



Contents

Preface xvii

1 An Introduction to Genetics 2

- The Historical Context of Genetics 3
 - Prehistoric Times: Domesticated Animals and Cultivated Plants 4
 - The Greek Influence: Hippocrates and Aristotle 4
 - 1600–1850: The Dawn of Modern Biology 5
 - Charles Darwin and Evolution 6
- Basic Concepts of Genetics 7
- Investigative Approaches in Genetics 10
- Genetics and Society 11
 - Eugenics and Euphenics 11
 - Genetic Advances in Agriculture and Medicine 12
- Chapter Summary 14
- Key Terms 14
- Problems and Discussion Questions 15
- Selected Readings 15

GENETICS, TECHNOLOGY, AND SOCIETY 13

- The Fruits of Plant Biotechnology: Edible Vaccines

2 Cell Division and Chromosomes 16

- Cell Structure 17
- Homologous Chromosomes, Haploidy, and Diploidy 19
- Mitosis and Cell Division 22
 - Interphase and the Cell Cycle 23
 - Prophase 24
 - Prometaphase and Metaphase 24
 - Anaphase 26
 - Telophase 26
- Cell Cycle Control 27
- Meiosis and Sexual Reproduction 28
 - An Overview of Meiosis 28
 - The First Meiotic Division: Prophase I 28
 - Metaphase I, Anaphase I, and Telophase I 32
 - The Second Meiotic Division 32
- Spermatogenesis and Oogenesis 32
- The Significance of Meiosis 34
- The Cytological Origin of the Mitotic Chromosome 35
- Specialized Chromosomes 35
 - Polytene Chromosomes 36
 - Lampbrush Chromosomes 36
- Chapter Summary 38
- Key Terms 38
- Insights and Solutions 39

- Problems and Discussion Questions 39
- Selected Readings 41

3 Mendelian Genetics 42

- Gregor Johann Mendel 43
- Mendel's Experimental Approach 44
- The Monohybrid Cross 44
 - Mendel's First Three Postulates 44
 - Modern Genetic Terminology 46
 - Punnett Squares 46
 - The Test Cross: One Character 47
- The Dihybrid Cross 47
 - Mendel's Fourth Postulate: Independent Assortment 48
 - The Test Cross: Two Characters 50
- The Trihybrid Cross 50
 - The Forked-Line Method, or Branch Diagram 50
- The Rediscovery of Mendel's Work 50
 - Unit Factors, Genes, and Homologous Chromosomes 53
- Independent Assortment and Genetic Variation 53
- Probability and Genetic Events 54
- Evaluating Genetic Data: Chi-Square Analysis 55
- Human Pedigrees 57
 - Chapter Summary 59
 - Key Terms 63
 - Insights and Solutions 61
 - Problems and Discussion Questions 63
 - Selected Readings 65

GENETICS, TECHNOLOGY, AND SOCIETY 60

- Improving the Genetic Fate of Purebred Dogs

4 Modification of Mendelian Ratios 66

- Potential Function of an Allele 67
- Symbols for Alleles 68
- Incomplete (Partial) Dominance 68
- Codominance 69
- Multiple Alleles 70
 - The ABO Blood Group 70
 - The Bombay Phenotype 70
 - Multiple Alleles in *Drosophila*: The *white* Locus 70
- Lethal Alleles 71
- Combinations of Two Gene Pairs 71
 - Gene Interaction: Discontinuous Variation 72
 - Epistasis 73
 - Novel Phenotypes 77
 - Other Modified Dihybrid Ratios 77

Complementation Analysis and Alleles	77
Genes on the X Chromosome	79
X-Linkage in <i>Drosophila</i>	79
X-Linked Inheritance in Humans	81
Sex-Limited and Sex-Influenced Inheritance	82
Chapter Summary	83
Key Terms	83
Insights and Solutions	84
Problems and Discussion Questions	86
Selected Readings	89

5 Quantitative Genetics 90

Quantitative Inheritance	91
Polygenes and the Multiple-Factor Hypothesis	91
Additive Alleles: The Basis of Continuous Variation	93
Calculating the Number of Polygenes	95
The Significance of Polygenic Control	96
Analysis of Polygenic Traits	96
The Mean	96
Variance	97
Standard Deviation	97
Standard Error of the Mean	98
Analysis of a Quantitative Character	98
Heritability	98
Broad-Sense Heritability	99
Narrow-Sense Heritability	100
Artificial Selection	100
Twin Studies in Humans	102
Mapping Quantitative Trait Loci	102
Chapter Summary	105
Insights and Solutions	105
Key Terms	106
Problems and Discussion Questions	107
Selected Readings	109

GENETICS, TECHNOLOGY, AND SOCIETY 104

The Green Revolution Revisited

6 Linkage and Chromosome Mapping 110

Linkage Versus Independent Assortment	111
The Linkage Ratio	113
Incomplete Linkage, Crossing Over, and Chromosome Mapping	113
Morgan and Crossing Over	114
Sturtevant and Mapping	116
Single Crossovers	116
Multiple Crossovers	117
Three-Point Mapping in <i>Drosophila</i>	118
Determining the Gene Sequence	120
A Mapping Problem in Maize	121
The Accuracy of Mapping Experiments	124
Interference and the Coefficient of Coincidence	124
The Genetic Map of <i>Drosophila</i>	125
Somatic Cell Hybridization and Human Gene Mapping	125

The Use of Haploid Organisms in Linkage and Mapping Studies	127
Gene-to-Centromere Mapping	128
Other Aspects of Genetic Exchange	128
Cytological Evidence for Crossing Over	129
Sister Chromatid Exchanges	130
Did Mendel Encounter Linkage?	131
Why Didn't Gregor Mendel Find Linkage?	131
Insights and Solutions	132
Chapter Summary	134
Key Terms	134
Problems and Discussion Questions	134
Selected Readings	137

7 Extranuclear Inheritance 138

Maternal Effect	139
<i>Ephestia</i> Pigmentation	139
<i>Limnaea</i> Coiling	140
Embryonic Development in <i>Drosophila</i>	140
Organelle Heredity	142
Chloroplasts: Variegation in Four O'Clock Plants	142
Iojap in Maize	142
<i>Chlamydomonas</i> Mutations	143
Mitochondria: <i>poky</i> in <i>Neurospora</i>	143
<i>Petite</i> in <i>Saccharomyces</i>	144
Mitochondrial DNA and Human Diseases	144
Infectious Heredity	146
Kappa in <i>Paramecium</i>	147
Infective Particles in <i>Drosophila</i>	148
Genomic Imprinting	148
Chapter Summary	151
Insights and Solutions	151
Key Terms	152
Problems and Discussion Questions	152
Selected Readings	153

GENETICS, TECHNOLOGY, AND SOCIETY 149

Mitochondrial DNA and the Mystery of the Romanovs

8 Chromosome Variation and Sex Determination 154

Variation in Chromosome Number: An Overview	155
Chromosome Composition and Sex Determination in Humans	155
Klinefelter and Turner Syndromes	156
47,XXX Syndrome	156
47,XYY Condition	157
The Human Y Chromosome and Male Development	158
The X Chromosome and Dosage Compensation	158
Barr Bodies and Dosage Compensation	158
The Lyon Hypothesis	159

The Mechanism of Inactivation	160
Chromosome Composition and Sex Determination in <i>Drosophila</i>	160
Aneuploidy	161
Monosomy	162
Partial Monosomy: Cri-du-Chat Syndrome	162
Trisomy	164
Down Syndrome	164
Viability in Human Aneuploid Conditions	166
Polyploidy and Its Origins	166
Autopolyploidy	167
Allopolyploidy	168
Variation in Chromosome Structure and Arrangement: An Overview	169
Deletions	170
Duplications	170
Gene Redundancy and Amplification—Ribosomal RNA Genes	170
The Bar Eye Mutation in <i>Drosophila</i>	171
The Role of Gene Duplication in Evolution	171
Inversions	172
Consequences of Inversions During Gamete Formation	173
Translocations	173
Translocations in Humans: Familial Down Syndrome	175
Fragile Sites in Humans	177
Fragile X Syndrome (Martin-Bell Syndrome)	177
The <i>FHIT</i> Gene and Human Lung Cancer	177
Chapter Summary	178
Key Terms	179
Insights and Solutions	180
Problems and Discussion Questions	181
Selected Readings	182

9 DNA—The Physical Basis of Life 184

Characteristics of the Genetic Material	185
The Genetic Material: Early Studies	186
Evidence Favoring DNA in Bacteria and Bacteriophages	186
Transformation Studies	187
The Hershey–Chase Experiment	189
Transfection Experiments	191
Observations Favoring DNA in Eukaryotes	192
Distribution of DNA	192
Mutagenesis	192
Direct Evidence Favoring DNA in Eukaryotes	192
RNA as the Genetic Material	193
The Structure of DNA	193
Nucleic Acid Chemistry	194
Base Composition Studies	196
X-Ray Diffraction Analysis	197
The Watson–Crick Model	197
Other Forms of DNA	199
The Structure of RNA	200
Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid	202

Hydrogen Bonds and the Analysis of Nucleic Acids	203
Molecular Hybridization Techniques	203
Reassociation Kinetics and Repetitive DNA	203
Chapter Summary	205
Key Terms	205
Insights and Solutions	206
Problems and Discussion Questions	207
Selected Readings	208

10 DNA—Replication and Synthesis 210

The Mode of DNA Replication	211
The Meselson–Stahl Experiment	212
Semiconservative Replication in Eukaryotes	212
Replication Origins and Forks	215
Synthesis of DNA in Microorganisms	216
DNA Polymerase I	216
Fidelity of Synthesis	216
Synthesis of Biologically Active DNA	217
DNA Polymerases II and III	217
DNA Synthesis: A Model	219
Unwinding the DNA Helix	219
Initiation of Synthesis	220
Continuous and Discontinuous DNA Synthesis	220
Concurrent Synthesis on the Leading and Lagging Strands	221
Proofreading	223
Summary of DNA Synthesis	223
Genetic Control of Replication	223
Eukaryotic DNA Synthesis	224
DNA Synthesis at the Ends of Linear Chromosomes	224
DNA Recombination	226
Gene Conversion	226
Chapter Summary	229
Key Terms	229
Insights and Solutions	230
Problems and Discussion Questions	230
Selected Readings	231

GENETICS, TECHNOLOGY, AND SOCIETY 228

Telomerase: The Key to Immortality?

11 Organization of DNA in Chromosomes and Genes 232

Viral and Bacterial Chromosomes	233
Mitochondrial and Chloroplast DNA	235
Molecular Organization and Function of Mitochondrial DNA	235
Molecular Organization and Function of Chloroplast DNA	236
Organization of DNA in Chromatin	237
Nucleosome Structure	237
Heterochromatin	238
Chromosome Banding	240

Organization of the Eukaryotic Genome	240
Eukaryotic Genomes and the C-Value Paradox	241
Repetitive DNA: Centromeres and Telomeres	242
Repetitive DNA: SINEs, LINEs, and VNTRs	243
Eukaryotic Gene Structure	244
Multigene Families: The α - and β -Globin Genes	244
Genome Analysis	246
The Genome Project	246
Chapter Summary	247
Key Terms	248
Insights and Solutions	248
Problems and Discussion Questions	249
Selected Readings	249

12 Storage and Expression of Genetic Information 250

The Genetic Code: An Overview	251
Early Thinking About the Code	252
Deciphering the Code: Initial Studies	252
Nirenberg and Matthaei's Homopolymer Codes	253
The Use of Mixed Copolymers	253
The Triplet Binding Technique	254
The Use of Repeating Copolymers	255
The Coding Dictionary	256
Degeneracy, Wobble, and Order in the Code	256
Initiation and Termination	257
Confirmation of Code Studies: Phage MS2	258
Universality of the Code?	258
Expression of Genetic Information: An Overview	259
Transcription: RNA Synthesis	259
RNA Polymerase	260
The Sigma Subunit, Promoters, and Template Binding	260
The Synthesis of RNA	261
Transcription in Eukaryotes	262
Eukaryotic Promoters, Enhancers, and Transcription Factors	262
Heterogeneous Nuclear RNA and Its Processing: Caps and Tails	263
Intervening Sequences and Split Genes	264
Splicing Mechanisms: Autocatalytic RNAs	265
Splicing Mechanisms: The Spliceosome	265
RNA Editing	267
Translation: Components Necessary for Protein Synthesis	267
Ribosomal Structure	267
tRNA Structure	269
Charging tRNA	270
Translation: The Process	270
Initiation (Steps 1–3 of Figure 12–17)	271
Elongation (Steps 4–9 of Figure 12–17)	271
Termination (Steps 10–11 of Figure 12–17)	271
Polyribosomes	271
Translation in Eukaryotes	274
Chapter Summary	276

Key Terms	276
Insights and Solutions	277
Problems and Discussion Questions	278
Selected Readings	279

GENETICS, TECHNOLOGY, AND SOCIETY 275

Antisense Oligonucleotides: Attacking the Messenger	
---	--

13 Regulation of Gene Expression 280

Genetic Regulation in Prokaryotes: An Overview	281
Lactose Metabolism in <i>E. coli</i> : An Inducible System	282
Structural Genes of the <i>lac</i> Operon	282
Regulatory Mutations in the <i>lac</i> Operon	282
The Operon Model: Negative Control	282
Genetic Proof of the Operon Model	283
Isolation and Crystallographic Analysis of the <i>lac</i> Repressor	284
The CAP Protein: Positive Control of the <i>lac</i> Operon	286
Tryptophan Metabolism in <i>E. coli</i> : A Repressible Gene System	286
Genetics of the <i>trp</i> Operon	286
Attenuation	287
Genetic Regulation in Phage Lambda: Lysogeny or Lysis?	288
Genetic Regulation in Eukaryotes: An Overview	289
Regulatory Elements and Eukaryotic Genes	290
Promoters	290
Enhancers	290
Transcription Factors and Gene Regulation	291
Genetic Analysis of Transcription Factors: <i>GAL4</i>	291
Structural Motifs of Transcription Factors	292
Assembling the Transcription Complex	293
Genomic Alterations and Gene Expression: DNA Methylation	294
Gene Regulation by Steroid Hormones	295
Postranscriptional Regulation of Gene Expression	296
Alternative Processing Pathways for mRNA	296
Chapter Summary	297
Key Terms	298
Insights and Solutions	298
Problems and Discussion Questions	299
Selected Readings	300

14 Proteins: The End Product of Genes 302

Garrod and Bateson: Inborn Errors of Metabolism	303
Phenylketonuria	304
The One-Gene:One-Enzyme Hypothesis	304

Beadle and Tatum: <i>Neurospora</i> Mutants	305
Genes and Enzymes: Analysis of Biochemical Pathways	305
One-Gene:One-Protein/One-Gene:One-Polypeptide	307
Sickle-Cell Anemia	307
Human Hemoglobins	307
Colinearity	309
Protein Structure and Function	310
Protein Structure	310
Chaperones and Protein Folding	313
Posttranslational Modification and Protein Targeting	314
Protein Function	315
Chapter Summary	317
Key Terms	317
Insights and Solutions	318
Problems and Discussion Questions	318
Selected Readings	319

GENETICS, TECHNOLOGY, AND SOCIETY 316

Mad Cows and Heresies: The Prion Story

15 DNA—Mutation, Repair, and Transposable Elements 320

Classification of Mutations	321
Spontaneous versus Induced Mutations	321
Gametic versus Somatic Mutations	322
Other Categories of Mutation	322
Detection of Mutation	323
Detection in Bacteria and Fungi	323
Detection in <i>Drosophila</i>	323
Detection in Plants	324
Detection in Humans	324
Spontaneous Mutation Rate	326
The Molecular Basis of Mutation	326
Tautomeric Shifts	326
Base Analogs	327
Alkylating Agents	327
Acridine Dyes and Frameshift Mutations	328
Apurinic Sites and Other Lesions	329
Ultraviolet Radiation and Thymine Dimers	330
Mutations in Humans: Case Studies	331
Trinucleotide Repeats in Fragile-X Syndrome, Myotonic Dystrophy, and Huntington Disease	332
Detection of Mutagenicity: The Ames Test	333
Repair of DNA	333
UV Radiation, Thymine Dimers, and Photoreactivation Repair	333
Excision Repair	333
Proofreading and Mismatch Repair	335
The SOS Response: Recombinational Repair	335
UV Radiation and Human Skin Cancer: Xeroderma Pigmentosum	335
High Energy Radiation	336

Site-Directed Mutagenesis	338
Knockout Genes and Transgenes	338
Transposable Genetic Elements	339
Insertion Sequences	339
Bacterial Transposons	340
The <i>Ac-Ds</i> System in Maize	340
<i>Copia</i> and <i>P</i> Elements in <i>Drosophila</i>	340
Transposable Elements in Humans	342
Chapter Summary	344
Key Terms	344
Insights and Solutions	345
Problems and Discussion Questions	346
Selected Readings	347

GENETICS, TECHNOLOGY, AND SOCIETY 343

Chernobyl's Legacy

16 Genetics of Bacteria and Bacteriophages 348

Bacterial Mutation and Growth	349
Genetic Recombination in Bacteria: Conjugation	350
F ⁺ and F ⁻ Bacteria	351
Hfr Bacteria and Chromosome Mapping	353
Recombination in F ⁺ × F ⁻ Matings: A Reexamination	354
The F' State and Merozygotes	354
The Rec Proteins and Bacterial Recombination	355
Plasmids	356
Bacterial Transformation	358
Transformation and Linked Genes	359
The Genetic Study of Bacteriophages	360
The T4 Phage Life Cycle	360
The Plaque Assay	360
Lysis and Lysogeny	363
Transduction: Virus-Mediated Bacterial DNA Transfer	363
The Lederberg-Zinder Experiment	363
The Nature of Transduction	364
Mutation and Recombination in Viruses	364
Other Strategies for Viral Reproduction	366
Reverse Transcriptase	366
Chapter Summary	367
Key Terms	367
Insights and Solutions	368
Problems and Discussion Questions	369
Selected Readings	371

17 DNA Biotechnology: Techniques and Analysis 372

Recombinant DNA Technology: An Overview	373
Constructing Recombinant DNA Molecules	374
Restriction Enzymes	374
Vectors	375

Cloning in <i>E. coli</i> Host Cells	377
Cloning in Eukaryotic Host Cells	377
Constructing Libraries of Cloned DNA Sequences	378
Genomic Libraries	379
cDNA Libraries	380
Recovering Cloned Sequences from a Library	381
Probes to Identify Specific Clones	381
Screening a Cloned Library	381
Chromosome Walking	381
PCR-Based DNA Cloning	382
Analysis of Cloned Sequences	384
Restriction Mapping	384
Nucleic Acid Blotting	385
DNA Sequencing	387
Chapter Summary	390
Key Terms	392
Insights and Solutions	392
Problems and Discussion Questions	392
Selected Readings	394

GENETICS, TECHNOLOGY, AND SOCIETY 391

DNA Fingerprints in Forensics: The Case of the Telltale Palo Verde

18 DNA Biotechnology: Applications and Ethics 396

Mapping Human Genes	397
RFLPs as Genetic Markers	397
Linkage Analysis Using RFLPs	398
Positional Cloning: The Gene for Neurofibromatosis	399
Diagnosing and Screening for Genetic Disorders	400
Sickle-Cell Anemia and Prenatal Genotyping	400
Allele-Specific Nucleotides and Genetic Screening	402
DNA Chips and Genetic Screening	403
The Ethics of Genetic Testing	404
Gene Therapy	404
Severe Combined Immunodeficiency (SCID): First-Generation Vectors	405
The Future of Gene Therapy: New Vectors and Target-Cell Strategies	405
Ethical Issues and the Future of Gene Therapy	405
DNA Fingerprints	406
Minisatellites and VNTRs	407
Forensic Applications	407
Genome Projects	408
The Bottom-Up Method: The <i>E. coli</i> Project	409
The Top-Down Approach: The <i>Drosophila</i> Genome	409
The Shotgun Method: Prokaryotic Genomes	410
The Human Genome Project	410
The Ethical, Legal, and Social Implications of the Human Genome Project	411
After the Genome Projects: What Next?	411

Biotechnology	412
Insulin Production	412
Herbicide-Resistant Crop Plants	414
Transgenic Plants and Vaccines	414
Chapter Summary	416
Key Terms	416
Insights and Solutions	418
Problems and Discussion Questions	419
Selected Readings	421

GENETICS, TECHNOLOGY, AND SOCIETY 417

Beyond Dolly: The Cloning of Humans

19 Genetics of Cancer and Immunology 422

Genes and Cancer	423
Genes That Predispose to Cancer	424
How Many Mutations Are Needed to Cause Cancer?	424
Tumor Suppressor Genes	424
Retinoblastoma (RB)	425
Breast Cancer Genes	426
The <i>p53</i> Gene and the Cell Cycle	426
Oncogenes	426
Origins of Oncogenes	427
Proto-Oncogenes and Oncogenes	427
A Genetic Model for Colon Cancer	428
The Steps in Colon Cancer	429
Mutations and Colon Cancer	430
Cancer and Genomic Instability	430
Gatekeeper Genes and Caretaker Genes in Cancer	431
Genomic Changes and Cancer	431
Chromosome Rearrangements and Leukemias	431
Translocations and Hybrid Genes	432
The Immune System	432
Genetic Diversity in the Immune System	433
Antibodies	433
Theories of Antibody Formation	434
Organization of the Immunoglobulin Genes	434
The HLA System	436
HLA Genes	437
Organ and Tissue Transplantation	437
Disorders of the Immune System	438
The Genetics of Immunodeficiency	438
Acquired Immunodeficiency Syndrome (AIDS)	439
Chapter Summary	440
Key Terms	442
Insights and Solutions	443
Problems and Discussion Questions	444
Selected Readings	445

GENETICS, TECHNOLOGY, AND SOCIETY 441

The Double-Edged Sword of Genetic Testing: The Case of Breast Cancer.

20 Genetics of Development and Behavior 446

- Basic Concepts of Developmental Genetics 447
- The Variable Gene Activity Theory 448
- Genomic Equivalence 448
- Genetics of Embryonic Development in *Drosophila* 449
 - Overview of *Drosophila* Development 449
 - Genetic Analysis of Embryogenesis 451
- Maternal-Effect Genes and the Basic Body Plan in *Drosophila* 453
 - Formation of the Anterior-Posterior Axis 453
 - The Posterior and Terminal Gene Sets 454
- Zygotic Genes and Segment Formation 455
 - Gap Genes 456
 - Pair-Rule Genes 456
 - Segment Polarity Genes 456
- Selector Genes 457
- Genetic Analysis of Behavior 459
- Genetics of Geotaxis in *Drosophila* 460
- Genetic Dissection of Behavior in *Drosophila* 462
 - Mosaics 462
 - Neurogenetics 464
- Human Behavior Genetics 466
 - Single-Gene Disorders 466
 - Multifactorial Traits 467
 - Insights and Solutions* 469
 - Chapter Summary* 470
 - Key Terms* 470
 - Problems and Discussion Questions* 470
 - Selected Readings* 471

GENETICS, TECHNOLOGY, AND SOCIETY 468

Coming to Terms with the Heritability of IQ

21 Population Genetics 472

- Populations and Gene Pools 473
- Calculating Allele Frequencies 474
- The Hardy-Weinberg Law 474
 - Assumptions for the Hardy-Weinberg Law 474
 - Testing for Equilibrium 476
- Extensions of the Hardy-Weinberg Law 477
 - X-Linked Genes 477
 - Multiple Alleles 478
- Using the Hardy-Weinberg Law: Calculating Heterozygote Frequency 479
- Factors That Alter Allele Frequencies in Populations 479
 - Mutation 479
 - Migration 481
 - Natural Selection 482
 - Fitness and Selection 483

- Selection in Natural Populations 484
- Genetic Drift 485
- Inbreeding 487
- Nonrandom Mating 487
- Genetic Effects of Inbreeding 487
- Chapter Summary* 490
- Key Terms* 490
- Insights and Solutions* 490
- Problems and Discussion Questions* 492
- Selected Readings* 493

GENETICS, TECHNOLOGY, AND SOCIETY 489

What Can We Learn from the Failure of the Eugenics Movement?

22 Genetics and Evolution 494

- Wallace, Darwin, and the Origin of Species 495
- Models of Speciation 496
 - Allopatric Speciation 496
 - Sympatric Speciation 497
 - Statispatric Speciation 498
- Isolating Mechanisms 498
- The Rate of Speciation 498
- Measuring Genetic Variation 501
 - Inbreeding Depression 501
 - Protein Polymorphisms 502
 - Variations in Nucleotide Sequence 503
- Evolution and Genetic Variation: A Dilemma 503
 - Neutralists and Variation 503
 - Selectionists and Variation 504
- Formation of Species 504
- Using Molecular Techniques to Study Evolution 506
 - Measuring the Genetic Distance Between Species 507
 - Protein Evolution 508
 - The Molecular Clock 508
 - Phylogenetic Trees 509
 - Molecular Studies on Human Evolution 510
 - Chapter Summary* 511
 - Key Terms* 512
 - Insights and Solutions* 512
 - Problems and Discussion Questions* 513
 - Selected Readings* 514

Appendix

- Answers to Selected Questions 519
- Glossary 529
- Credits 547
- Index 551