNA se...](#)

[Figure 13.5 Recombinant DNAs can be joined using compatible ends formed by dig...](#)

[Figure 13.6 A single gene from a region of the genome can be cloned using PCR ...](#)