GLOBAL EDITION

Concepts of Genetics

ELEVENTH EDITION

William S. Klug • Michael R. Cummings
Charlotte A. Spencer • Michael A. Palladino

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PEARSON

CONCEPTS OF GENETICS

ELEVENTH EDITION
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THE COLLEGE OF NEW JERSEY

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ILLINOIS INSTITUTE OF TECHNOLOGY

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Dedication

To Kathy, Lee Ann, Bob, and Cindy, who mean the very most to us, and serve as our respective foundations when we are writing, and when we are not.

WSK, MRC, CAS, and MAP

About the Authors

William S. Klug is an Emeritus Professor of Biology at The College of New Jersey (formerly Trenton State College) in Ewing, New Jersey, where he served as Chair of the Biology Department for 17 years. He received his B.A. degree in Biology from Wabash College in Crawfordsville, Indiana, and his Ph.D. from Northwestern University in Evanston, Illinois. Prior to coming to The College of New Jersey, he was on the faculty of Wabash College as an Assistant Professor, where he first taught genetics, as well as general biology and electron microscopy. His research interests have involved ultrastructural and molecular genetic studies of development, utilizing oogenesis in *Drosophila* as a model system. He has taught the genetics course as well as the senior capstone seminar course in Human and Molecular Genetics to undergraduate biology majors for over four decades. He was the recipient in 2001 of the first annual teaching award given at The College of New Jersey, granted to the faculty member who "most challenges students to achieve high standards." He also received the 2004 Outstanding Professor Award from Sigma Pi International, and in the same year, he was nominated as the Educator of the Year, an award given by the Research and Development Council of New Jersey.

Michael R. Cummings is Research Professor in the Department of Biological, Chemical, and Physical Sciences at Illinois Institute of Technology, Chicago, Illinois. For more than 25 years, he was a faculty member in the Department of Biological Sciences and in the Department of Molecular Genetics at the University of Illinois at Chicago. He has also served on the faculties of Northwestern University and Florida State University. He received his B.A. from St. Mary's College in Winona, Minnesota, and his M.S. and Ph.D. from Northwestern University in Evanston, Illinois. In addition to this text and its companion volumes, he has also written textbooks in human genetics and general biology for nonmajors. His research interests center on the molecular organization and physical mapping of the heterochromatic regions of human acrocentric chromosomes. At the undergraduate level, he teaches courses in Mendelian and molecular genetics, human genetics, and general biology, and has received numerous awards for teaching excellence given by university faculty, student organizations, and graduating seniors.

Charlotte A. Spencer is a retired Associate Professor from the Department of Oncology at the University of Alberta in Edmonton, Alberta, Canada. She has also served as a faculty member in the Department of Biochemistry at the University of Alberta. She received her B.Sc. in Microbiology from the University of British Columbia and her Ph.D. in Genetics from the University of Alberta, followed by postdoctoral training at the Fred Hutchinson Cancer Research Center in Seattle, Washington. Her research interests involve the regulation of RNA polymerase II transcription in cancer cells, cells infected with DNA viruses, and cells traversing the mitotic phase of the cell cycle. She has taught courses in biochemistry, genetics, molecular biology, and oncology, at both undergraduate and graduate levels. In addition, she has written booklets in the Prentice Hall Exploring Biology series, which are aimed at the undergraduate nonmajor level.

Michael A. Palladino is Dean of the School of Science and Professor of Biology at Monmouth University in West Long Branch, New Jersey. He received his B.S. degree in Biology from Trenton State College (now known as The College of New Jersey) and his Ph.D. in Anatomy and Cell Biology from the University of Virginia. He directs an active laboratory of undergraduate student researchers studying molecular mechanisms involved in innate immunity of mammalian male reproductive organs and genes involved in oxygen homeostasis and ischemic injury of the testis. He has taught a wide range of courses for both majors and nonmajors and currently teaches genetics, biotechnology, endocrinology, and laboratory in cell and molecular biology. He has received several awards for research and teaching, including the 2009 Young Investigator Award of the American Society of Andrology, the 2005 Distinguished Teacher Award from Monmouth University, and the 2005 Caring Heart Award from the New Jersey Association for Biomedical Research. He is co-author of the undergraduate textbook *Introduction to Biotechnology*, Series Editor for the Benjamin Cummings *Special Topics in Biology* booklet series, and author of the first booklet in the series, *Understanding the Human Genome Project*.

Brief Contents

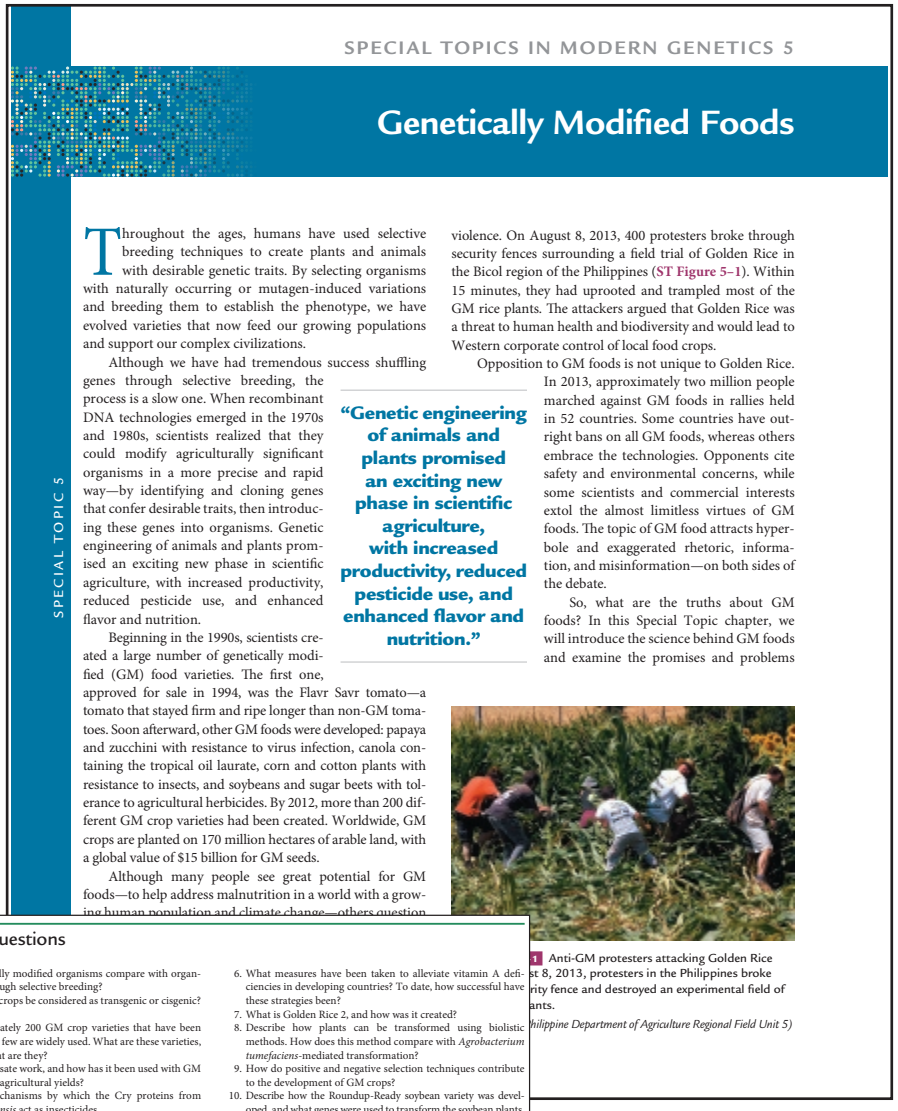
Explore Cutting Edge Topics

EXPANDED!

Six Special Topics in Modern Genetics

mini-chapters concisely explore cutting-edge, engaging, relevant topics, and three are new to the Eleventh Edition:

- Epigenetics
- ***New!*** Emerging Roles of RNA
- DNA Forensics
- Genomics and Personalized Medicine
- ***New!*** Genetically Modified Foods
- ***New!*** Gene Therapy



SPECIAL TOPICS IN MODERN GENETICS 5

SPECIAL TOPIC 5

Genetically Modified Foods

Throughout the ages, humans have used selective breeding techniques to create plants and animals with desirable genetic traits. By selecting organisms with naturally occurring or mutagen-induced variations and breeding them to establish the phenotype, we have evolved varieties that now feed our growing populations and support our complex civilizations.

Although we have had tremendous success shuffling genes through selective breeding, the process is a slow one. When recombinant DNA technologies emerged in the 1970s and 1980s, scientists realized that they could modify agriculturally significant organisms in a more precise and rapid way—by identifying and cloning genes that confer desirable traits, then introducing these genes into organisms. Genetic engineering of animals and plants promised an exciting new phase in scientific agriculture, with increased productivity, reduced pesticide use, and enhanced flavor and nutrition.

"Genetic engineering of animals and plants promised an exciting new phase in scientific agriculture, with increased productivity, reduced pesticide use, and enhanced flavor and nutrition."

Beginning in the 1990s, scientists created a large number of genetically modified (GM) food varieties. The first one, approved for sale in 1994, was the Flavr Savr tomato—a tomato that stayed firm and ripe longer than non-GM tomatoes. Soon afterward, other GM foods were developed: papaya and zucchini with resistance to virus infection, canola containing the tropical oil laurate, corn and cotton plants with resistance to insects, and soybeans and sugar beets with tolerance to agricultural herbicides. By 2012, more than 200 different GM crop varieties had been created. Worldwide, GM crops are planted on 170 million hectares of arable land, with a global value of $15 billion for GM seeds.

Although many people see great potential for GM foods—to help address malnutrition in a world with a growing human population and climate change—others question

violence. On August 8, 2013, 400 protesters broke through security fences surrounding a field trial of Golden Rice in the Bicol region of the Philippines (ST Figure 5–1). Within 15 minutes, they had uprooted and trampled most of the GM rice plants. The attackers argued that Golden Rice was a threat to human health and biodiversity and would lead to Western corporate control of local food crops.

Opposition to GM foods is not unique to Golden Rice. In 2013, approximately two million people marched against GM foods in rallies held in 52 countries. Some countries have outright bans on all GM foods, whereas others embrace the technologies. Opponents cite safety and environmental concerns, while some scientists and commercial interests extol the almost limitless virtues of GM foods. The topic of GM food attracts hyperbole and exaggerated rhetoric, information, and misinformation—on both sides of the debate.

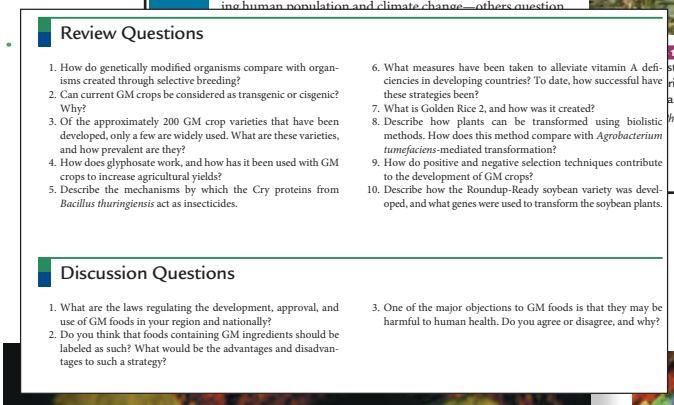
So, what are the truths about GM foods? In this Special Topic chapter, we will introduce the science behind GM foods and examine the promises and problems

1 Anti-GM protesters attacking Golden Rice
st 8, 2013, protesters in the Philippines broke
rity fence and destroyed an experimental field of
ants.
hilippine Department of Agriculture Regional Field Unit 5)

NEW!

End-of-Chapter Questions

are provided for each Special Topic chapter to help students review key ideas and to facilitate class discussions. Questions are assignable through MasteringGenetics



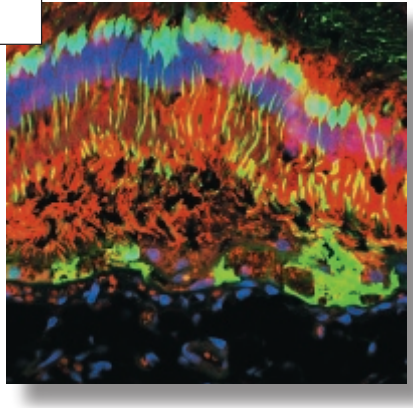
Review Questions

1. How do genetically modified organisms compare with organisms created through selective breeding?
2. Can current GM crops be considered as transgenic or cisgenic? Why?
3. Of the approximately 200 GM crop varieties that have been developed, only a few are widely used. What are these varieties, and how prevalent are they?
4. How does glyphosate work, and how has it been used with GM crops to increase agricultural yields?
5. Describe the mechanisms by which the Cry proteins from *Bacillus thuringiensis* act as insecticides.
6. What measures have been taken to alleviate vitamin A deficiencies in developing countries? To date, how successful have these strategies been?
7. What is Golden Rice 2, and how was it created?
8. Describe how plants can be transformed using biolistic methods. How does this method compare with *Agrobacterium tumefaciens*-mediated transformation?
9. How do positive and negative selection techniques contribute to the development of GM crops?
10. Describe how the Roundup-Ready soybean variety was developed, and what genes were used to transform the soybean plants.

Discussion Questions

1. What are the laws regulating the development, approval, and use of GM foods in your region and nationally?
2. Do you think that foods containing GM ingredients should be labeled as such? What would be the advantages and disadvantages to such a strategy?
3. One of the major objections to GM foods is that they may be harmful to human health. Do you agree or disagree, and why?

New! Photos and illustrations have been added throughout the text.



Explore Classic and Modern Approaches

NEW!

Evolving Concept of the Gene sections, integrated in key chapters, highlight how scientists' understanding of the gene has changed over time.

Chapters 3, 4, 5, 6, 10, 12, 14, 16, 21

Chapter 10

EVOLVING CONCEPT OF THE GENE

Based on the model of DNA put forward by Watson and Crick in 1953, the gene was viewed for the first time in molecular terms as a sequence of nucleotides in a DNA helix that encodes genetic information. ■

Chapter 21

EVOLVING CONCEPT OF A GENE

Based on the work of the ENCODE project, we now know that DNA sequences that have previously been thought of as "junk DNA", which do not encode proteins, are nonetheless often transcribed into what we call noncoding RNA (ncRNA). Since the function of some these RNAs is now being determined, we must consider whether the concept of the gene should be expanded to include DNA sequences that encode ncRNAs. At this writing, there is no consensus, but it is important for you to be aware of these current findings as you develop your final interpretation of a gene. ■

NEW!

Modern Approaches to Understanding Gene Function feature introduces the impact of modern gene targeting approaches on our understanding of gene function. Each entry explores experimental approaches, analyzes data, and relates to a concept discussed in the chapter.

Includes discussion questions.

MODERN APPROACHES TO UNDERSTANDING GENE FUNCTION

Mouse Models of Down Syndrome

The underlying hypothesis concerning the genetic basis of Down syndrome is that the presence of three copies of chromosome 21 leads to the overexpression of some portion of the genes on that chromosome and that the resulting gene products are responsible for the multiple characteristics associated with the complete phenotype. It is possible that, even though Down syndrome is not caused by a single gene, individual genes may be responsible for specific characteristics making up the syndrome. Elucidation

of the same content and arrangement of *orthologs*, genes with similar sequences that are present in different species. One of the earliest models created (Ts16) has an extra copy of mouse chromosome 16, and indeed it displays some, but not all, human Down syndrome characteristics. Therefore Ts16 mice are missing some of the critical orthologs present on Hsa21. Ts16 mice also have extra copies of other genes not present on Hsa21.

Further investigation has established that mouse chromosomes 10 and 17 also contain orthologs for

hydrocephalus, accumulation of cerebrospinal fluid in the brain, and a resulting rounded and enlarged cranium. There are no known genes on Hsa21 that are directly associated with hydrocephalus in humans, so this condition is likely caused by expressing multiple copies of several orthologs.

Conclusion:

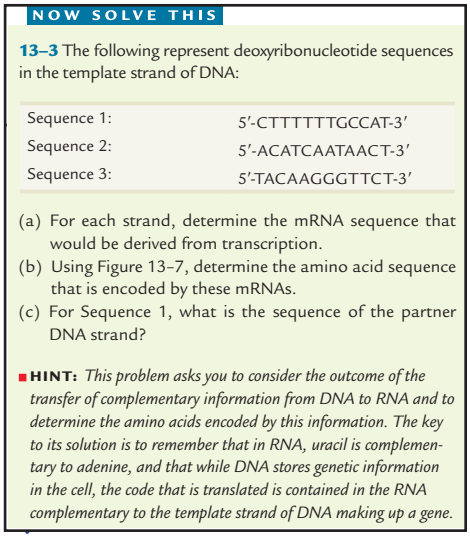
Research with mouse models has demonstrated that no single gene is responsible for all phenotypes associated with Down syndrome, but instead that overexpression of many genes is necessary to produce the full human syndrome. The creation of new models such as the

Topics include:

- Identifying Mendel's Gene for Regulating White Flower Color in Peas (Ch. 3)
- *Drosophila Sxl* Gene Induces Female Development (Ch. 7)
- Mouse Models of Down Syndrome (Ch. 8)
- Lethal Knockouts of DNA Ligase Genes (Ch. 11)
- Transposon-Mediated Mutations Reveal Genes Involved in Colorectal Cancer (Ch. 15)
- MicroRNAs Regulate Ovulation in Female Mice (Ch. 17)
- Single-Gene Signaling Mechanism Reveals Secrets to Head Regeneration in Planaria (Ch. 18)
- *RbAp48* and a Potential Molecular Mechanism for Age-Related Memory Loss (Ch.24)

Learn and Practice Problem Solving

Learn problem-solving skills by pausing to complete integrated *Now Solve This* problems.



NOW SOLVE THIS

13–3 The following represent deoxyribonucleotide sequences in the template strand of DNA:

Sequence 1:	5′-CTTTTTTGCCAT-3′
Sequence 2:	5′-ACATCAATAACT-3′
Sequence 3:	5′-TACAAGGGTTCT-3′

(a) For each strand, determine the mRNA sequence that would be derived from transcription.
(b) Using Figure 13–7, determine the amino acid sequence that is encoded by these mRNAs.
(c) For Sequence 1, what is the sequence of the partner DNA strand?

HINT: *This problem asks you to consider the outcome of the transfer of complementary information from DNA to RNA and to determine the amino acids encoded by this information. The key to its solution is to remember that in RNA, uracil is complementary to adenine, and that while DNA stores genetic information in the cell, the code that is translated is contained in the RNA complementary to the template strand of DNA making up a gene.*

Apply problem-solving strategies by studying hints, and checking your work against the Answers Appendix.

INSIGHTS AND SOLUTIONS

As a student, you will be asked to demonstrate your knowledge of transmission genetics by solving various problems. Success at this task requires not only comprehension of theory but also its application to more practical genetic situations. Most students find problem solving in genetics to be both challenging and rewarding. This section is designed to provide basic insights into the reasoning essential to this process.

Genetics problems are in many ways similar to word problems in algebra. The approach to solving them is identical: (1) analyze the problem carefully; (2) translate words into symbols and define each symbol precisely; and (3) choose and apply a specific technique to solve the problem. The first two steps are the most critical. The third step is largely mechanical.

The simplest problems state all necessary information about a P_1 generation and ask you to find the expected ratios of the F_1 and F_2 genotypes and/or phenotypes. Always follow these steps when you encounter this type of problem:

(a) Determine insofar as possible the genotypes of the individuals in the P_1 generation.

(b) Determine what gametes may be formed by the P_1 parents.

(c) Recombine the gametes by the Punnett square or the forked-line method, or if the situation is very simple, by inspection. From the genotypes of the F_1 generation, determine the phenotypes. Read the F_1 phenotypes.

(d) Repeat the process to obtain information about the F_2 generation.

Determining the genotypes from the given information requires that you understand the basic theory of transmission genetics. Consider this problem: *A recessive mutant allele, black, causes a very dark body in Drosophila when homozygous. The normal wild-type color is described as gray. What F_2 phenotypic ratio is predicted when a black female is crossed to a gray male whose father was black?*

To work out this problem, you must understand dominance and recessiveness, as well as the principle of segregation. Furthermore, you must use the information about the male parent's father. Here is one logical approach to solving this problem:

The female parent is black, so she must be homozygous for the mutant allele (*bb*). The male parent is gray and must therefore have at least one dominant allele (*B*). His father was

Apply the approach we just studied to the following problems.

1. Mendel found that full pea pods are dominant over constricted pods, while round seeds are dominant over wrinkled seeds. One of his crosses was between full, round plants and constricted, wrinkled plants. From this cross, he obtained an F_1 generation that was all full and round. In the F_2 generation, Mendel obtained his classic 9:3:3:1 ratio. Using this information, determine the expected F_1 and F_2 results of a cross between homozygous constricted, round and full, wrinkled plants.

Solution: First, assign gene symbols to each pair of contrasting traits. Use the lowercase first letter of each recessive trait to designate that trait, and use the same letter in uppercase to designate the dominant trait. Thus, *C* and *c* indicate full and constricted pods, respectively, and *W* and *w* indicate the round and wrinkled phenotypes, respectively.

Determine the genotypes of the P_1 generation, form the gametes, combine them in the F_1 generation, and read off the phenotype(s):

P_1: *ccWW* (constricted, round) × *CCww* (full, wrinkled)

Gametes: *cW* × *Cw*

F_1: *CcWw* (full, round)

You can immediately see that the F_1 generation expresses both dominant phenotypes and is heterozygous for both gene pairs. Thus, you expect that the F_2 generation will yield the classic Mendelian ratio of 9:3:3:1. Let's work it out anyway, just to confirm this expectation, using the forked-line method. Both gene pairs are heterozygous and can be expected to assort independently, so we can predict the F_2 outcomes from each gene pair separately and then proceed with the forked-line method.

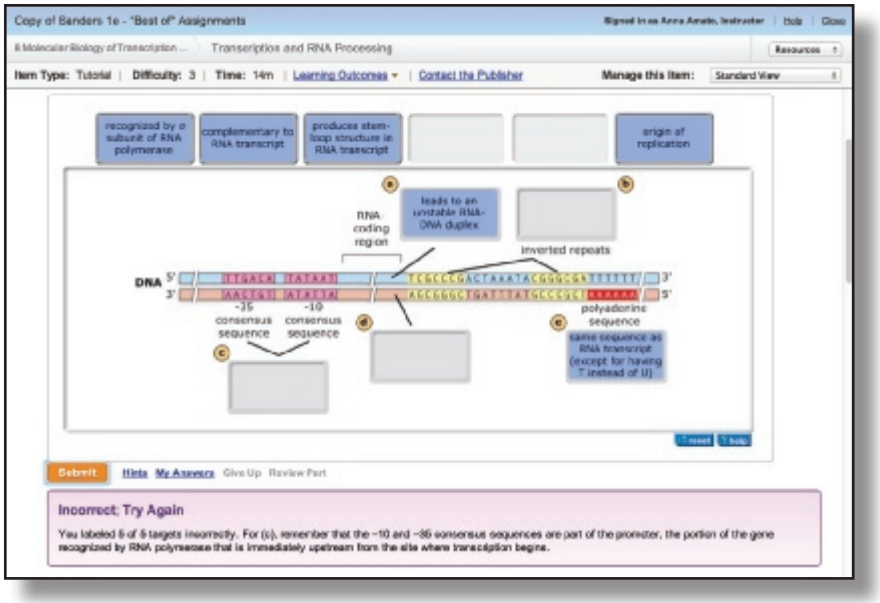
The F_2 offspring should exhibit the individual traits in the following proportions:

$Cc \times Cc$ $Ww \times Ww$

Strengthen your problem-solving strategies by studying the step-by-step solutions and rationales modeled in ***Insights and Solutions.***

MasteringGenetics™

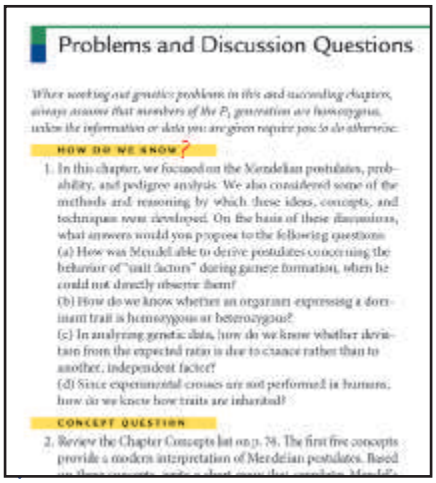
MasteringGenetics helps students master key genetics concepts while reinforcing problem solving skills with hints and feedback specific to their misconceptions.



Tutorial topics include:

- Pedigree analysis
- Sex linkage
- Gene interactions
- DNA replication
- RNA processing
- Genomics

"How Do We Know?" questions ask students to identify and examine the experimental basis underlying important concepts.



Problems and Discussion Questions

When working out genetics problems in this and succeeding chapters, always assume that members of the P_1 generation are homozygous, unless the information or data you are given require you to do otherwise.

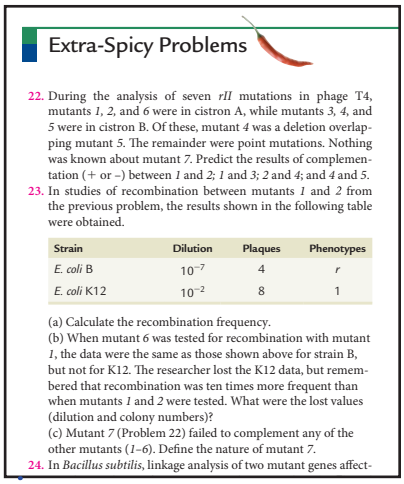
HOW DO WE KNOW?

1. In this chapter, we focused on the Mendelian postulates, probability, and pedigree analysis. We also considered some of the methods and reasoning by which these ideas, concepts, and techniques were developed. On the basis of these discussions, what answers would you propose to the following questions:
(a) How was Mendel able to derive postulates concerning the behavior of "unit factors" during gamete formation, when he could not directly observe them?
(b) How do we know whether an organism expressing a dominant trait is homozygous or heterozygous?
(c) In analyzing genetic data, how do we know whether deviation from the expected ratio is due to chance rather than to another, independent factor?
(d) Since experimental crosses are not performed in humans, how do we know how traits are inherited?

CONCEPT QUESTION

2. Review the Chapter Concepts list on p. 78. The first five concepts provide a modern interpretation of Mendelian postulates. Based

NEW! Concept Questions ask students to check their understanding of Key Concepts.



Extra-Spicy Problems

22. During the analysis of seven *rII* mutations in phage T4, mutants *1*, *2*, and *6* were in cistron A, while mutants *3*, *4*, and *5* were in cistron B. Of these, mutant *4* was a deletion overlapping mutant *5*. The remainder were point mutations. Nothing was known about mutant *7*. Predict the results of complementation (+ or –) between *1* and *2*; *1* and *3*; *2* and *4*; and *4* and *5*.
23. In studies of recombination between mutants *1* and *2* from the previous problem, the results shown in the following table were obtained.

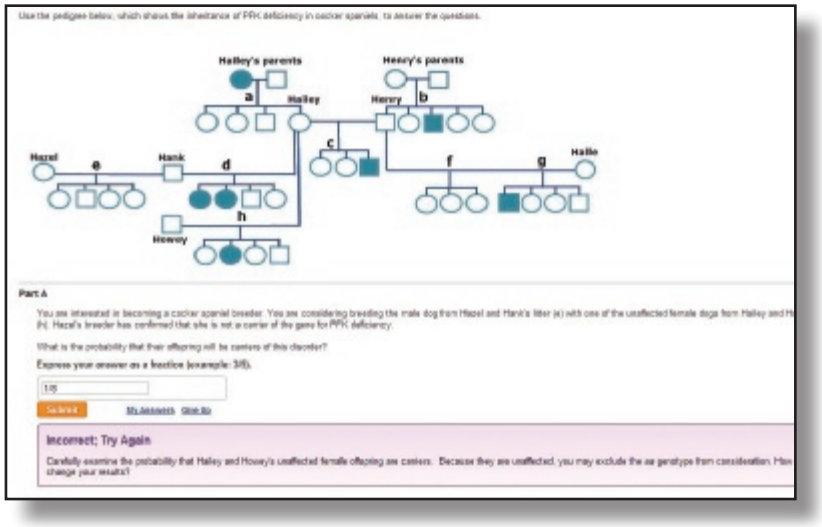
Strain	Dilution	Plaques	Phenotypes
E. coli B	10^{-7}	4	*r*
E. coli K12	10^{-2}	8	1

(a) Calculate the recombination frequency.
(b) When mutant *6* was tested for recombination with mutant *1*, the data were the same as those shown above for strain B, but not for K12. The researcher lost the K12 data, but remembered that recombination was ten times more frequent than when mutants *1* and *2* were tested. What were the lost values (dilution and colony numbers)?
(c) Mutant *7* (Problem 22) failed to complement any of the other mutants (*1*–*6*). Define the nature of mutant *7*.
24. In *Bacillus subtilis*, linkage analysis of two mutant genes affect-

Extra-Spicy Problems challenge students to solve complex problems, many based on data derived from primary genetics literature.

MasteringGenetics™

NEW! 140 Additional Practice Problems offer more opportunities to develop problem solving skills. These questions appear only in MasteringGenetics, and they include targeted wrong answer feedback to help students learn from their mistakes.



Prepare students for the challenging problems they will see on tests and exams: question types include sorting, labeling, entering numerical information, multiple choice, and fill-in-the-blank.

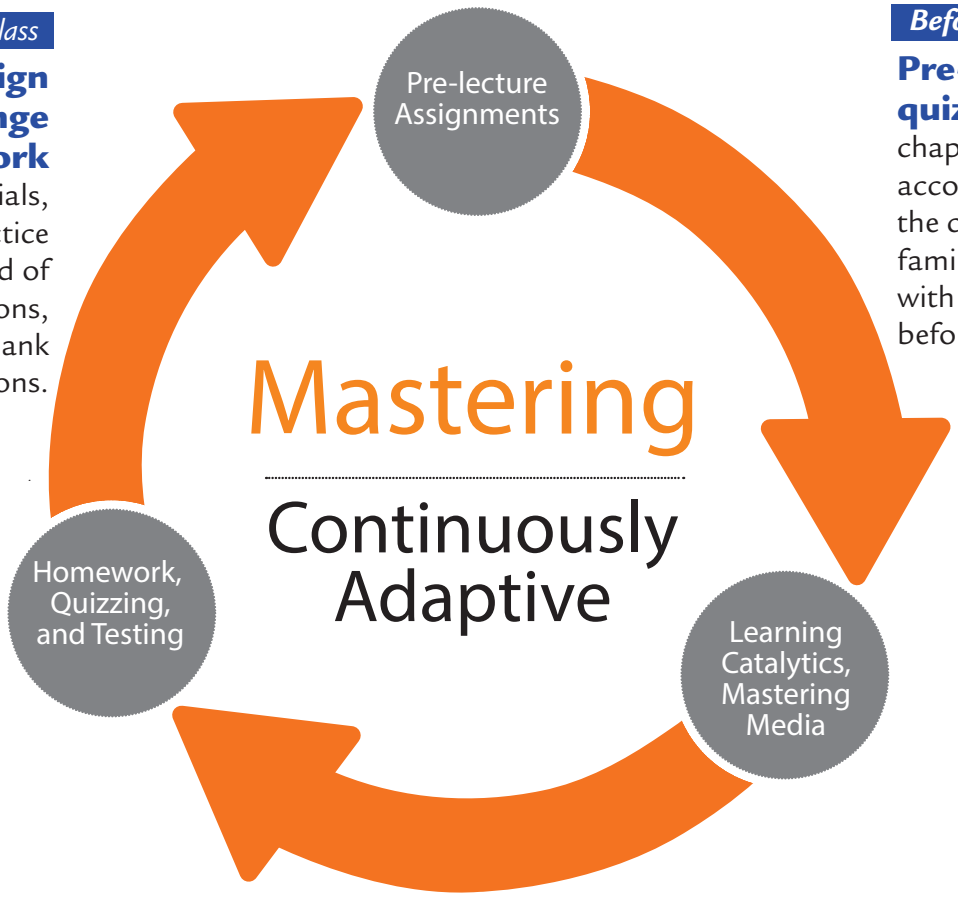
Complete the **Problems and Discussion Questions** at the end of each chapter. 90% of questions are now available in MasteringGenetics .

Succeed with MasteringGenetics

MasteringGenetics is a powerful online learning and assessment system proven to help students learn problem-solving skills. You'll find activities for use **before class, during class, and after class.**

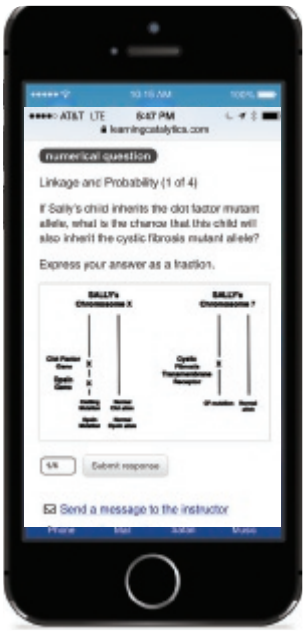
After Class

You can assign a broad range of homework including tutorials, activities, practice problems, end of chapter questions, and test bank questions.



Before Class

Pre-built reading quizzes for every chapter hold students accountable for reading the chapter and familiarizing themselves with basic concepts before coming to class.



During Class

NEW! **Learning Catalytics** is a "bring your own device" (smartphone, tablet, or laptop) assessment and active classroom system that expands the possibilities for student engagement. Using Learning Catalytics, genetics instructors can deliver a wide range of auto-gradable or open-ended questions that test content knowledge and build critical thinking skills.

Instructors can create their own questions, draw from community content shared by colleagues, or access Pearson's new library of question clusters that explore challenging topics through a series of 2-5 questions that focus on a single scenario or data set, build in difficulty, and require higher-level thinking.

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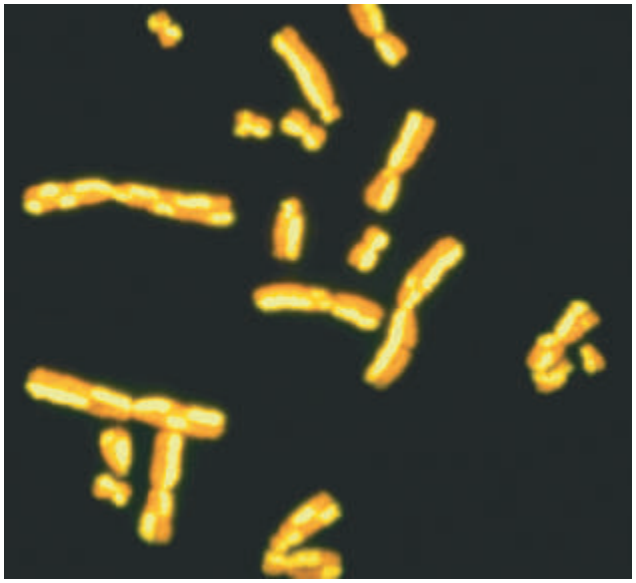
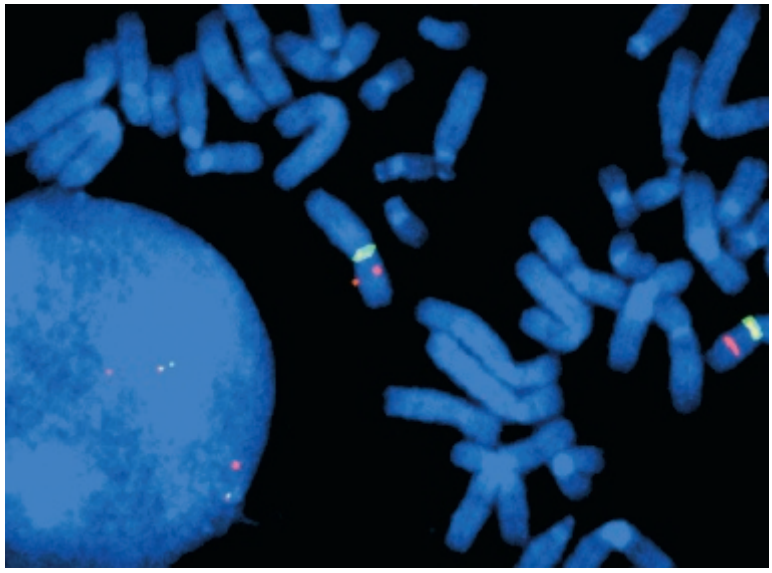
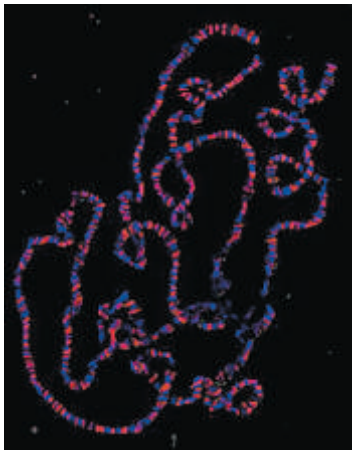
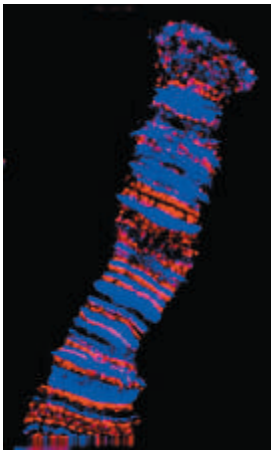




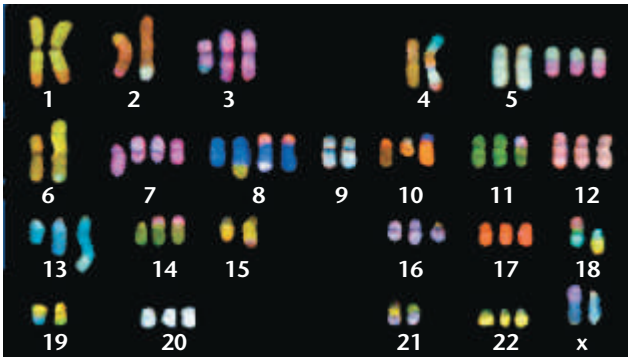
PART THREE
GENE EXPRESSION, REGULATION, AND DEVELOPMENT

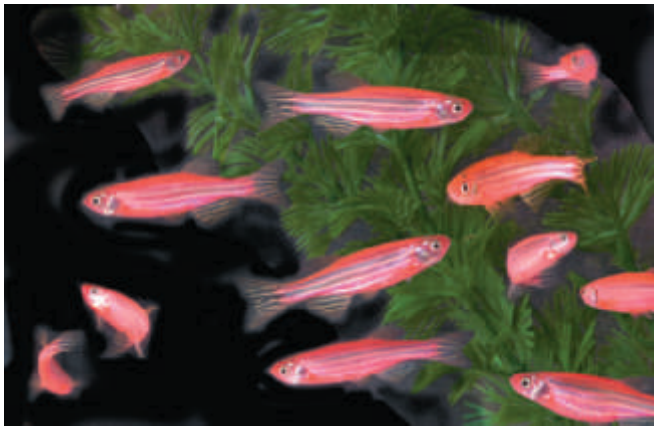




18 Developmental Genetics *479*

19 Cancer and Regulation of the Cell Cycle *503*





SPECIAL TOPICS IN MODERN GENETICS 4

Genomics and Personalized Medicine *746*

SPECIAL TOPICS IN MODERN GENETICS 5

Genetically Modified Foods *758*

SPECIAL TOPICS IN MODERN GENETICS 6

Gene Therapy *772*

Preface

It is essential that textbook authors step back and look with fresh eyes as each edition of their work is planned. In doing so, two main questions must be posed: (1) How has the body of information in their field—in this case Genetics—grown and shifted since the last edition; and (2) What pedagogic innovations might be devised and incorporated into the text that will unquestionably enhance students' learning? The preparation of the 11th edition of *Concepts of Genetics*, a text now entering its fourth decade of providing support for students studying in this field, has occasioned still another fresh look. And what we focused on in this new edition, in addition to the normal updating that is inevitably required, were two things: (1) the need to increase the opportunities for instructors and students to engage in **active and cooperative learning approaches**, either within or outside of the classroom; and (2) the need to provide more **comprehensive coverage of important, emerging topics** that do not yet warrant their own traditional chapters.

Regarding the first point, and as discussed in further detail below, we have added a new feature called **Modern Understanding of Gene Function**, which appears within many chapters. In addition, we have retained the very popular **Genetics, Technology, and Society** essays that appear at the end of many chapters. This feature includes an active learning format called *Your Turn*, which directly engages the student with provocative assignments. These features are in addition to **Exploring Genomics** entries, and together, these all may serve as the basis for interactions between small groups of students, either in or out of the classroom. Regarding emerging topics, we continue to include a unique approach in genetics textbooks that offers readers a set of abbreviated, highly focused chapters that we label **Special Topics in Modern Genetics**. In this edition, these provide uniquely cohesive coverage of six important topics: *Epigenetics*, *Emerging Roles of RNA*, *Genomics and Personalized Medicine*, *DNA Forensics*, *Genetically Modified Foods*, and *Gene Therapy*. Three of these (*RNA, GM Foods,* and *Gene Therapy)* are new to this edition.

Goals

In the 11th edition of *Concepts of Genetics*, as in all past editions, we have five major goals. Specifically, we have sought to:

- Emphasize the basic concepts of genetics.
- Write clearly and directly to students in order to provide understandable explanations of complex, analytical topics.
- Maintain our strong emphasis on and provide multiple approaches to problem solving.
- Propagate the rich history of genetics, which so beautifully illustrates how information is acquired during scientific investigation.
- Create inviting, engaging, and pedagogically useful full-color figures enhanced by equally helpful photographs to support concept development.

These goals collectively serve as the cornerstone of *Concepts of Genetics*. This pedagogic foundation allows the book to be used in courses with many different approaches and lecture formats.

Writing a textbook that achieves these goals and having the opportunity to continually improve on each new edition has been a labor of love for us. The creation of each of the eleven editions is a reflection not only of our passion for teaching genetics, but also of the constructive feedback and encouragement provided by adopters, reviewers, and our students over the past three decades.

New to This Edition

- **Special Topics in Modern Genetics**—We have been pleased with the popular reception that the Special Topics in Modern Genetics chapters has received. First introduced in the tenth edition, our goal has been to provide abbreviated, cohesive coverage of important topics in genetics that are not always easily located in textbooks. Professors have used these focused, flexible chapters as the backbone of lectures, as inspiration for student assignments outside of class, and as the basis of group assignments and presentations.

  New to this edition are chapters on topics of great significance in genetics: Emerging Roles of RNA, Genetically Modified Foods, and Gene Therapy. For all Special Topic chapters, we have added a series of questions that send the student back into the chapter to review key ideas or provide the basis of personal contemplations and group discussions.

- **Modern Approaches to Understanding Gene Function** This new feature highlights how advances in genetic technology have led to our modern understanding of gene

function. Appearing in many chapters, this feature also prompts students to apply their analytical thinking skills, linking the experimental technology to the findings that enhance our understanding of gene function.

- **Evolving Concept of the Gene** Also new to this edition is a short feature, integrated in appropriate chapters, that highlights how scientists' understanding of what a gene is has changed over time. Since we cannot see genes, we must infer just what this unit of heredity is, based on experimental findings. By highlighting how scientists' conceptualization of the gene has advanced over time, we aim to help students appreciate the process of discovery that has led to an ever more sophisticated understanding of hereditary information.
- **Concept Question** A new feature, found as the second question in the Problems and Discussion Questions at the end of each chapter, asks the student to review and comment on common aspects of the Chapter Concepts, listed at the beginning of each chapter. This feature places added emphasis on our pedagogic approach of conceptual learning.
- **Neurogenetics** A major change that is evident in the Table of Contents involves Chapter 24. Previously entitled Behavior Genetics, this chapter has been reworked and redefined to reflect the wealth of information regarding the impact of genetics on the field of neurobiology, linking genetic analysis to brain function and brain disorders. Thus, the fully revised Chapter 24 is now entitled Neurogenetics.
- **MasteringGenetics** This robust online homework and assessment program guides students through complex topics in genetics, using in-depth tutorials that coach students to correct answers with hints and feedback specific to their misconceptions. New content for *Concepts of Genetics 11e* includes a library of Practice Problems that are like end of chapter questions and only appear in MasteringGenetics. These problems offer a valuable extension of questions available for assignments. These questions include wrong answer feedback to help students learn from their mistakes.

New and Updated Topics

While we have revised each chapter in the text to present the most current findings in genetics, below is a list of some of the most significant new and updated topics present in this edition.

Ch. 1: Introduction to Genetics
- New chapter introduction vignette emphasizing translational medicine

Ch. 3: Mendelian Genetics
- New Understanding Gene Function section: Identifying Mendel's Gene for Regulating White Flower Color in Peas
- New end-of-chapter problems based on Migaloo, the albino hump-backed whale

Ch. 7: Sex Determination and Sex Chromosomes
- New coverage on paternal age effects (PAEs) in humans
- New Understanding Gene Function section: *Drosophila Sxl* Gene Induces Female Development

Ch. 8: Chromosome Mutations: Variation in Number and Arrangement
- Updated coverage of fragile-X syndrome
- New Understanding Gene Function section: Mouse Models of Down Syndrome

Ch. 9: Extranuclear Inheritance
- New coverage on mitochondrial swapping and the prevention of mtDNA-based disorders

Ch. 11: DNA Replication and Recombination
- Updated coverage of DNA Pol III holoenzyme
- Revised figures involving DNA synthesis
- New coverage of the initiation of bacterial DNA synthesis
- New coverage of homologous recombination and gene conversion
- New coverage of replication of telomeric DNA
- New Understanding Gene Function section: Lethal Knockouts of DNA Ligase Genes

Ch. 12: DNA Organization in Chromosomes
- New coverage of kinetochore structure and function

Ch. 14: Translation and Proteins
- Revision of all ribosome figures

Ch. 15: Gene Mutation, DNA Repair, and Transposition
- New data on spontaneous mutation rates in humans.
- Reorganization and updates for mutation classification
- Updated coverage of xeroderma pigmentosum and DNA repair mechanisms
- New Understanding Gene Function section: Transposon-Mediated Mutations Reveal Genes Involved in Colorectal Cancer

Ch. 16: Regulation of Gene Expression in Prokaryotes
- Updated coverage of gene regulation by riboswitches

Ch. 17: Regulation of Gene Expression in Eukaryotes
- Expanded coverage of chromatin modifications
- Introduction of Weintraub and Groudine's experiments involving chromatin structure and transcription regulation
- Updated coverage of promoter and enhancer structures and functions
- Updated coverage of the mechanisms of transcription activation and repression
- Updated section on RNA silencing
- New section: ENCODE Data Are Transforming Our Concepts of Eukaryotic Gene Regulation
- New Understanding Gene Function section: MicroRNAs Regulate Ovulation in Female Mice

Ch. 18: Developmental Genetics
- New section: Binary Switch Genes and Signaling Pathways, including four new figures
- New Understanding Gene Function section: Single-Gene Signaling Mechanism Reveals Secrets to Head Regeneration in Planaria

Ch. 19: Cancer and Regulation of the Cell Cycle
- New coverage of the progressive nature of colorectal cancers
- Revised and updated coverage of driver and passenger mutations
- Expanded coverage of the role of viruses in human cancers

Ch. 20: Recombinant DNA Technology
- Expanded coverage and new figure on third-generation DNA sequencing
- New section on gene targeting that includes content and figures on gene knockout animals, conditional knockouts, and transgenic animals

Ch. 21: Genomics, Bioinformatics, and Proteomics
- Updated coverage of the Human Microbiome Project
- New content introducing exome sequencing
- Updated coverage of personal genome projects
- Revised and expanded coverage of the Encyclopedia of DNA Elements (ENCODE) Project
- New content and figure covering chromatin-immunoprecipitation (ChIP) and ChIP-sequencing (ChIPSeq)
- New Case Study discussing the microbiome as a risk factor for disease

Ch. 22: Applications and Ethics of Genetic Engineering and Biotechnology
- New section and figure on Synthetic Biology for Bioengineering Applications
- New coverage and figure on deducing fetal genome sequences from maternal blood
- Updated coverage of prenatal genetic testing
- Updated coverage of the minimal genome
- New coverage involving genetic analysis by sequencing individual genomes for clinical purposes and single-cell sequencing
- Revised ethics section to include additional discussion on the analysis of whole genome sequences, preconception testing, DNA patents, and destiny predictions
- Major revision of PDQ content and additional new questions
- New Genetics, Technology, and Society essay: Privacy and Anonymity of Genomic Data
- New Case Study on cancer-killing bacteria

Ch. 23: Quantitative Genetics and Multifactorial Traits
- Updated coverage of quantitative trait loci (QTL) in studying multifactorial phenotypes

Ch. 24: Neurogenetics
- Conversion of the Behavior Genetics chapter to one entitled Neurogenetics, with emphasis on molecular events in the brain and nervous system related to behavior. Includes 10 new figures and 3 new tables.
- New Understanding Gene Function section: *RbAp48* and a Potential Molecular Mechanism for Age-Related Memory Loss

Ch. 25: Population and Evolutionary Genetics
- New coverage on macroevolution and the rate of speciation
- Revision of the discussion of the molecular clock
- Two new sections: The Complex Origins of Our Genome and Our Genome Is a Mosaic

Special Topic Chapter 1: Epigenetics
- New section: MicroRNAs and Long Non-Coding RNAs

Special Topic Chapter 2: Emerging Roles of RNA
- New chapter on the newly discovered emerging roles of RNA—focuses on the diverse functions of RNAs with an emphasis on noncoding RNA

Special Topic Chapter 3: DNA Forensics
- New coverage describing how DNA can be inadvertently transferred to a crime scene, leading to false arrests
- New coverage of DNA phenotyping