BIOLOGICAL SCIENCE

Red-tailed Hawk, *Buteo jamaicensis*
The red-tailed hawk searches for a wide variety of small prey, capturing them by swooping from the air or diving from a stationary perch. Buteos like the red-tailed hawk are adapted for predation, with broad wings and tail for soaring flight, curved talons for grasping prey, large forward-rotated eyes for acute long-distance vision, and a sharp tearing beak. The red-tailed hawk's colouration, which is darker above and paler underneath, camouflages it from below. The red-tailed hawk's opportunistic hunting skills have helped it to be the most widely distributed hawk in North America.

BIOLOGICAL SCIENCE

Second Canadian Edition

SCOTT FREEMAN

University of Washington

MIKE HARRINGTON

University of Alberta

JOAN SHARP

Simon Fraser University

PEARSON

Toronto

"I would like to dedicate this book to my grandparents, the best teachers one could hope for."
—Mike Harrington

"For Yusef, who finds the world a fascinating place, and in memory of Yasmin, who found comfort in nature."
—Joan Sharp

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Brief Contents

Detailed Contents

About the Authors

SCOTT FREEMAN received his Ph.D. in Zoology from the University of Washington and was subsequently awarded an Alfred P. Sloan Postdoctoral Fellowship in Molecular Evolution at Princeton University. His current research focuses on the scholarship of teaching and learning—specifically **(1)** how active learning and peer teaching techniques increase student learning and improve performance in introductory biology and **(2)** how the levels of exam questions vary among introductory biology courses, standardized postgraduate entrance exams, and professional school courses. He has also done research in evolutionary biology on topics ranging from nest parasitism to the molecular systematics of the blackbird family. Scott teaches introductory biology for majors at the University of Washington and is coauthor, with Jon Herron, of the standard-setting undergraduate text *Evolutionary Analysis*.

MIKE HARRINGTON completed his B.Sc. and Ph.D. in the Zoology Department of the University of British Columbia. His graduate work on *Drosophila* chromatin structure combined classical and molecular genetics. He is presently a Faculty Lecturer in the Biological Sciences Department at the University of Alberta. He teaches cell biology at the first- and second-year levels and genetics at the second-, third-, and fourth-year levels. His teaching goals are **(1)** to find ways to incorporate current scientific research into introductory courses, **(2)** to develop new ways to expand a course's boundaries with online material, and **(3)** to use clicker classroom response systems to teach content with questions.

JOAN SHARP received her B.A. and B.Sc. from McGill University and her M.Sc. from the University of British Columbia. She is a Senior Lecturer at Simon Fraser University, where she teaches Introduction to Biology, General Biology, Ecology, and Vertebrate and Invertebrate Biology. Her teaching and research interests include a number of areas: **(1)** Prior or newly acquired misconceptions interfere with student success in building meaningful biological understanding. It is important to understand common misconceptions and to develop activities that allow students to address and correct their misconceptions. Concept inventories can be used to measure students' learning gains to assess the success of teaching strategies targeting student misconceptions. **(2)** Students' written work can serve as a starting point to address areas of misunderstanding and to help students refine and express biological ideas. **(3)** Case studies engage students with key concepts by using meaningful real-world scenarios. The use of clickers allows the implementation of case studies in large lecture courses, facilitating small group discussion and increasing student learning.

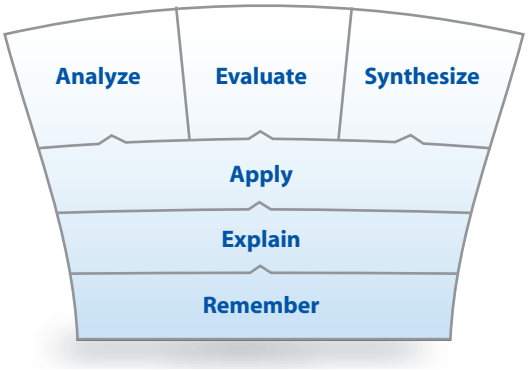
Illustrator

KIM QUILLIN combines expertise in biology and information design to create lucid visual representations of biological principles. She received her B.A. in Biology at Oberlin College and her Ph.D. in Integrative Biology from the University of California, Berkeley (as a National Science Foundation Graduate Fellow), and taught undergraduate biology at both schools. Students and instructors alike have praised Kim's illustration programs for *Biological Science*, as well as *Biology: A Guide to the Natural World* by David Krogh and *Biology: Science for Life* by Colleen Belk and Virginia Borden, for their success in the visual communication of biology. Kim is a Lecturer in the Department of Biological Sciences at Salisbury University.

Preface to Instructors

This book is for instructors who want to help their students learn how to think like a biologist. Our students need to learn the language of biology and understand fundamental concepts, but they also need to apply these concepts to new situations, analyze experimental design, synthesize results, and evaluate hypotheses and data.

We wrote this book for instructors who embrace this challenge—who want to help their students learn how to think like a biologist. The essence of higher education is to promote higher-order thinking. Our job is to help students understand biological science at all six levels of Bloom's taxonomy of learning.



Bloom's Taxonomy. An annotated version of this graphic can be found in "Preface to Students: How to Use This Book" at the front of this book.

The Evolution of a Textbook

Evolution can be extremely fast in populations with short generation times and high mutation rates. Biology textbooks are no exception. Generation times have to be short because the pace of research in biology and student learning is so fast. This book, in particular, evolves quickly because it incorporates so many new ideas with each edition. Some of these "alleles" are novel mutations, but most arrive via lateral transfer—from advisors, reviewers, friends, students, and the literature.

What's New in This Edition

This revision was about making the book a better teaching and learning tool. To help students manage the mass of information and ideas that is contemporary biology, we broke long paragraphs into shorter paragraphs, made liberal use of numbered lists and bulleted lists to "chunk" information and ideas, and broke out dozens of new sections and subsections.

In addition, we came up with a long list of new or expanded features.

- **Canadian Content** We have updated and expanded the Canadian content throughout the book. Each chapter now has at least one Canadian Research or Canadian Issues box. We have chosen examples that both illustrate one of the main concepts in the chapter and highlight the diversity of science being done in Canadian universities, colleges, and other organizations. These boxes now end with a "Think About It" question to allow students to test their understanding of the material.
- **The Big Picture** These new two-page spreads are meant to help students see the forest for the trees. They are concept maps that focus on particularly critical areas—Energy, Genetic Information, Evolution, Macromolecules, Ecology, and How Multicellular Organisms Work. Each synthesizes content and concepts from an array of chapters and includes exercises for students to complete. You'll recognize these pages readily—their edges are coloured black (for example, see The Big Picture: Macromolecules on pages 110–111). In addition, the book's MasteringBiology® website has 10 new concept map activities based on Big Picture content that will allow you to explore the concepts and their connections with your students during lectures.
- **BioSkills** Students completing introductory biology need to have acquired skills—the ability to read a graph, interpret an equation, understand the bands on a gel. The previous edition of *Biological Science* contained a series of appendices focused on key skills for introductory biology students. Instructors and students found them extraordinarily helpful. New in this edition are BioSkills on using the metric system, common Latin and Greek roots, techniques for isolating and visualizing cell components, cell and tissue culture methods, and model organisms. BioSkills are located in Appendix B.
- **Answer Key** New to the Second Canadian Edition are suggested answers to all questions and exercises in the textbook. Students asked us to make this important change between editions to make the book a more complete study tool. The answer key will allow them to self-check their understanding while reading and when reviewing for exams. Answers are in Appendix A.
- **Experiment Boxes** This text's hallmark has always been its emphasis on experimental evidence—on teaching how we know what we know. In the previous edition, key experiments were converted to a boxed format so students could easily navigate through the logic of the question, hypothesis, and test. In this edition, we added a new question to every experiment box to encourage students to analyze some aspect of the experiment's design.

- **Art Program** Recent research shows that students are more likely to interpret phylogenetic trees correctly if the trees are designed with U-shaped branches instead of Y-shaped branches. We responded by redesigning every phylogenetic tree in the text. To make other subject areas more accessible to visual learners, we enlarged figures, replaced hundreds of photos with clearer images, and strove to streamline labels and graphics across the board. (More on improvements to the art program below.)
- **MasteringBiology Quizzes** MasteringBiology gives students round-the-clock access to quizzes. We developed 550 new assignable questions based on the book's "Blue Thread" questions (more on the "Blue Thread" and its evolution below). We also developed a cumulative practice test to simulate what a real exam might be like. To help students keep up with their reading, we created 55 new reading quizzes—one for each chapter—that you can assign through MasteringBiology.
- **MasteringBiology Experimental Inquiry Tutorials** The call to teach students about the process of science has never been louder. In response, a team led by Tom Owens of Cornell University developed 10 new interactive tutorials on classic scientific experiments—ranging from Meselson–Stahl on DNA replication to the Grants' work on Galápagos finches and Connell's work on competition. Students who use these interactive tutorials should be better prepared to think critically about experimental design and evaluate the wider implications of the data—preparing them to do the work of real scientists in the future.
- **MasteringBiology BioFlix Animations and Tutorials** BioFlix™ are movie-quality, 3-D animations available on MasteringBiology. They focus on the most difficult core topics and are accompanied by in-depth, online tutorials that provide hints and feedback to help guide student learning. Thirteen BioFlix were available with the previous edition of *Biological Science*. Five new BioFlix 3-D animations and tutorials have been developed for this edition—on mechanisms of evolution, homeostasis, gas exchange, population ecology, and the carbon cycle.

Changes to Gold Thread Scaffolding

The previous edition introduced a set of tools designed to help with a chronic problem for novice learners: picking out important information. Novices highlight every line in the text and try to memorize everything mentioned in lecture; experts instinctively home in on the key unifying ideas.

For students to make the novice-to-expert transition, we have to help them with features like:

1. **Key concepts** that are declared at the start of each chapter, highlighted with a key icon within the chapter, and reviewed at the end of the chapter.
2. **In-text highlighting**, in gold, that directs their attention to particularly important ideas.
3. **Check Your Understanding boxes**, at the end of key sections, with a bulleted list of key points.
4. **Summary tables** that pull information together in a compact format that is easy to review and synthesize.

Changes to Blue Thread Scaffolding

Each edition of this text has added tools to help students with metacognition—understanding what they do and don't understand. Novices like to receive information passively, and easily persuade themselves that they know what's going on. Experts are skeptical—they want to solve some problems before they're convinced that they know and understand an idea.

In the previous edition, we formalized the metacognitive tools in *Biological Science* as a "Blue Thread" set of questions; in this edition, we revised each question and put answers in the back of the book for easy student access.

1. **In-text "You should be able to's"** offer exercises on topics that professors and students have identified as the most difficult concepts in each chapter.
2. **Caption Questions and Exercises** challenge students to examine critically the information in a figure or table—not just absorb it.
3. **Think About It** questions test or expand on an important concept in each Canadian Research and Canadian Issues box.
4. **Check Your Understanding boxes** present two to three tasks that students should be able to complete in order to demonstrate a mastery of summarized key ideas.
5. **Chapter Summaries** include "You should be able to" problems or exercises related to each of the key concepts declared in the gold thread.
6. **End-of-Chapter Questions** are organized around Bloom's taxonomy of learning, so students can test their understanding at the knowledge, comprehension, and application levels.

The fundamental idea is that if students really understand a piece of information or a concept, they should be able to do something with it. How do you get to Carnegie Hall? Practise.

As students mature as biologists-in-training and start taking upper-division courses, most or all of this scaffolding can disappear. By the time our students are in their fourth year, they should have enough expertise to construct a high-level understanding on their own. But if a well-designed scaffold isn't there to get them started in their first and second years when they are novices, most will flounder. We have to help them learn how to become good students.

Supporting Visual Learners

Figures can help students, especially visual learners, at all levels of Bloom's Taxonomy—not only to understand and remember the material, but also to exercise higher levels of critical thinking. The overall goal of the Second Canadian Edition art revision was to hone the figures for accessibility to help novice learners recognize and engage with important visual information. In addition

to redesigning the previously mentioned phylogenetic trees, Kim Quillin led the effort to enhance virtually every other aspect of the visual-teaching program.

- **Art and Photos** Kim enlarged art and photographs in figures throughout the book to increase clarity by making details physically easier to see. She also reduced the amount of detail in labels and graphics to simplify, simplify, simplify.
- **Colour Use** Kim continues to use colour strategically to draw attention to important parts of the figures. In this revision, she boosted colour contrast in many figures to make the art more vibrant and the details easier to see.
- **Molecular Icons** Kim redesigned many molecular icons to simplify their shapes. The overall contours are based on molecular coordinates, when available, to accurately represent size and geometry, but she smoothed the textures for a simpler appearance—one that is more memorable and pleasing.
- **Molecular Models** New molecular models have been introduced to help students visualize structure–function relationships. In Chapter 5, for example, redesigned 2-D line drawings of sugars are now paired with 3-D ball-and-stick models.
- **"Pointers"** The Second Canadian Edition figures still use pointer annotations as a "whisper in the ear" to guide students in interpreting figures, but Kim has replaced the hand with an arrow to be more precise.

Acknowledgments

Reviewers

The peer review system is the key to quality and clarity in science publishing. In addition to providing a filter, the investment that respected individuals make in vetting the material—catching errors or inconsistencies and making suggestions to improve the presentation—gives authors, editors, and readers confidence that what they are publishing and reading meets rigorous professional standards.

Peer review plays the same role in textbook publishing. The time and care that this book's reviewers have invested is a tribute to their professional integrity, their scholarship, and their concern for the quality of teaching. This edition has been revised and improved based on insights from the following individuals:

Eric Alcorn, *Acadia University*
Greg Beaulieu, *University of Victoria*
Todd Bishop, *Dalhousie University*
Peter Boag, *Queen's University*
Dora Cavallo-Medved, *University of Windsor*
Brett Couch, *University of British Columbia*
Christine Dalton, *University of the Fraser Valley*
Nancy Flood, *Thompson Rivers University*
Chris Garside, *formerly of the University of Ontario Institute of Technology, now at University of Toronto, St. George*
Kim Gilbride, *Ryerson University*
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Carla Starchuk, *University of Alberta*
Alexandra Venter, *Athabasca University*
Usha Viveganathan, *Mohawk College*
Debbie Wheeler, *University of the Fraser Valley*
Ken Wilson, *University of Saskatchewan*

Supplements Contributors

Instructors depend on an impressive array of support materials—in print and online—to design and deliver their courses. The student experience would be much weaker without the study guide, test bank, activities, animations, quizzes, and tutorials written by the following individuals:

Study on the Go—Nancy Flood, *Thompson Rivers University*
PowerPoint and PRS Questions—Sharon Gillies, *University of the Fraser Valley*
Testbank—Tamara Kelly and Nicole Nivillac, *York University*

Book Team

As coauthors on the Second Canadian edition of *Biological Science*, we would like to thank all the talented people who were involved in the production of our textbook. This very professional team was headed by Gary Bennett, Vice President and Editorial Director. We are grateful for the guidance of both Michelle Sartor and Lisa Rahn, who replaced Michelle as Senior Acquisitions Editor.

Ken Ko of Queen's University shared the writing duties with us on the topics of Canadian research on plant systems and on gene regulation. We are impressed by the polished art produced by Julia Hall from our hand-drawn scribbles.

Developmental Editor Joanne Sutherland patiently and expertly provided guidance and encouragement throughout the process, while the final version of the text was guided by Project Manager Carrie Fox and Copyeditor Audra Gorgiev, directed by Lead Project Manager Avinash Chandra, and effectively and efficiently managed by in-house Project Manager Rachel Thompson.

It is always a genuine pleasure to work with Senior Marketing Manager Kim Ukrainec and Marketing Coordinator Kathie Kirchsteiger. These dedicated individuals supervise Pearson Canada's talented sales reps, who listen to professors, advise the editorial staff, and get the book into student hands.

Finally, we would like to offer our heartfelt thanks for the detailed suggestions from the reviewers who cast a careful eye over each draft chapter. Their thoughtful comments are very much appreciated.

Serving a Community of Teachers

There is nothing that inspires us more than getting together with other biology instructors and "talking shop." These meetings may be during teaching workshops or less formal get-togethers. While we all have our own personal teaching styles, these styles are a collection of ideas tested and refined with our colleagues—or borrowed outright!

Research on biology education is gathering momentum, trying to catch up on the trail blazed by physics education researchers, bringing the same level of rigour to our classrooms that we bring to our lab benches and field sites. We try to bring the spirit and practice of evidence-based teaching into this textbook, and welcome your comments, suggestions, and questions.

Thank you for considering this text, and for your work on behalf of your students. We have the best jobs in the world.

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Content Highlights of the Second Canadian Edition

As discussed in the preface, a major focus of this revision is to enhance the pedagogical utility of *Biological Science*. New Canadian content has been added to many of the chapters. Another major goal is to ensure that the content reflects the current state of science and is accurate. In addition, every chapter has been rigorously evaluated for discussions that, in the previous edition, may have been too complex or overly detailed. As a result of this scrutiny, certain sections in every chapter have been simplified, content has been pruned judiciously, and the approach to certain topics has been re-envisioned to enhance student comprehension. In this section, some of the key content improvements to the textbook are highlighted.

Unit 1 The Molecules of Life

Chapter 1 A new experiment on ant navigation and discussions of tree-based naming systems and artificial selection in maize has been added. Coverage is expanded on the definition of life.

Chapter 2 The descriptions of bond angles and the geometry of simple molecules are simplified. Added is a discussion on the hot-start hypothesis as well as a new Key Concept on the nature of chemical energy.

Chapter 3 This chapter has been streamlined by eliminating discussion of optical isomers/chirality and reducing coverage of enzyme kinetics and reaction rates. New Canadian content includes the impact of prions on the cattle industry and new "designer proteins" being developed at the University of Guelph.

Chapter 4 The discussion of RNA is expanded to include recently discovered roles for RNAs in cells. There are more detailed explanations on how nucleotides are named and how DNA molecules are measured. "Designer nucleotides" made at McMaster University are the subject of a new Canadian Research box. Also added is a new summary table (**Table 4.1**) comparing DNA and RNA structure.

Chapter 5 A stronger emphasis on the link between electronegativity of atoms and potential energy in, C—C, C—H, C—O and bonds is developed. New ball-and-stick models are added to clarify the differences in location and orientation of functional groups.

Chapter 6 Coverage of secondary active transport has been expanded. Also included in this chapter is current research on the "first cell" and a discussion of nonrandom distribution of membrane proteins and phospholipids.

Unit 2 Cell Structure and Function

Chapter 7 Recent discoveries on bacterial cell structure is described in a new Canadian Research box. The relationships between chloroplasts and other plastids and between the lysosomes and other endomembrane system components have been emphasized. Centrifugation is moved to **BioSkills 11** in Appendix B.

Chapter 8 New sections on quorum sensing in bacteria and cross-talk among signal-transduction pathways have been added. Canadian research on both of these topics has also been included.

Chapter 9 The discussions of mitochondrial structure, ATP yield from glucose oxidation, and the role of GDP in the citric acid cycle have been updated. The introductory section on cellular respiration has been simplified. The ATP synthase enzyme is the subject of a new Canadian Research box.

Chapter 10 A new section on regulation (inhibition) has been added. The sections on C_4 and CAM photosynthesis now emphasize the role of these pathways in increasing CO_2 concentrations versus water conservation. The Canadian research described in this chapter has been updated to describe a project to improve photosynthesis in rice that is currently under way at the University of Toronto.

Chapter 11 The beginning of the chapter has been completely revised to include why and how each step of mitosis occurs. Mitosis is now presented in three ways: (1) the events that define each stage, (2) the reason why the cell does what it does, and (3) how the chromosome behaviour is the result of microtubule, cohesin, condensin, and nuclear lamin proteins working in progression. The discussion on the role of activated MPF has been updated to include the triggering M phase of the cell cycle. Animal cell culture methods are moved to **BioSkills 12** in Appendix B.

Unit 3 Gene Structure and Expression

Chapter 12 The topic of crossovers has been expanded and is the subject of a new Canadian Research box. The discussions of recombination rates and aneuploidy rates in humans are updated. New micrographs have been added to the phases of meiosis figure (**Figure 12.7**).

Chapter 13 The linkage discussion and notation in fly crosses have been simplified. Sex-linkage is moved to the Mendelian section (**Section 13.4** The Chromosome Theory of Inheritance), and mapping is now covered in **Box 13.1** Quantitative Methods:

Linkage. A new summary table (**Table 13.3**) presenting basic vocabulary used in Mendelian genetics has been added.

Chapter 14 A new space-filling model of DNA has been added to **Figure 14.4**. The *E. coli* DNA polymerases I and III are now described independently. Canadian research on the relationship between telomerase, telomeres, and cancer has been included.

Chapter 15 Discussions on mutation in the melanocortin receptor (link to mouse-coat colour camouflage) and karyotypes of cancerous cells have been added. A new Canadian Research box on fur colour in mink provides an opportunity for students to practise using the genetic codon table.

Chapter 16 The sections on transcription in bacteria and eukaryotes are now combined. The structure of the translation initiation complex in bacteria has been updated to reflect current science; snRNAs have been added to the discussion of RNA splicing. The subject of gene expression in organelles is described within a new Canadian Research box.

Chapter 17 The chapter was streamlined with the removal of discussions of DNA fingerprinting and the structure of the operator and DNA-binding proteins. Treatment of catabolite repression/positive control has been trimmed. A practical application of bacterial gene expression done at the Université Laval has been added.

Chapter 18 Included in this chapter is a new summary table (**Table 18.1**) comparing control of gene expression in bacteria and eukaryotes. The chapter now describes the types of histone proteins in eukaryotes and new Canadian research on the relationship between these proteins and cancer. Also added are discussions on ubiquitination and protein degradation, the importance of epigenetic inheritance (chromosome structure), and the histone code hypothesis.

Chapter 19 **Figure 19.11** has been updated to show Sanger sequencing done with fluorescently labelled nucleotides. Southern/Northern/Western blots have moved to **BioSkills 9** in Appendix B. The discussions on golden rice, the impact of GM crops, and SNP association studies for human diseases have been updated with the most recent research. Notes on "next-generation" sequencing technologies have been included.

Chapter 20 Human health applications now emphasize the use of genomics and microarrays to study cancer. Several datasets are updated, including sequencing database totals. New notes on miRNA genes, metagenomics, and the definition of the gene have been added.

Unit 4 Developmental Biology

Chapter 21 The discussions of *bicoid* and regulatory gene cascades are simplified. New material on auxin as a master regulator in early development and the importance of apoptosis have been added.

Chapter 22 The discussion about sea urchin fertilization and variation has been streamlined.

Chapter 23 A new section introducing basic concepts in angiosperm gametogenesis has been added.

Unit 5 Evolutionary Processes and Patterns

Chapter 24 A section on the internal consistency of diverse data as evidence for evolution, including a new phylogeny and time line of whale evolution, has been added. **Figure 24.6**, depicting the evolution of the Galápagos mockingbird, and long-term data on ground finches (**Figure 24.18**) are updated to reflect the most current science. There is a new graph on the evolution of drug resistance in pathogenic bacteria (**Figure 24.14**).

Chapter 25 The genetic drift example has changed from breeding in a small population on Pitcairn Island to coin flips simulating mating in a single couple (using data from the author's classroom). The prairie lupine gene flow example is replaced by recent work on an island population of the great tit, *Parus major*. Notes on balancing selection, assortative mating, and interactions among evolutionary forces have been included.

Chapter 26 The ecological species concept has been added to the species definitions included in the chapter. The speciation-by-vicariance example has been changed from ratites to snapping shrimp, and the sympatric speciation example featuring soapberry bugs has been changed to apple/hawthorn flies.

Chapter 27 The sections on adaptive radiation and mass extinction have been completely reorganized. A new hypothesis for the cause of the Cambrian explosion is included, and detail on the "new genes, new bodies" hypothesis has been removed. Presentation of "Life's Time Line" has been significantly overhauled (see **Figures 27.8, 27.9**, and **27.10**). The Burgess Shale fossil site is now introduced in this chapter.

Unit 6 The Diversification of Life

The model organisms have been moved to **BioSkills 14** in Appendix B. Phylogenetic trees have been redrawn to reflect a horizontal orientation with U-shaped branches for easier comprehension.

Chapter 28 New information on mechanisms of pathogenicity is added. Extensive updates include new notes on archaeon–eukaryote polymerases, the discovery of extensive biomass in the marine subfloor, an archaeon associated with a human disease, discovery of N-fixation and nitrification in archaea, and bacteriorhodopsin's role in phototrophy.

Chapter 29 A stronger emphasis on endosymbiosis as a theme in protist diversification has been threaded throughout this chapter.

Chapter 30 New content on green algae as a grade and on convergence in vascular tissue in mosses/vascular plants and gnetophytes/angiosperms has been added.

Chapter 31 The dynamic nature of mycelia, the importance of glomalin in soil, the role of mating types, and the discovery

of "multigenomic" asexual glomales all have new supporting material.

Chapter 32 The treatment of embryonic tissues, developmental patterns, the coelom, and body symmetry has been updated to reflect the latest scientific thinking. A shift in emphasis to the origin of the neuron and cephalization has been implemented. A new Canadian Research box describes an early Cambrian site in Jasper National Park, Alberta, that has yielded microfossils identified as the oldest molluscan radulae.

Chapter 33 New commentary on the independent transitions to land as well as a clarified discussion on the nature of the ecdysozoan–lophotrochozoan split are included. The discussion of annelids is updated to reflect recent results. A new Canadian Issues box describes the First Census of Marine Life and the Canadian Healthy Oceans Network (CHONe), which worked with the census to establish a biodiversity database for Canada's Pacific, Arctic, and Atlantic oceans.

Chapter 34 The coverage of the echinoderm endoskeleton has been expanded and a phylogeny of early tetrapods has been added to the fin-to-limb transition figure (**Figure 34.16**). New data have been incorporated in the evolution-of-fishes time line (**Figure 34.11**). The treatment of the taxonomic status of hagfishes and lampreys, evolution of the jaw (**Figure 34.14**), and *H. sapiens* migration (**Figure 34.48**) also include the most recent data available. The emphasis on the adaptive significance of the amniotic egg has changed from watertightness to increased size and support. Emphasis in the discussion of viviparity has changed to the adaptive advantage of embryo portability and temperature control. The recent analysis of *Ardipithecus ramidus* as the first hominin, with data on estimated body mass and braincase volume, has been included.

Chapter 35 The material on HIV phylogeny has been moved to the section on emerging viruses.

Unit 7 How Plants Work

Chapter 36 Surface-area-to-volume ratios have been added as a theme in root and shoot systems. New information on contractile roots in *Ficus* and bulbs is incorporated into this chapter.

Chapter 37 New content on aquaporins and the transmembrane route to root xylem has been added, and coverage of why air has such low water pressure potential has been expanded. New Canadian research is included that considers the adaptive value of plastic responses of bluebunch wheatgrass under the increasingly dry conditions that climate change is bringing to many regions in the Canadian interior.

Chapter 38 The description of nitrogen fixation has been clarified.

Chapter 39 A new Canadian Research box explores how plant signalling networks influence growth in plants. **Figure 39.8** on the acid-growth hypothesis has been redesigned, and the discussion of polar auxin transport is simplified. New commentary on the role of brassinosteroids in growth regulation and on "talking trees" is included. The coverage of the receptors for GA, auxin, ABA, and brassinosteroids and MeSA's role in the SAR has been updated with the most current research. Plant tissue culture methods have been moved to **BioSkills 12** in Appendix B.

Chapter 40 Comments on day-length sensing and on pollination syndromes are new to this chapter.

Unit 8 How Animals Work

Chapter 41 New details on tissue types (especially connective tissue) have been incorporated. The discussion of thermoregulation has been completely reorganized for a more logical flow The research of Carleton University's Ken Storey, who explores how some animals survive cold Canadian winters, is now included.

Chapter 42 The sections on the shark rectal gland and the mammalian loop of Henle have been revised to improve focus.

Chapter 43 A description of incomplete digestive systems is now included, and coverage of comparative aspects of digestive tract structure and function has been expanded.

Chapter 44 Information on the types of circulatory systems and types of blood vessels has been consolidated. Details on surface tension and lung elasticity have been removed, while new content on countercurrent exchange in fish gills has been added.

Chapter 45 The chapter and section introductions have been rewritten to introduce a comparative context and to make the neuron-to-systems chapter organization more transparent. New content on interspecific variation in nervous systems has been added.

Chapter 46 The chapter has been shortened and its focus sharpened by the removal of nonessential information. A new Canadian Research box explores why large numbers of migratory bats are killed by turbines at wind farms in southern Alberta.

Chapter 47 New material on EPO abuse in athletes has been included.

Chapter 48 A new Canadian Issues box describes Canada's Assisted Human Reproduction Act. The section on sperm competition includes new data from experiments on seed beetles.

Chapter 49 The discussion of the V regions of BCRs and antibodies and recombination in BCR/TCR genes has been simplified. New content on autoimmune disorders and diseases associated with immunosuppression, allergies, and immunodeficiency diseases has been added. The discussion of vaccination has been expanded.

Unit 9 Ecology

Chapter 50 A new Canadian Research box explores whether sockeye salmon stocks vary in their ability to cope with

increasing temperatures during migration. New information on the importance of nutrient availability in aquatic ecosystems, with details on lake turnover and ocean upwelling, is included. A new section on the Wallace line has also been added.

Chapter 51 The content in this chapter has been completely reorganized to increase cohesiveness. It is presented as a series of questions in behavioural ecology, with each question addressed at the proximate and ultimate levels with separate case studies. Material on modes of learning, innate behaviour, bat–moth interactions, sex change in wrasses, and acoustic and visual signaling in red-winged blackbirds has been trimmed. New content on animal eusociality and on child abuse in humans has been added.

Chapter 52 Discussion of the hare–lynx cycle field experiment has been reorganized for clarity, with new supporting "Results" data added to accompanying **Figure 52.13**.

Chapter 53 New content has been added on species richness and resistance of communities to invasion, the use of predators or parasites as biocontrol agents, and character displacement in finches. The discussion of succession in Glacier Bay is reorganized and simplified. The discussion of alternative hypotheses to explain the latitudinal gradient in species richness has been expanded and clarified. Simon Fraser University paleontologist Bruce Archibald and his colleagues have found a novel way to investigate the role of climatic factors in producing latitudinal gradient in species richness, as explained in the new Canadian Research box.

Chapter 54 The chapter was rewritten and reorganized to sharpen its focus on human impacts. Sections on trophic cascades and biomagnification have been added, as have recent data on human appropriation of NPP, sources of nutrient gain and loss, and the impact of ocean acidification on coral growth.

Chapter 55 New content on the impact of global climate change and a new section on ways to preserve biodiversity are now included. Two new boxes on quantitative methods have been added: one on estimating species numbers and species losses and the other on population viability analysis. Discussion of Canada's Species at Risk Act (SARA) has been moved to this chapter and is discussed in **Canadian Issues 55.1**. Revised **Canadian Issues 55.2** considers the fate of polar bears in a warming Arctic.

Supplements

Instructor Resources

All instructor resources are available on a flash drive (978-0-321-72911-8) and can also be downloaded from the instructor resources area of MasteringBiology.

- The entire textbook illustration program is available in JPEG format with and without labels. Illustrations have been individually enhanced for optimal in-class projection.
- The entire illustration program is also available with editable labels and leaders in chapter-by-chapter Microsoft PowerPoint® presentations.
- A second set of PowerPoint presentations offers lecture outlines for each chapter, augmented by key text illustrations and hyperlinks to animations.
- A third set of PowerPoint presentations is layered to allow select key figures to be presented in a step-by-step manner.
- In-class active lecture questions correlated by chapter can be used with any classroom response system and are available in PowerPoint format.
- Canadian case studies picking up ideas raised in the Canadian Research and Issues boxes are available to explore these studies further and investigate how to apply them in the world. Teaching notes include an Introduction, Learning Objectives, Student Misconceptions, Classroom Management, Supplementary Questions, and References.
- The Instructor Guide includes lecture outlines, active-learning lecture activities, answers to end-of-chapter questions, and innovative material to help motivate and engage students.
- Test Bank and Computerized Test Bank questions are ranked according to Bloom's Taxonomy. Improved TestGen® software makes assembling tests much easier. The Test Bank is also available in Microsoft Word® format.

Student Resources

- The eText addresses the changing needs of students and instructors. Found within MasteringBiology, this electronic version of the text links directly to animations, quizzes, and videos.

- The Study Guide (978-0-321-82868-2) presents a breakdown of key biological concepts, and helps students focus on the fundamentals of each chapter. It is designed in two parts to help students study more effectively. Part I is intended as a "survival guide," and Part II explores the material in the textbook, chapter by chapter.

MasteringBiology

Students who purchase a new copy of the text receive free access to MasteringBiology® (*www.masteringbiology.com*), which contains valuable videos, animations, and practice quizzes to help students learn and prepare for exams.

THE BIG PICTURE New to the Second Canadian Edition, The Big Pictures are interactive concept maps based on seven overarching topics in biology that help students synthesize information across broad concepts and not get lost in the details.

Macromolecules (Chapters 2–6)

- How monomers are used to make macromolecules
- How macromolecules can be classified

Energy (Chapters 9 and 10)

- How photosynthesis yields sugar
- How cellular respiration yields ATP
- How photosynthesis relates to cellular respiration

Genetic Information (Chapters 12–18)

- How genes are expressed
- How genetic information is copied and transmitted
- How genetic information changes

Evolution (Chapters 24–27)

- How species evolve
- How species form the tree of life

How Vascular Plants Work (Chapters 36–39)

- How vascular plants capture light energy and take up CO_2
- How vascular plants obtain water and inorganic nutrients
- How vascular plants respond to hostile organisms

How Humans Work (Chapters 41–47, 49)

- How humans obtain nutrients and maintain homeostasis
- How humans recognize and respond to hostile organisms

Ecology (Chapters 50–55)

- How organisms interact in their environment
- How energy flows and nutrients cycle through ecosystems

BIOFLIX™ BioFlix are 3-D movie-quality animations with carefully constructed student tutorials, labelled slide shows, study sheets, and quizzes, that bring biology to life.

WEB ACTIVITIES Web Activities help students learn biological concepts via simple, cartoon-style animations and contain pre-quizzes and post-quizzes to test student's understanding of biology's dynamic processes and concepts.

DISCOVERY VIDEOS Brief videos from the Discovery™ Channel on 29 different biology topics are available for student viewing along with a corresponding video quiz.

VIDEOS Additional molecular and microscopy videos provide vivid images of processes of the cell.

BIOSKILLS BioSkills (in Appendix B) provide background on key skills and techniques for introductory biology students. New to the Second Canadian Edition are online questions that give students practice building their skill set.

GRAPHIT! Graphing tutorials show students how to plot, interpret, and critically evaluate real data.

Chapter 1

- An Introduction to Graphing

Chapter 50

- Animal Food Production Efficiency and Food Policy
- Atmospheric CO_2 and Temperature Changes

Chapter 52

- Age Pyramids and Population Growth

Chapter 53

- Species Area Effect and Island Biogeography

Chapter 55

- Forestation Change
- Global Fisheries and Overfishing
- Municipal Solid Waste Trends in the United States
- Global Freshwater Resources
- Prospects for Renewable Energy
- Global Soil Degradation

WORD STUDY TOOLS New to the Second Canadian Edition are Latin and Greek root word flash cards to help students practise the language of biology. In addition, an audio glossary provides correct pronunciation to help students learn key terms introduced in the book.

CUMULATIVE TEST Every chapter offers 20 Practice Test questions that students can pool from different chapters into a Cumulative Test to simulate a practice exam.

RSS FEEDS Real Simple Syndication directly links breaking news from four important sources: NPR (National Public Radio), *Scientific American*, *Science Daily News*, and *BioScience*. Current articles reinforce the dynamic nature of science in our daily lives.

eTEXT The eText of *Biological Science*, Second Canadian Edition, is available online 24/7 for students' convenience. New annotation, highlighting, and bookmarking tools allow students to personalize the material for efficient review.

STUDY ON THE GO At the end of every chapter, students will find a QR code (a.k.a. quick response code) that links to Study on the Go mobile content. Students can access text-specific resources, including quizzes and flashcards, through their smartphones, allowing them to study whenever and wherever they wish!

Students can go to one of the sites below to see how to download a free app to their smartphone that facilitates access to these resources. Once the app is installed, the phone will scan the code and link to a website containing *Biological Science's* Study on the Go content.

ScanLife
http://getscanlife.com

NeoReader
http://get.neoreader.com

QuickMark
http://www.quickmark.com.tw

MASTERINGBIOLOGY MEDIA AT A GLANCE

	BIOFLIX	WEB ACTIVITIES	VIDEOS	BIOSKILLS
1 Biology and the Tree of Life		Artificial Selection; Introduction to Experimental Design		The Metric System; Reading Graphs; Reading a Phylogenetic Tree; Some Common Latin and Greek Roots Used in Biology
Unit 1 The Molecules of Life				
2 Water and Carbon: The Chemical Basis of Life		The Properties of Water		Reading Chemical Structures; Using Logarithms; Making Concept Maps; Reading Graphs
3 Protein Structure and Function		Condensation and Hydrolysis Reactions; Activation Energy and Enzymes	An Idealized Alpha Helix (A); An Idealized Alpha Helix (B); An Idealized Beta-Pleated Sheet (A); An Idealized Beta-Pleated Sheet (B)	
4 Nucleic Acids and the RNA World		Structure of RNA and DNA	Stick Model of DNA; Surface Model of DNA	Separating and Visualizing Molecules; Biological Imaging: Microscopy and X-Ray Crystallography
5 An Introduction to Carbohydrates		Carbohydrate Structure and Function		
6 Lipids, Membranes, and the First Cells	Membrane Transport	Diffusion and Osmosis; Membrane Transport Proteins	Space-Filling Model of Cholesterol; Stick Model of Cholesterol; Space-Filling Model of Phosphatidylcholine; Stick Model of a Phosphatidylcholine	Biological Imaging: Microscopy and X-Ray Crystallography; Separating and Visualizing Molecules
Unit 2 Cell Structure and Function				
7 Inside the Cell	Tour of an Animal Cell; Tour of a Plant Cell	Transport into the Nucleus; A Pulse-Chase Experiment	Confocal vs. Standard Fluorescence Microscopy; Cytoplasmic Streaming; Crawling Amoeba	Separating Cell Components by Centrifugation; Biological Imaging: Microscopy and X-Ray Crystallography; Separating and Visualizing Molecules
8 Cell–Cell Interactions			Connexon Structure	Separating and Visualizing Molecules
9 Cellular Respiration and Fermentation	Cellular Respiration	Redox Reactions; Glucose Metabolism	Space-Filling Model of ATP (adenosine triphosphate); Stick Model of ATP (adenosine triphosphate)	

MASTERINGBIOLOGY MEDIA AT A GLANCE *(continued)*

	BIOFLIX	WEB ACTIVITIES	VIDEOS	BIOSKILLS
10 Photosynthesis	Photosynthesis	Chemiosmosis; Photosynthesis; Strategies for Carbon Fixation	Space-Filling Model of Chlorophyll	
11 The Cell Cycle	Mitosis	The Phases of Mitosis; Four Phases of the Cell Cycle	Mitosis	Separating and Visualizing Molecules; Cell and Tissue Culture Methods
Unit 3 Gene Structure and Expression				
12 Meiosis	Meiosis	Meiosis; Mistakes in Meiosis		Combining Probabilities; Using Statistical Tests and Interpreting Standard Error Bars
13 Mendel and the Gene		Mendel's Experiments; The Principle of Independent Assortment		Model Organisms; Combining Probabilities; Reading Graphs
14 DNA and the Gene: Synthesis and Repair	DNA Replication	DNA Synthesis		Separating Cell Components by Centrifugation; Cell and Tissue Culture Methods; Using Logarithms; Reading Graphs
15 How Genes Work		The One-Gene One-Enzyme Hypothesis; The Triplet Nature of the Genetic Code		
16 Transcription, RNA Processing, and Translation	Protein Synthesis	RNA Synthesis; Synthesizing Proteins	A Stick-and-Ribbon Rendering of a tRNA	
17 Control of Gene Expression in Bacteria		The *lac* Operon	Cartoon Model of the *lac* Repressor from *E. coli*	
18 Control of Gene Expression in Eukaryotes		Transcription Initiation in Eukaryotes	Cartoon Model of the DNA-Binding Portion of TATA-Box Binding Protein Interacting with DNA; Cartoon Model of the GAL4 Transcription Factor from the Yeast *S. cerevisiae*	Biological Imaging: Microscopy and X-Ray Crystallography; Separating and Visualizing Molecules
19 Analyzing and Engineering Genes		Producing Human Growth Hormone; The Polymerase Chain Reaction	Cartoon Model of the BamH1a Endonuclease	Separating and Visualizing Molecules
20 Genomics		Human Genome Sequencing Strategies		Model Organisms; Using Logarithms
Unit 4 Developmental Biology				
21 Principles of Development		Early Pattern Formation in *Drosophila*	A Cartoon and Stick Model of the Homeodomain of the Engrailed Protein from *Drosophila* Interacting with DNA	Model Organisms; Cell and Tissue Culture Methods
22 An Introduction to Animal Development		Early Stages of Animal Development		
23 An Introduction to Plant Development				Model Organisms
Unit 5 Evolutionary Processes and Patterns				
24 Evolution by Natural Selection		Natural Selection for Antibiotic Resistance		Reading a Phylogenetic Tree; Model Organisms; Reading Graphs

MASTERINGBIOLOGY MEDIA AT A GLANCE *(continued)*

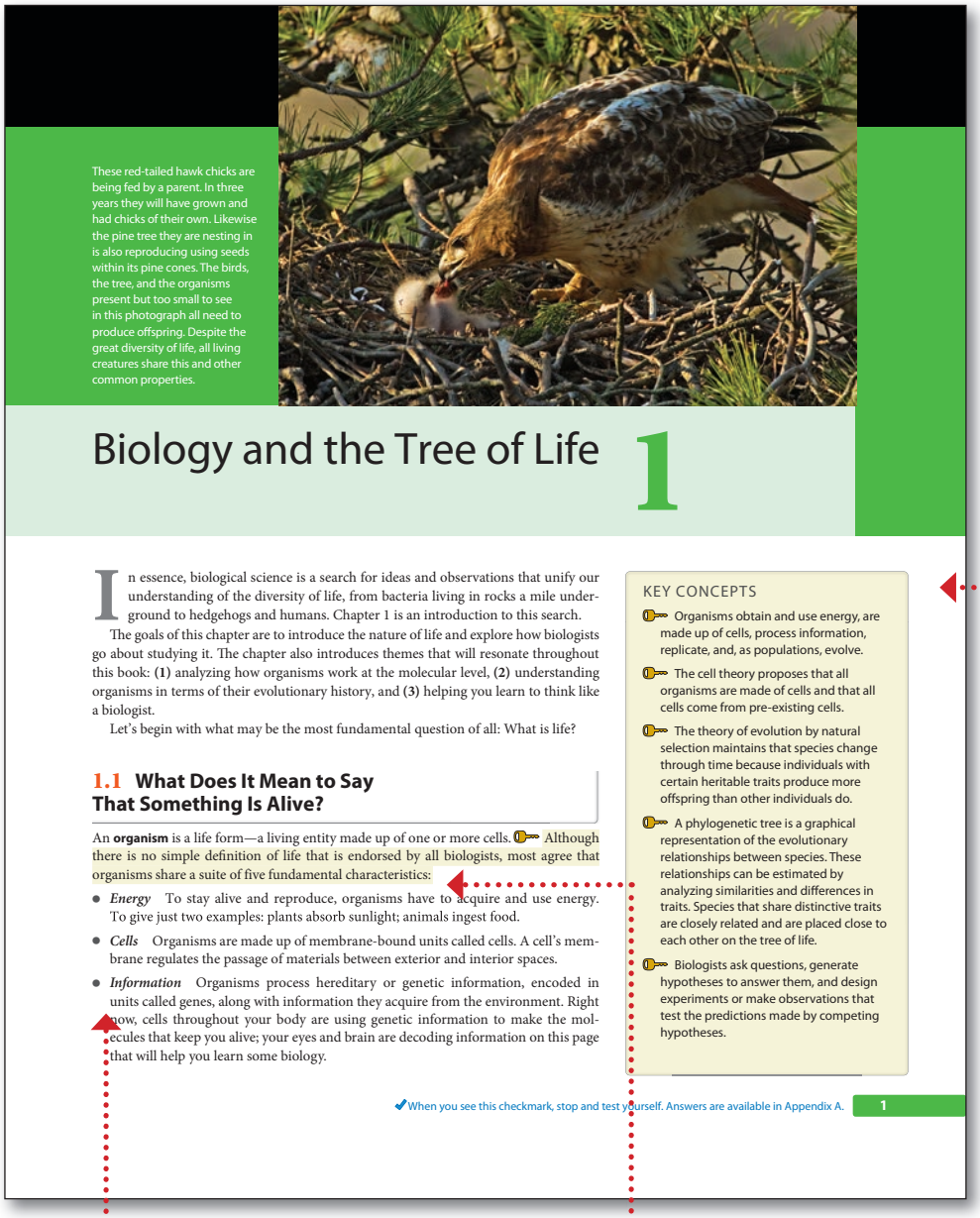
	BIOFLIX	WEB ACTIVITIES	VIDEOS	BIOSKILLS
25 Evolutionary Processes	Mechanisms of Evolution	The Hardy–Weinberg Principle; Three Modes of Natural Selection		Combining Probabilities; Using Statistical Tests and Interpreting Standard Error Bars; Reading Graphs
26 Speciation		Allopatric Speciation; Speciation by Changes in Ploidy		Reading a Phylogenetic Tree
27 Phylogenies and the History of Life		Adaptive Radiation		Reading a Phylogenetic Tree
Unit 6 The Diversification of Life				
28 Bacteria and Archaea		The Tree of Life		Reading a Phylogenetic Tree; Model Organisms
29 Protists		Alternation of Generations in a Protist	A Crawling Amoeba	Biological Imaging: Microscopy and X-Ray Crystallography; Model Organisms
30 Green Algae and Land Plants		Plant Evolution and the PhylogeneticTree		
31 Fungi		Life Cycle of a Mushroom		
32 An Introduction to Animals		The Architecture of Animals		
33 Protostome Animals		Protostome Diversity		Model Organisms
34 Deuterostome Animals		Deuterostome Diversity		
35 Viruses		The HIV Replicative Cycle		Biological Imaging: Microscopy and X-Ray Crystallography; Separating and Visualizing Molecules
Unit 7 How PlantsWork				
36 Plant Form and Function		Plant Growth		
37 Water and Sugar Transport in Plants	Water Transport in Plants	Solute Transport in Plants	Plasmolysis of Plant Cells	
38 Plant Nutrition		Soil Formation and Nutrient Uptake		
39 Plant Sensory Systems, Signals, and Responses		Sensing Light; Plant Hormones; Plant Defences		Cell and Tissue Culture Methods
40 Plant Reproduction		Reproduction in Flowering Plants; Fruit Structure and Development		
Unit 8 How Animals Work				
41 Animal Form and Function		Surface Area/Volume Relationships; Homeostasis		Using Logarithms
42 Water and Electrolyte Balance in Animals		The Mammalian Kidney		

MASTERINGBIOLOGY MEDIA AT A GLANCE *(continued)*

	BIOFLIX	WEB ACTIVITIES	VIDEOS	BIOSKILLS
43 Animal Nutrition	Homeostasis: Regulating Blood Sugar	The Digestion and Absorption of Food; Understanding Diabetes Mellitus		Biological Imaging: Microscopy and X-Ray Crystallography; Separating and Visualizing Molecules
44 Gas Exchange and Circulation	Gas Exchange	Gas Exchange in the Lungs and Tissues; The Human Heart		
45 Electrical Signals in Animals	How Neurons Work; How Synapses Work	Membrane Potentials; Action Potentials	The Acetylcholine Receptor	Using Logarithms
46 Animal Sensory Systems and Movement	Muscle Contraction	The Vertebrate Eye; Structure and Contraction of Muscle Fibres	The Acetylcholine Receptor	
47 Chemical Signals in Animals		Endocrine System Anatomy; Hormone Actions on Target Cells	Cartoon Model of the DNA Binding Motif of a Zinc Finger Transcription Factor Binding to DNA	Separating Cell Components by Centrifugation
48 Animal Reproduction		Human Gametogenesis; Human Reproduction		Using Logarithms; Reading a Phylogenetic Tree
49 The Immune System in Animals		The Inflammatory Response; The Adaptive Immune Response	Chemotaxis of a Neutrophil	
Unit 9 Ecology				
50 An Introduction to Ecology		Tropical Atmospheric Circulation		
51 Behavioural Ecology		Homing Behaviour in Digger Wasps		
52 Population Ecology	Population Ecology	Modelling Population Growth; Human Population Growth and Regulation		
53 Community Ecology		Life Cycle of a Malaria Parasite; Succession		
54 Ecosystems	The Carbon Cycle	The Global Carbon Cycle		
55 Biodiversity and Conservation Biology		Habitat Fragmentation		Using Logarithms

Preface to Students: How to Use This Book

Focus on the Gold Thread



These red-tailed hawk chicks are being fed by a parent. In three years they will have grown and had chicks of their own. Likewise the pine tree they are nesting in is also reproducing using seeds within its pine cones. The birds, the tree, and the organisms present but too small to see in this photograph all need to produce offspring. Despite the great diversity of life, all living creatures share this and other common properties.

Biology and the Tree of Life 1

In essence, biological science is a search for ideas and observations that unify our understanding of the diversity of life, from bacteria living in rocks a mile underground to hedgehogs and humans. Chapter 1 is an introduction to this search.

The goals of this chapter are to introduce the nature of life and explore how biologists go about studying it. The chapter also introduces themes that will resonate throughout this book: **(1)** analyzing how organisms work at the molecular level, **(2)** understanding organisms in terms of their evolutionary history, and **(3)** helping you learn to think like a biologist.

Let's begin with what may be the most fundamental question of all: What is life?

1.1 What Does It Mean to Say That Something Is Alive?

An **organism** is a life form—a living entity made up of one or more cells. Although there is no simple definition of life that is endorsed by all biologists, most agree that organisms share a suite of five fundamental characteristics:

- ***Energy*** To stay alive and reproduce, organisms have to acquire and use energy. To give just two examples: plants absorb sunlight; animals ingest food.
- ***Cells*** Organisms are made up of membrane-bound units called cells. A cell's membrane regulates the passage of materials between exterior and interior spaces.
- ***Information*** Organisms process hereditary or genetic information, encoded in units called genes, along with information they acquire from the environment. Right now, cells throughout your body are using genetic information to make the molecules that keep you alive; your eyes and brain are decoding information on this page that will help you learn some biology.

KEY CONCEPTS

- Organisms obtain and use energy, are made up of cells, process information, replicate, and, as populations, evolve.
- The cell theory proposes that all organisms are made of cells and that all cells come from pre-existing cells.
- The theory of evolution by natural selection maintains that species change through time because individuals with certain heritable traits produce more offspring than other individuals do.
- A phylogenetic tree is a graphical representation of the evolutionary relationships between species. These relationships can be estimated by analyzing similarities and differences in traits. Species that share distinctive traits are closely related and are placed close to each other on the tree of life.
- Biologists ask questions, generate hypotheses to answer them, and design experiments or make observations that test the predictions made by competing hypotheses.

When you see this checkmark, stop and test yourself. Answers are available in Appendix A.

1

Key Concepts

Start with Key Concepts on the first page of every chapter. Read these gold key points first to familiarize yourself with the chapter's big ideas.

MORE! Bulleted Lists

Take note of bulleted lists that "chunk" information and ideas. This will help you manage the information that you are learning in the course.

Gold Highlighting

Watch for important information highlighted in gold. Gold highlighting is always a signal to slow down and pay special attention.

Gold Key

Material related to Key Concepts will be signalled with a gold key.

SUMMARY TABLE 3.1 **Protein Structure**

Level	Description	Stabilized by	Example: Hemoglobin
Primary	The sequence of amino acids in a polypeptide	Peptide bonds	Gly Ser Asp Cys
Secondary	Formation of α-helices and β-pleated sheets in a polypeptide	Hydrogen bonding between groups along the peptide-bonded backbone; thus, depends on primary structure	One α-helix
Tertiary	Overall three-dimensional shape of a polypeptide (includes contribution from secondary structures)	Bonds and other interactions between R-groups, or between R-groups and the peptide-bonded backbone; thus, depends on primary structure	One of hemoglobin's subunits
Quaternary	Shape produced by combinations of polypeptides (thus, combinations of tertiary structures)	Bonds and other interactions between R-groups, and between peptide backbones of different polypeptides; thus, depends on primary structure	Hemoglobin, which consists of four polypeptide subunits

Summary Tables

Summary Tables pull information together in a compact format that is easy to review and synthesize.

CHECK YOUR UNDERSTANDING

If you understand that . . .

- Natural selection occurs when heritable variation in certain traits leads to improved success in reproduction.
- Evolution is a change in the characteristics of a population over time.

You should be able to . . .

On the graph you just analyzed, describe the average kernel protein content over time in a maize population where *no* selection occurred.

Answers are available in Appendix A.

Check Your Understanding

The gold half of the Check Your Understanding boxes summarizes important information from the section you just read. Stop and ask yourself: Do I *really* understand every bullet point?

CHAPTER 1 REVIEW

Media is in the Study Area at www.masteringbiology.com MB

Summary of Key Concepts

Organisms obtain and use energy, are made up of cells, process information, replicate, and, as populations, evolve.

- There is no single, well-accepted definition of life. Instead, biologists point to five characteristics that organisms share.

✔ You should be able to explain why the cells in a dead organism are different from the cells in a live organism.

The cell theory proposes that all organisms are made of cells and that all cells come from pre-existing cells.

- The cell theory identified the fundamental structural unit common to all life.

✔ You should be able to describe the evidence that supported the pattern and process components of the cell theory.

The theory of evolution by natural selection maintains that species change through time because individuals with certain heritable traits produce more offspring than other individuals do.

- The theory of evolution states that all organisms are related by common ancestry.
- Natural selection is a well-tested explanation for why species change through time and why they are so well adapted to their habitats.

✔ You should be able to explain why the average protein content of seeds in a natural population of a grass species would increase over time if seeds with higher protein content survive better and grow into individuals that produce many seeds with high protein content when they mature.

MB **Web Activity** Artificial Selection

A phylogenetic tree is a graphical representation of the evolutionary relationships between species. These relationships can be estimated by analyzing similarities and differences in traits. Species that share distinctive traits are closely related and are placed close to each other on the tree of life.

- The cell theory and the theory of evolution predict that all organisms are part of a genealogy of species and that all species trace their ancestry back to a single common ancestor.
- To reconstruct this phylogeny, biologists have analyzed the sequence of components in rRNA and other molecules found in all cells.
- A tree of life, based on similarities and differences in these molecules, has three major lineages: the Bacteria, Archaea, and Eukarya.

✔ You should be able to explain how biologists can determine whether newly discovered species are members of Bacteria, Archaea, or Eukarya by analyzing their rRNA or other molecules.

Biologists ask questions, generate hypotheses to answer them, and design experiments or make observations that test the predictions made by competing hypotheses.

- Biology is the scientific study of living organisms.

✔ You should be able to explain (1) the relationship between a hypothesis and a prediction and (2) why experiments are convincing ways to test predictions.

MB **Web Activity** Introduction to Experimental Design

Summary of Key Concepts

The succinct Summary of Key Concepts reviews important concepts in short, manageable bullet points.

Practise with the Blue Thread.

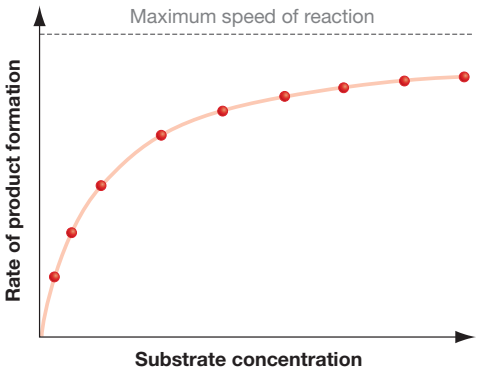
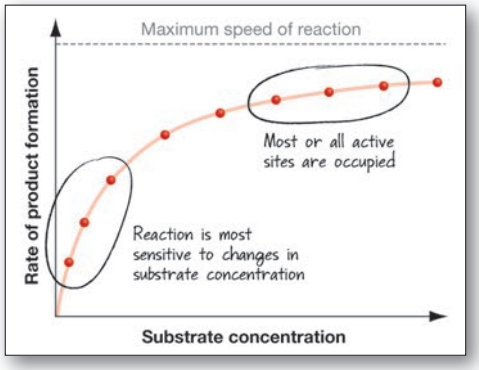


FIGURE 3.23 Kinetics of an Enzyme-Catalyzed Reaction. The general shape of this curve is characteristic of enzyme-catalyzed reactions.

✔**EXERCISE** Label the parts of the graph that represent where **(1)** the reaction rate is most sensitive to changes in substrate concentration and **(2)** most or all of the active sites present are occupied.

Caption Questions and Exercises

These challenge you to critically examine the information in a figure or table—not just absorb it.



Drawing Exercises

Some caption questions and exercises contain artwork from the textbook that you will be asked to draw on or modify.

NEW! Suggested Answers

Suggested answers for the Blue Thread Questions and Exercises are provided in Appendix A.

"You Should Be Able To" Exercises

Text passages flagged with blue type and the words "You should be able to" offer exercises on concepts that professors and students have identified as most difficult. These are the topics most students struggle with on exams.

Evolution occurs when heritable variation leads to differential success in reproduction. ✔**If you understand this concept, you should be able to modify Figure 1.3 to show what happened when the same researchers selected individuals with the lowest kernel protein content to be the parents of the next generation.**

CHECK YOUR UNDERSTANDING

If you understand that . . .

- Natural selection occurs when heritable variation in certain traits leads to improved success in reproduction.
- Evolution is a change in the characteristics of a population over time.

✔ **You should be able to . . .**

On the graph you just analyzed, describe the average kernel protein content over time in a maize population where *no* selection occurred.

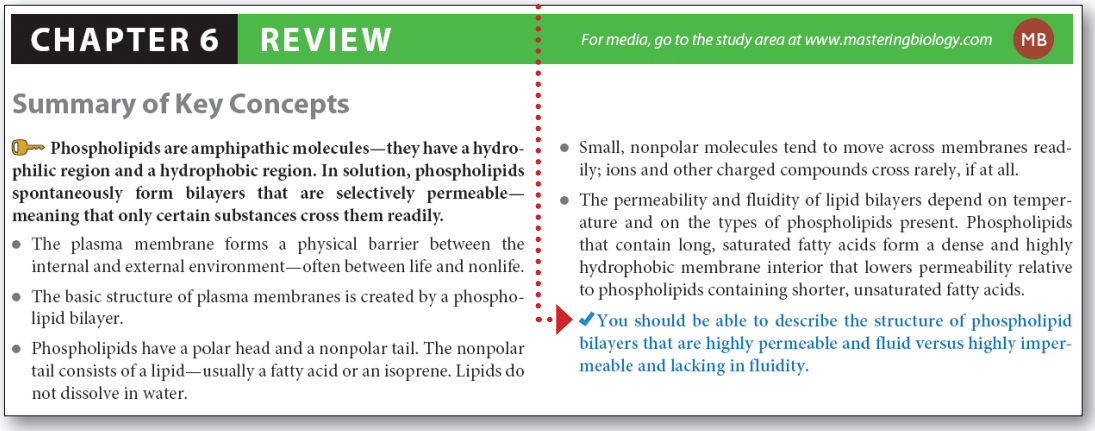
Answers are available in Appendix A.

Check Your Understanding

The blue half of the Check Your Understanding boxes asks you to do something with the information in the top half. If you can't complete these exercises, go back and reread that section of the chapter.

Chapter Summaries

End-of-chapter "You should be able to" problems or exercises help you review the key concepts declared in the gold thread.



CHAPTER 6 REVIEW

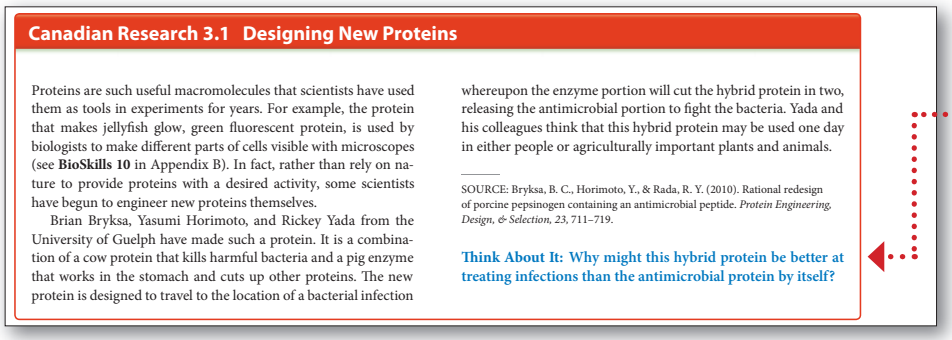
For media, go to the study area at www.masteringbiology.com MB

Summary of Key Concepts

Phospholipids are amphipathic molecules—they have a hydrophilic region and a hydrophobic region. In solution, phospholipids spontaneously form bilayers that are selectively permeable—meaning that only certain substances cross them readily.

- The plasma membrane forms a physical barrier between the internal and external environment—often between life and nonlife.
- The basic structure of plasma membranes is created by a phospholipid bilayer.
- Phospholipids have a polar head and a nonpolar tail. The nonpolar tail consists of a lipid—usually a fatty acid or an isoprene. Lipids do not dissolve in water.
- Small, nonpolar molecules tend to move across membranes readily; ions and other charged compounds cross rarely, if at all.
- The permeability and fluidity of lipid bilayers depend on temperature and on the types of phospholipids present. Phospholipids that contain long, saturated fatty acids form a dense and highly hydrophobic membrane interior that lowers permeability relative to phospholipids containing shorter, unsaturated fatty acids.

✔You should be able to describe the structure of phospholipid bilayers that are highly permeable and fluid versus highly impermeable and lacking in fluidity.



Canadian Research 3.1 Designing New Proteins

Proteins are such useful macromolecules that scientists have used them as tools in experiments for years. For example, the protein that makes jellyfish glow, green fluorescent protein, is used by biologists to make different parts of cells visible with microscopes (see **BioSkills 10** in Appendix B). In fact, rather than rely on nature to provide proteins with a desired activity, some scientists have begun to engineer new proteins themselves.

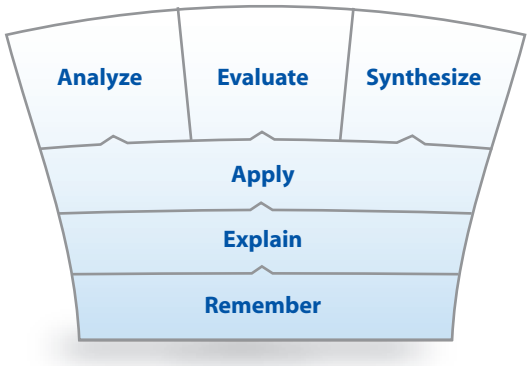
Brian Bryksa, Yasumi Horimoto, and Rickey Yada from the University of Guelph have made such a protein. It is a combination of a cow protein that kills harmful bacteria and a pig enzyme that works in the stomach and cuts up other proteins. The new protein is designed to travel to the location of a bacterial infection whereupon the enzyme portion will cut the hybrid protein in two, releasing the antimicrobial portion to fight the bacteria. Yada and his colleagues think that this hybrid protein may be used one day in either people or agriculturally important plants and animals.

SOURCE: Bryksa, B. C., Horimoto, Y., & Rada, R. Y. (2010). Rational redesign of porcine pepsinogen containing an antimicrobial peptide. *Protein Engineering, Design, & Selection, 23*, 711–719.

Think About It: Why might this hybrid protein be better at treating infections than the antimicrobial protein by itself?

Think About It Questions

Canadian Research and Canadian Issues boxes each end with a question that will test or expand on your understanding of an important concept.



Bloom's Taxonomy

Bloom's Taxonomy categorizes six levels of learning competency. The Blue Thread Questions and Exercises in the textbook test on the higher levels of the scale—Explain, Apply, Analyze, Evaluate, and Synthesize—to help you develop critical thinking skills and prepare you for exams.

Steps to Understanding

End-of-chapter questions are scaled along Bloom's Taxonomy.

✔TEST YOUR KNOWLEDGE

Begin by testing your knowledge of new facts.

✔TEST YOUR UNDERSTANDING

Once you're confident in your knowledge of the material, demonstrate your understanding by answering the Test Your Understanding questions.

✔APPLYING CONCEPTS TO NEW SITUATIONS

Challenge yourself even further by applying your understanding of the concepts to new situations.

Keep sight of the big picture.

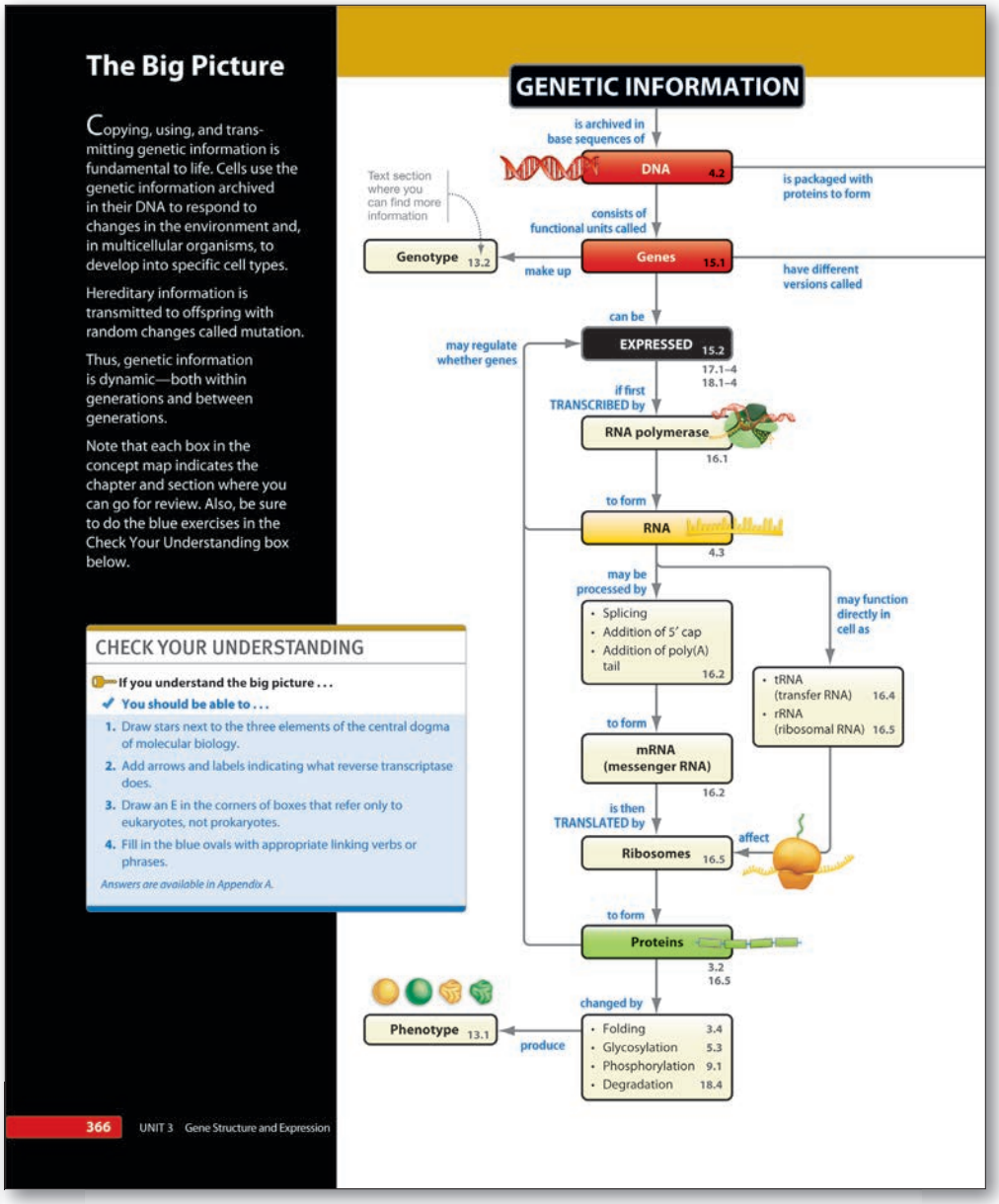
Concept maps help you to keep sight of "big picture" relationships among biological concepts.

NEW! Big Picture Concept Maps

Seven remarkable Big Picture concept maps help you synthesize information across the chapters on energy, genetics, evolution, and ecology.

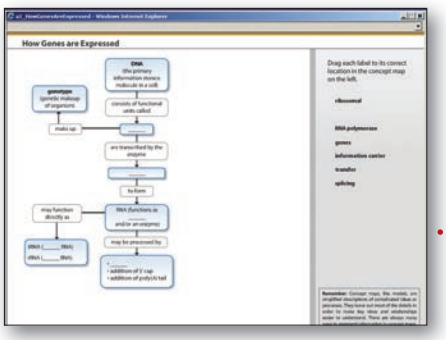
Check Your Understanding

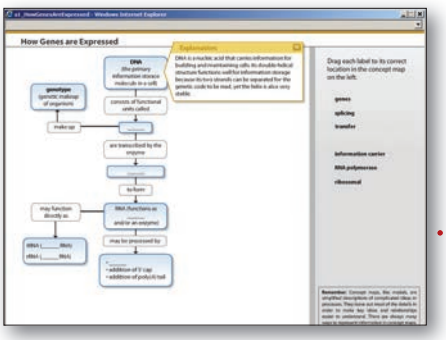
Check your understanding of these big picture relationships by answering the Blue Thread Questions.

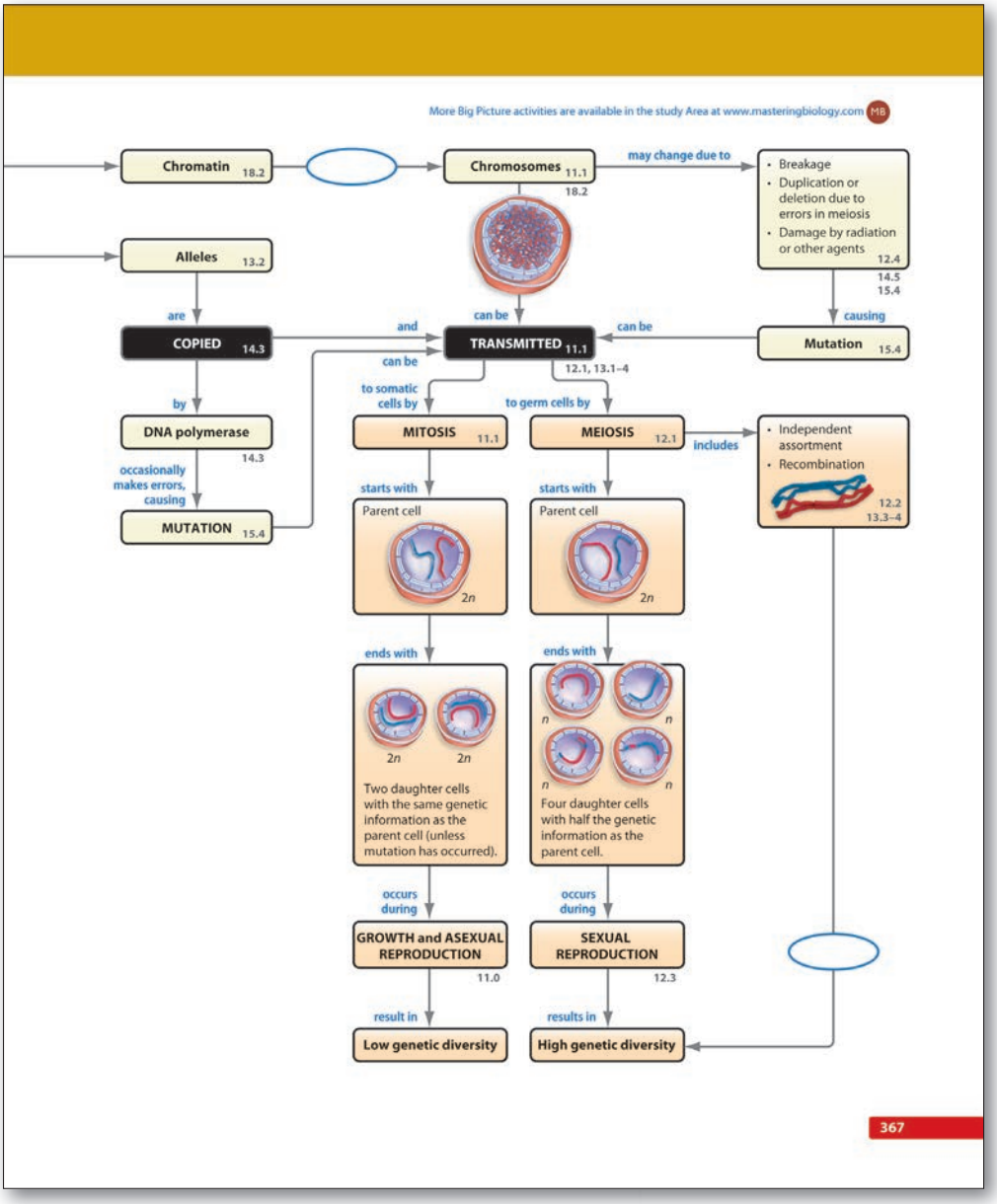


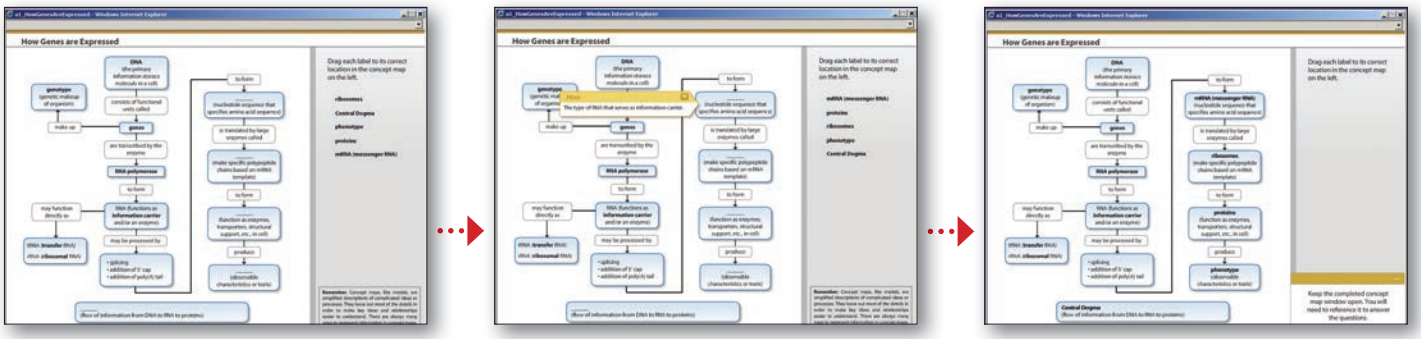
MasteringBiology®

Your professor may assign interactive Big Picture concept map exercises at www.masteringbiology.com.






More Big Picture activities are available in the study Area at www.masteringbiology.com
MB
Chromatin 18.2
Chromosomes 11.1
18.2
may change due to
Breakage
Duplication or deletion due to errors in meiosis
Damage by radiation or other agents
12.4
14.5
15.4
Alleles 13.2
are
can be
causing
COPIED 14.3
and
TRANSMITTED 11.1
can be
Mutation 15.4
12.1, 13.1–4
can be
to somatic cells by
to germ cells by
by
DNA polymerase
14.3
MITOSIS 11.1
MEIOSIS 12.1
includes
Independent assortment
Recombination
12.2
13.3–4
occasionally makes errors, causing
MUTATION 15.4
starts with
starts with
Parent cell
2n
Parent cell
2n
ends with
ends with
2n
2n
Two daughter cells with the same genetic information as the parent cell (unless mutation has occurred).
n
n
n
n
Four daughter cells with half the genetic information as the parent cell.
occurs during
occurs during
GROWTH and ASEXUAL REPRODUCTION
11.0
SEXUAL REPRODUCTION
12.3
result in
results in
Low genetic diversity
High genetic diversity
367


How Genes are Expressed
How Genes are Expressed
How Genes are Expressed

Learn to think like a scientist. Here's how.

A unique emphasis on the process of scientific discovery and experimental design teaches you how to think like a scientist as you learn fundamental biology concepts.

Experiment Boxes

Study Experiment Boxes to help you understand how experiments are designed and give you practice interpreting data.

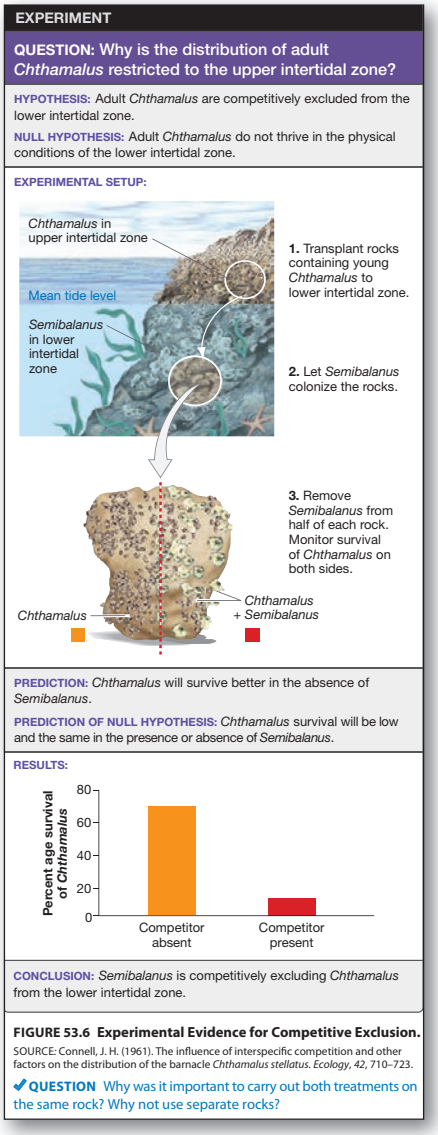


FIGURE 53.6 Experimental Evidence for Competitive Exclusion.

SOURCE: Connell, J. H. (1961). The influence of interspecific competition and other factors on the distribution of the barnacle *Chthamalus stellatus*. *Ecology, 42*, 710–723.

✔ **QUESTION** Why was it important to carry out both treatments on the same rock? Why not use separate rocks?

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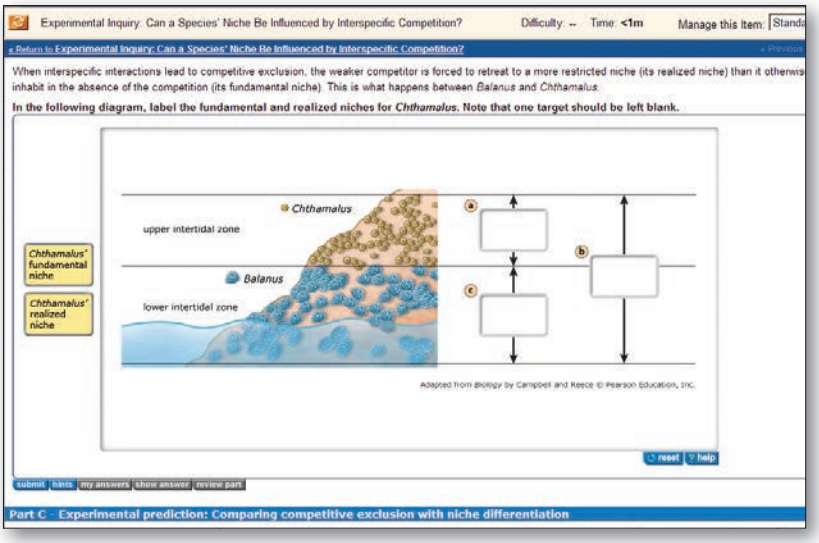
www.masteringbiology.com

NEW! Experimental Inquiry Tutorials

Experimental Inquiry Tutorials based on some of biology's most seminal experiments can be found on **www.masteringbiology.com**. Your instructor may assign these. They will give you practice analyzing the experimental design and data, and help you understand reasoning that led scientists from the data they collected to their conclusions.

Some of the topics include:

- The Process of Science
- Engelmann's Photosynthesis and Wavelengths of Light
- Morgan's Cross with White-Eyed Males
- Meselson-Stahl's Semiconservative Replication
- Steinhardt et al and Hafner et al's Polyspermy
- Grant's Changes in Finch Beak Size
- Went's Phototropism and Auxin Distribution
- Coleman's Obesity Gene
- Connell's Competition in Barnacles
- Bormann, Likens et al's Nutrient Cycling in Hubbard Brook Forest

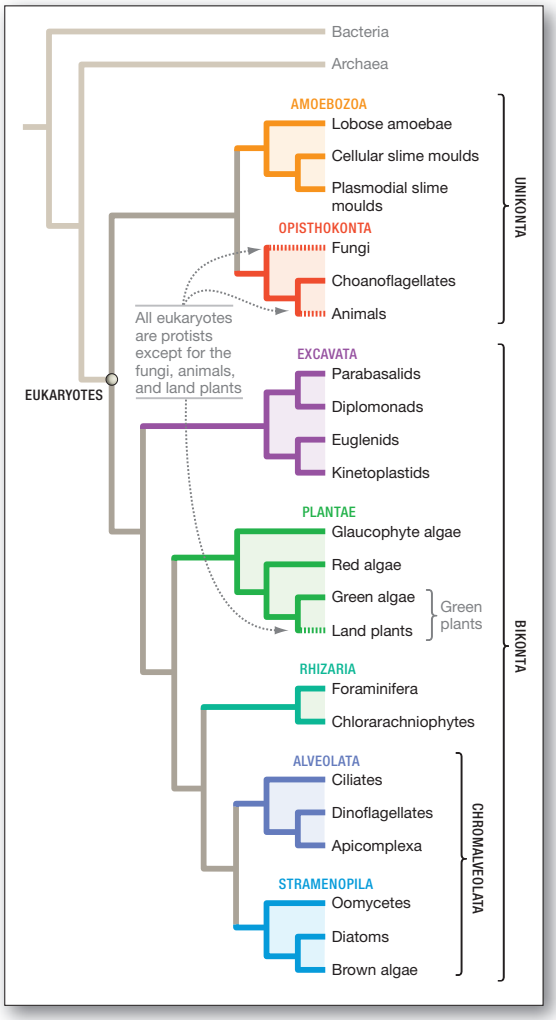


NEW! Source Citations

Each Experiment Box now cites the original research paper, encouraging you to extend your learning by exploring the primary literature.

NEW! Experiment Box Questions

Each Experiment Box now includes a question that asks students to analyze the design of the experiment.



NEW! Redesigned Phylogenetic Trees

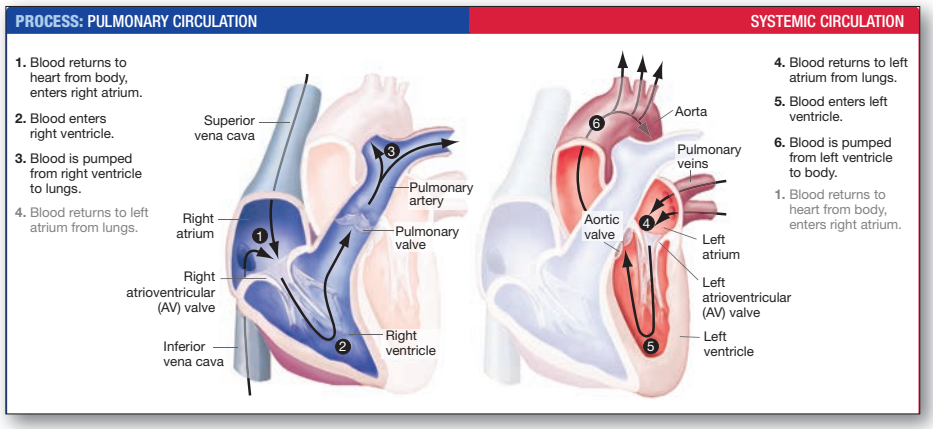
Practice "tree thinking" using these newly redesigned phylogenetic trees. Their U-shaped, top-to-bottom format is consistent with the way such trees are most commonly depicted in the scientific literature.

Expanded BioSkills Appendix

BIOSKILLS

Build skills that will be important to your success in future courses. At relevant points in the text, you'll find references to the expanded BioSkills Appendix that will help you learn and practice the following foundational skills:

- NEW! The Metric System
- Reading Graphs
- Reading a Phylogenetic Tree
- NEW! Some Common Latin and Greek Roots Used in Biology
- Using Statistical Tests and Interpreting Standard Error Bars
- Reading Chemical Structures
- Using Logarithms
- Making Concept Maps
- Separating and Visualizing Molecules
- Biological Imaging: Microscopy and X-Ray Crystallography
- NEW! Separating Cell Components by Centrifugation
- NEW! Cell Culture Methods
- Combining Probabilities
- NEW! Model Organisms



Informative Figures

Think through complex biological processes with figures that clearly define concepts.