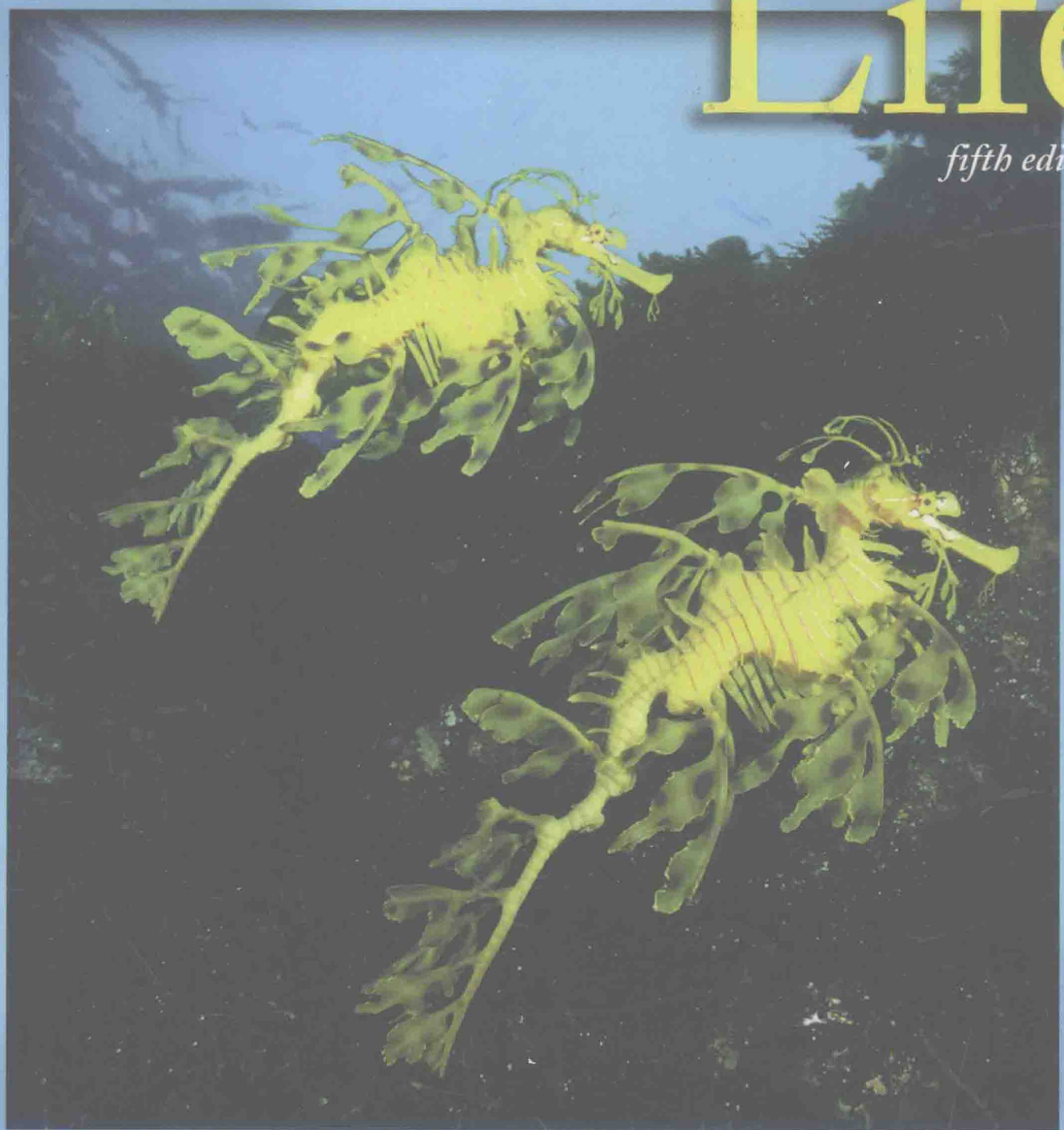
Life

fifth edition



Lewis • Gaffin • Hoefnagels • Parker

Life

Ricki Lewis
Contributing Editor, The Scientist

Douglas Gaffin
The University of Oklahoma

Mariëlle Hoefnagels
The University of Oklahoma

Bruce Parker
Utah Valley State College

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About the Authors

Ricki Lewis

Ricki Lewis has built a multifaceted career around communicating the excitement of life science, especially genetics and biotechnology. She earned her Ph.D. in genetics in 1980 from Indiana University, working with homeotic mutations in *Drosophila melanogaster.*

Ricki is author of *Human Genetics: Concepts and Applications;* co-author of two human anatomy and physiology textbooks; and author of *Discovery: Windows on the Life Sciences,* an essay collection about research and the nature of scientific investigation. As a Contributing Editor to *The Scientist,* a magazine read by scientists worldwide, she writes frequently on the latest research and news in biotechnology. Since 1980, Ricki has published more than 3,000 articles in a variety of magazines, and taught several courses at several colleges. Ricki has provided genetic counseling for a large private medical practice, in Schenectady, NY, since 1984, where she helps people make decisions about reproductive choices. She is a member of the National Association of Biology Teachers, The American Society of Human Genetics, and the National Association of Science Writers.

Ricki lives in upstate New York with chemist husband Larry, three daughters, and various cats and guinea pigs. rickilewis@nasw.org

Douglas Gaffin

Douglas Gaffin holds a bachelor of science degree from the University of California at Berkeley, and he earned his Ph.D. in zoology from Oregon State University in Corvallis in 1994. His research interests are in sensory neurobiology, where his special focus is on the behavior and sensory physiology of sand scorpions. He has extensive biology teaching experience and has taught students in courses ranging from junior high school to graduate school levels. Doug is currently Dean of University College and associate professor in the Department of Zoology at the University of Oklahoma, and he has the privilege of teaching introductory zoology to thousands of undergraduates each year. His innovative teaching style and ability to inspire students have been recognized with awards both regionally and nationally. Among other organizations, he is a member of the Society for Neuroscience, the International Society for Neuroethology, the American Arachnological Society, and the National Association of Biology Teachers. In his spare time he enjoys traveling, riding his bike, playing volleyball, and picking the banjo. One of his favorite activities is going to the desert each summer to observe and conduct field research on sand scorpions in their native habitat. ddgaffin@ou.edu

Mariëlle Hoefnagels

Mariëlle Hoefnagels was raised near San Francisco, and received her B.S. in environmental science (1987) from the University of California at Riverside. After working in a soil analysis lab in Oregon for two years, she earned her master's degree in soil science from North Carolina State University (1991). Her research, on interactions between beneficial fungi and salt marsh plants, led her to return to Oregon to complete her Ph.D. in plant pathology (Oregon State University, 1997). Mariëlle's dissertation work focused on the use of bacterial biological control agents to reduce the spread of fungal pathogens on seeds. She is now assistant professor at the University of Oklahoma, where she teaches nonmajors courses in biology and microbiology, and a course on fungi for advanced botany and microbiology majors. Her current research is on the interactions between plants and beneficial microorganisms in prairie soils, and she particularly enjoys involving undergraduates in her research during the summer. She is a member of the National Association of Biology Teachers, the Association of Biology Laboratory Education, and the American Phytopathological Society. Her hobbies include reading, traveling, gardening, and playing volleyball. hoefnagels@ou.edu

Bruce Parker

Bruce Parker received his Ph.D. in molecular biology/biochemistry from Utah State University in 1988. His areas of expertise include virology, molecular cell biology, and biochemistry. He spent two years in London working on research into viruses that cause cancer, followed by another two years on the same project at St. Jude Children's Research Hospital in Memphis. He has taught general biology for nonmajors and majors at Utah Valley State College since 1992 and has been nominated for Faculty of the Year for six of those years. Bruce currently serves as department chairperson at Utah Valley State College and is included in *Who's Who Among America's Teachers* for 1998. His hobbies include computer programming and amateur radio, when he is not fishing somewhere. parkerbr@uvsc.edu

Preface

The goal of *Life* has always been to engage the nonscientist or possible-scientist in understanding how life works. We try to do that in a way that is fun, meaningful, and valuable in making informed decisions on an ever-growing array of issues, from teaching evolution to human cloning. This new edition continues our presentation of **cutting-edge life science** and the technology that it spawns, with timely additions, such as coverage of stem cell biology and bacterial biofilms. At reviewer request, the new edition expands discussions of natural selection, classification of the basal eukaryotes, plant hybridization and grafting, and arthropods. **The genetics chapters have new, additional problem sets.**

Because review panels assured us that we were on track with the level and content of topics, for this fifth edition we focused on **improving accessibility.** Changes are simple yet striking. A **totally new design** is friendlier and less cluttered. **Figure and table references** appear in bold type so that students can easily find related discussion. **Scale bars** have been added to micrographs so that students can appreciate the relative size of structures and organisms. **New in-text cross-references** aid recall and catalyze the conceptual connections that underlie biology.

The popular features that make learning from *Life* an enjoyable experience have been retained. These include short summaries beneath major headings; Mastering Concepts questions at the end of each section; chapter-by-chapter lists of balanced, up-to-date, student friendly resources for further reference; and the clear and interesting narrative style.

Features of the Fifth Edition

The Writers—Teaching with Style

The fifth edition of *Life* reunites four biologists whose areas of expertise complement beautifully. Geneticist and science journalist Ricki Lewis originated the text, using a unique style that weaves solid biology content with intriguing tales of scientific discovery and real-life cases and applications. Veterans from the fourth edition of *Life* are Douglas Gaffin and Mariëlle Hoefnagels of the University of Oklahoma and Bruce Parker of Utah Valley State College. Ricki has taught a variety of courses and has provided genetic counseling to a private medical practice since 1984. Doug, Mariëlle, and Bruce are active instructors who use multimedia approaches to teach undergraduate biology to hundreds of majors and nonmajors each semester, and all have earned recognition on their campuses as outstanding teachers.

Devotion to, and passion about, teaching and communicating unite our team. We thoroughly enjoy telling those interesting stories that are so easy to find at all levels of biology, from molecules to ecology—the stories that, when told correctly, mesmerize even the most reluctant students, causing them to perk up and think, "Wow, I never knew that! So that's why . . . !" We all love to watch students get excited about learning a subject they once viewed as too hard or too intimidating. Our areas of research expertise complement beautifully, including animal physiology and behavior, plant-microorganism interactions, genetics, developmental biology, molecular biology, and biochemistry.

Together, the *Life* authors cover the breadth of general biology and make it easy for you to present the latest information to your students, using the most accessible multimedia tools available. The unique mix of scientific expertise and journalistic experience results in a textbook that is not only substantial, but also accessible.

The Content—Today's Science for Today's Students

As a contributing editor to the magazine *The Scientist,* Ricki Lewis has a heads-up on much ongoing research, which finds its way into the pages of *Life.* Here are just some of the timely updates you will find in this edition:

- Adaptive immunity
- Antisense and knockout technologies
- Bacterial biofilms
- Bioweaponry
- COX-2 inhibitors
- Genome economy
- Human genome analysis
- Organ transplants
- Regeneration
- SNPs and DNA profiling
- Soil nutrients and fertilizers
- Somatic cell nuclear transfer
- Stem cell biology
- Therapeutic cloning
- Toll-like receptors

Unit 4, The Diversity of Life, is always a work-in-progress, as new data and new ways of looking at the living world reveal new classification possibilities. *Life's* "tree of life" illustrations, developed by Douglas Gaffin and found in this unit and others, encapsulate

species relationships and evolutionary trends in an easy-to-follow form. While *Life's* classification schemes combine traditional and molecular approaches to taxonomy, we are careful to explain that new molecular data also throw the classification of life into upheaval—and acknowledge that the classification schemes in this book are provisional. It is important for students to realize that biological facts and concepts are not written in stone, that despite popular notions of scientific "proof," science is constantly changing to embrace new information. We would rather present the current state of taxonomic thought, uncertainties and all, than perpetuate dated classifications. For example, we revised and rearranged the animal diversity chapters to reflect the currently accepted split of protostomes into lophotrochozoans and ecdysozoans. The traditional scheme is included for comparison, but the book adopts the new classification scheme.

The Relevance—Highlights on Health, Biotechnology, and Scientific Inquiry

This fifth edition continues *Life's* emphasis on the practical side of biology. Each chapter begins with a compelling essay that describes a real-life scientific issue, ranging from the worldwide decline of amphibian populations, to the evolutionary impact of the varied shapes of male genitalia (in beetles), to ways to harness stem cells to repair organs. The content in each chapter supports and extends the ideas in the opening essays. Each chapter features one or more boxes that highlight the relevance of the content to health, biotechnology, or scientific inquiry.

- "Health" boxes have a human touch. Health 36.1, for example, explores the unprecedented risk that miniscule glass particles from the World Trade Center collapse on September 11, 2001 pose to the human respiratory system.
- "Biotechnology" boxes showcase how science segues into practical applications, with looks at such diverse tools as PCR, gene therapy, *in vitro* evolution, artificial photosynthesis, molecular taxonomy, and use of DNA profiling to identify victims of the 9/11 tragedy.
- "Investigating Life" boxes remove some of the mystique of science, inviting the student to see the logic behind real experiments. Investigating Life 14.1, for example, presents compelling evidence for evolution among animals inhabiting a polluted river. Students who equate evolution with origin of life scenarios or dinosaurs may be surprised to learn that the process can be observed on relatively short timescales—today. These boxes encourage students to think as scientists do. In Investigating Life 28.1, for instance, students predict the structures of mutant flowers, applying a few simple rules governing the interaction of three genes during development.

The Art Program—A Visual Voyage

Life's art is not only visually spectacular, but also pedagogically sound, providing a consistent look from cover to cover. Repeated themes provide continuity, from biochemical reactions to life cycles to feedback loops in animal physiology to evolutionary tree diagrams. Use of color, arrows, and symbols is standardized throughout the text, easing learning and remembering. For example, DNA, membranes, and other cell structures have a consistent look and color throughout. We have also selected unusual and interesting photos to show students glimpses of the natural world that they may never have seen before. The art and photos are combined in page layouts that are attractive and inviting—and above all, help students to learn.

The Media Support—Outstanding Lecture Resources Bring the Classroom to Life

As we teach biology on our campuses, we love to bring the subject to life for our students by showing them organisms that move, processes that develop over time, and state-of-the-art graphics to capture their interest and imagination. It was important to us that *Life* provide that same kind of support for every instructor using it, no matter what their level of comfort with new technology. We worked to provide media support that is not only spectacular, but also easy to use.

When writing *Life,* we considered which supplements we find most useful as instructors. At the top of our list were computer files of textbook art, presented in a format that we could really *use* in our multimedia lectures. We found that the small size and poor contrast of the bitmapped files offered with most textbooks could not be effectively utilized in a large lecture hall. We wanted more flexibility. We wanted files that we could manipulate ourselves so that we could tell our own stories in our own way. As a result, we have developed a large library of PowerPoint-compatible, vectorized art files that an instructor can manipulate to support his or her individual lecture style and pace. We call this feature **Active Art,** and it's just one component of an innovative and integrated new program of media support at your fingertips.

Using *Active Art,* you are able to bring difficult concepts to your students in an easy to understand, step-by-step manner. Approximately 200 key art pieces are broken into smaller digestible parts so you can bring each piece into your lecture in whatever order or format you choose. You can also manipulate *Active Art.* You can move, resize, or change the color of any or all objects in any piece of art. *Active Art* uses Microsoft PowerPoint's ungroupable art feature. Startup instructions are provided if you are not familiar with this feature.

Active Art is only one of the dynamic features you will find on McGraw-Hill's new **Instructor's Presentation CD-ROM** to support your use of *Life.* This outstanding lecture resource also includes PowerPoint lecture outlines, electronic files of text tables, a complete library of both labelled and unlabelled images, and photographs from the text.

In addition, instructors and students will find generous support for teaching and learning with the new enhanced **Online Learning Center** with **PowerWeb: Biology** and **Electronic Study Partner 2.0.** See the inside covers for more information about these tremendous learning aids.

A Word of Thanks

We offer special thanks to the reviewers who spent hours pouring over chapter drafts in meticulous detail, spotting errors and inconsistencies, confirming what works and gently critiquing what doesn't and pointing out sections that we could clarify.

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Supplements for the Instructor

Instructor's Presentation CD-ROM

This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and quizzes, dynamic course website content, or attractive printed support materials. The digital assets on this cross-platform CD-ROM are grouped by chapter within the following easy-to-use folders.

Art Library Full-color digital files of all illustrations in the book, plus the same art saved in unlabeled versions, can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. These images are also pre-inserted into blank PowerPoint slides for ease of use.

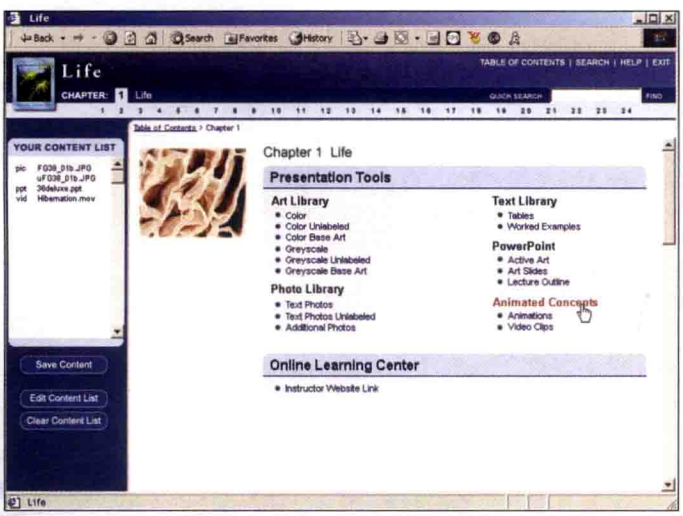
Photo Library Digital files of instructionally significant photographs from the text can be reproduced for multiple classroom uses.

PowerPoint Lecture Outlines Ready-made presentations that combine art and lecture notes are provided for each chapter of the text. These lectures can be used as they are, or can be tailored to reflect your preferred lecture topics and sequences.

Table Library Every table that appears in the text is provided in electronic form.

In addition to the content found within each chapter, the Instructor's Presentation CD-ROM for *Life* contains an extensive

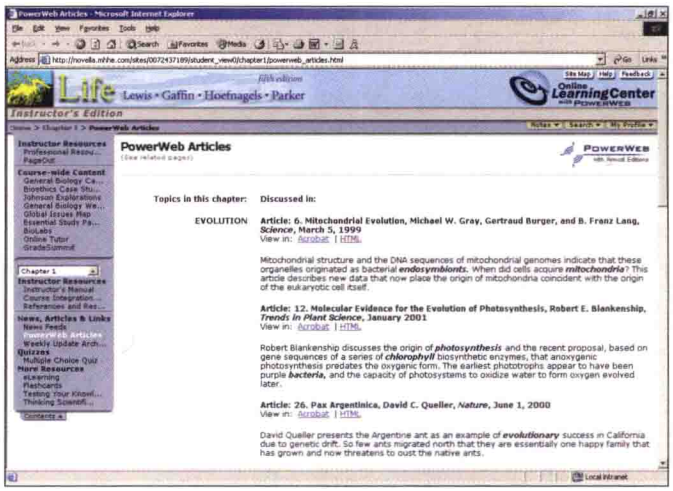
Active Art Library Active Art consists of art files from key figures from the book that have been converted to a format that allows the artwork to be edited inside of Microsoft PowerPoint. Each piece of art inside an Active Art presentation can be broken down to its core elements, grouped or ungrouped, and edited to create customized illustrations.



Online Learning Center

www.mhhe.com/life5

Through the enhanced *Life* Online Learning Center, everything you need for effective, interactive teaching and learning is at your fingertips. Moreover, this vast McGraw-Hill resource is **easily loaded into course management systems** such as WebCT or Blackboard. Contact your local McGraw-Hill representative for details.



Instructor tools located on the enhanced Online Learning Center include:

Instructor's Manual Prepared by text author Bruce Parker, this valuable resource includes chapter objectives and interesting tidbits not found in the textbook, lists areas of difficulty for students along with suggestions for resolving those difficulties effectively, and provides teaching suggestions for various content areas.

Course Integration Guide Quickly determines the lecture and media resources available for teaching a topic to efficiently produce dynamic, personalized lectures and teaching materials.

PowerWeb: Biology Offers access to course-specific current articles, real-time news, course updates, and research links. Bring your course into today's world with the resources available here to you and your students.

BioLabs Give students the opportunity to run online lab simulations to enhance or supplement the wet lab experience. BioLabs help students understand the scientific method as they improve their data-gathering and data-handling skills.

Professional Resources McGraw-Hill has compiled an array of web resources that provide additional references for topics in the text, teaching materials, and access to professional publications.

iLaBS

Interactive Laboratories and Biological Simulations

Interactive Laboratories and Biological Simulations, or **iLabs,** teach students real-life biomolecular applications and techniques using fun, web-based programs. Students can explore cutting-edge technologies like DNA profiling and restriction mapping, repeating lab procedures until they are comfortable with the techniques. Because they can generate multiple sets of data, students gain practice in data interpretation and problem solving. **iLaBS** also provide the opportunity for students to virtually experience time-consuming or complicated labs without the necessity for physical facilities.

Visit www.mhhe.com/ilabs or ask your McGraw-Hill sales representative for more information about **iLaBS.**

Instructor's Testing and Resource CD-ROM

This cross-platform CD-ROM provides a wealth of resources for the instructor. Supplements featured on this CD-ROM include a computerized test bank prepared by text author Bruce Parker, utilizing Brownstone Diploma® testing software to quickly create customized exams. This user-friendly program allows instructors to search for questions by topic, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test. Word files of the test bank are included for those instructors who prefer to work outside of the test-generator software. Other assets on the Instructor's Testing and Resource CD-ROM are grouped within easy-to-use folders.

Transparencies

All of the illustrations from the text are included in this set of 750 transparencies. Approximately 50 illustrations from which the labels have been removed are also included. ISBN 007-243729-4

Animations

The **Life Science Animations 3.0 CD-ROM** contains more than 300 animations of important biological concepts and processes. The **Life Sciences Animations 3D Videotape** contains 42 key biological processes, narrated and animated with dynamic three-dimensional graphics in full color.

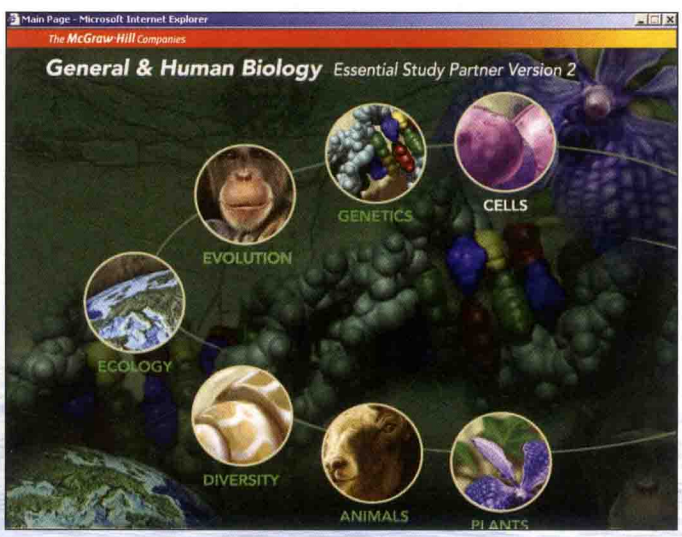
Supplements for the Student

Online Learning Center

www.mhhe.com/life5

Resources on the enhanced *Life* Online Learning Center support each chapter in the text. Some of the learning tools available through the Online Learning Center include:

E-learning sessions with animations of key processes, art quizzes, outline summaries, and more featuring McGraw-Hill's **Essential Study Partner 2.0**



Self-quizzing with immediate feedback

Electronic flashcards to review vocabulary

Biolabs with dissection techniques, equipment tutorials, setup and safety procedures, and more

PowerWeb: Biology offering access to course-specific current articles, real-time news, course updates, and research links

Online Tutoring moderated by qualified instructors and only an email away

Turn to the inside covers of this text to learn more about the exciting features provided for students through the enhanced *Life* Online Learning Center.

Student Study Guide

Prepared by Sandra Latourelle of the State University of New York at Plattsburgh, this student resource contains activities and questions to help reinforce chapter concepts. ISBN 007-243725-1

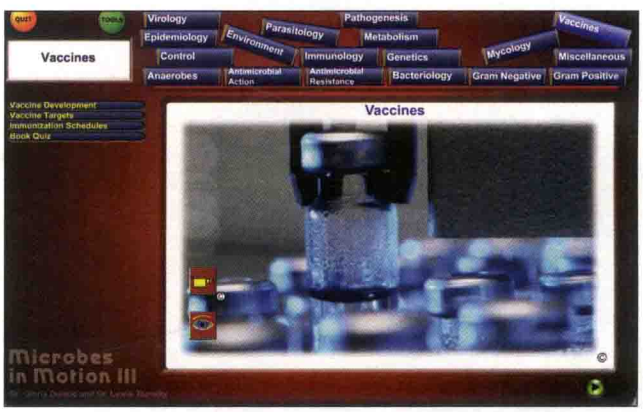
GradeSummit

This Internet exam preparation service offers thousands of unique, course-specific exam-like questions. GradeSummit provides a variety of ways for students to analyze what they know and don't know and then quickly guides them to those subject areas where spending the majority of their study time will help the most.

For more information, students and instructors should visit www.gradesummit.com.

Media Resources

Microbes in Motion CD-ROM allows students to actively explore microbial structure and function. ISBN 007-233438-X



HealthQuest CD-ROM allows users to assess their current health and wellness status, determine their health risks and relative life expectancy, explore options, and make decisions to improve the behaviors that impact their health. ISBN 007-256036-3

Life Science Living Lexicon CD-ROM carefully explains the rules of word construction and derivation and offers complete definitions of key terms. ISBN 069-737993-0

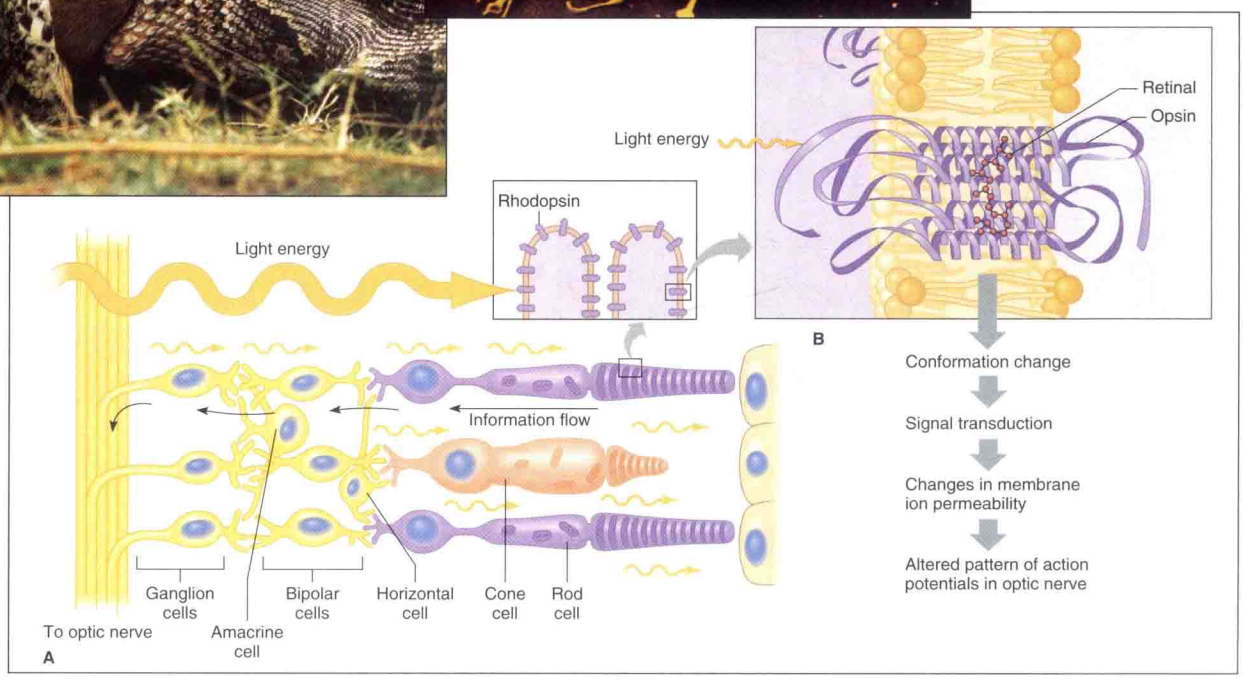
Instructive Art Program

Illustration Team

Precision Graphics of Champaign, Illinois, is a specialized composition house. Their own staff of illustrators developed the art program for the fifth edition of *Life*. Each person on the team brought her own skills and strengths to the subject matter. **Connie Balek,** the lead developer at Precision Graphics, not only has a degree in biology, but she also holds a master of fine arts degree in medical and biological illustration from the University of Michigan. **Joanne Bales** has been a medical illustrator at Precision Graphics since 1992 and utilizes her extensive health-care and nursing background in developing illustrations. And **Jan Troutt,** the natural science art director, brings many years of unparalleled experience in rendering art for many of today's leading biology titles. This team collaborated on each piece of art to build an accurate and solid program that will help students learn about life.

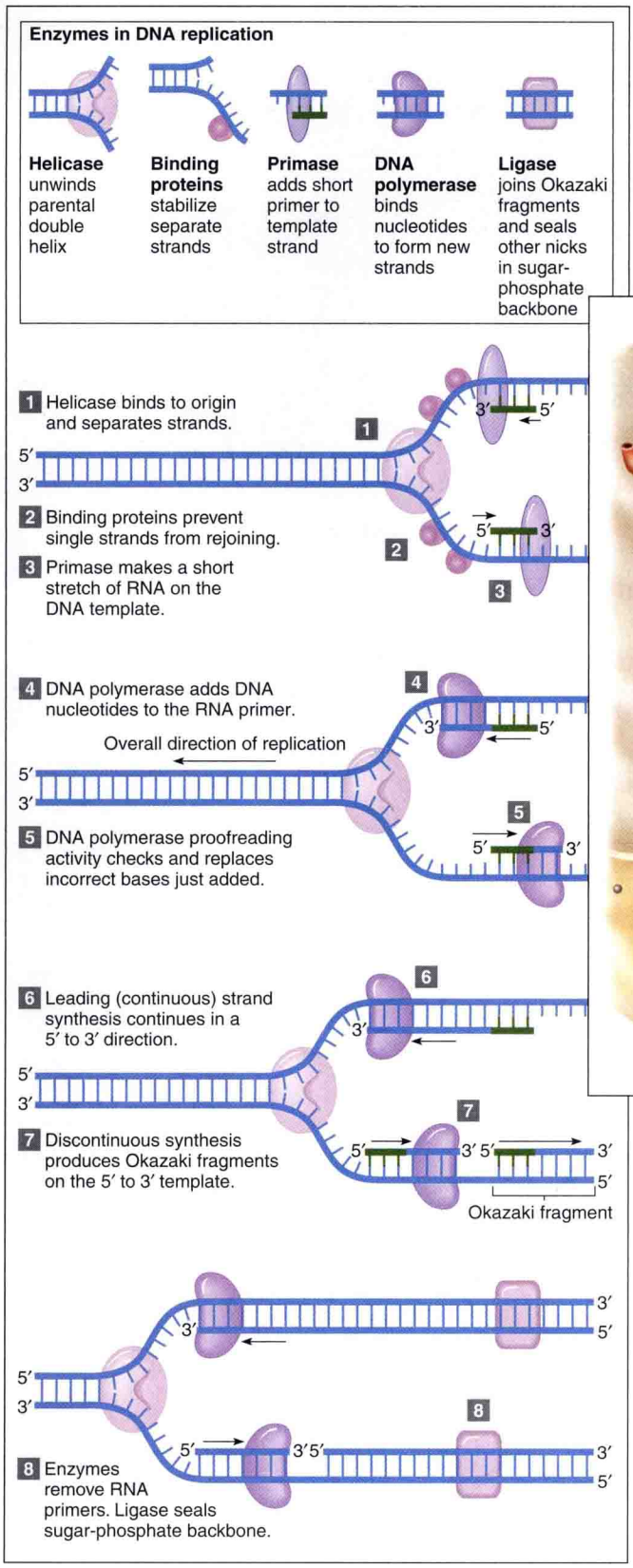
The accurate and artistically compelling illustrations greatly enhance the student's understanding of difficult processes and concepts. A combination of art styles brings concepts to life. All figure references appear in bold type for easy correlation to the text.

- **Fascinating photos and stunning micrographs**

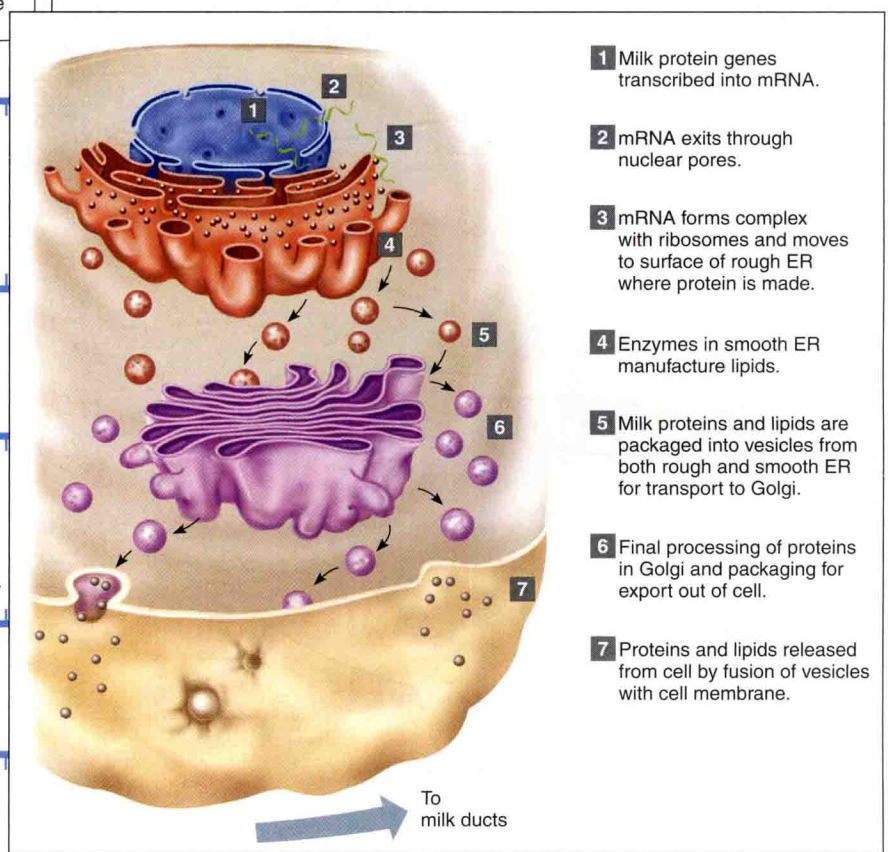


- **Overview Figures** simplify complex interactions and provide a sound study tool.

Art Program

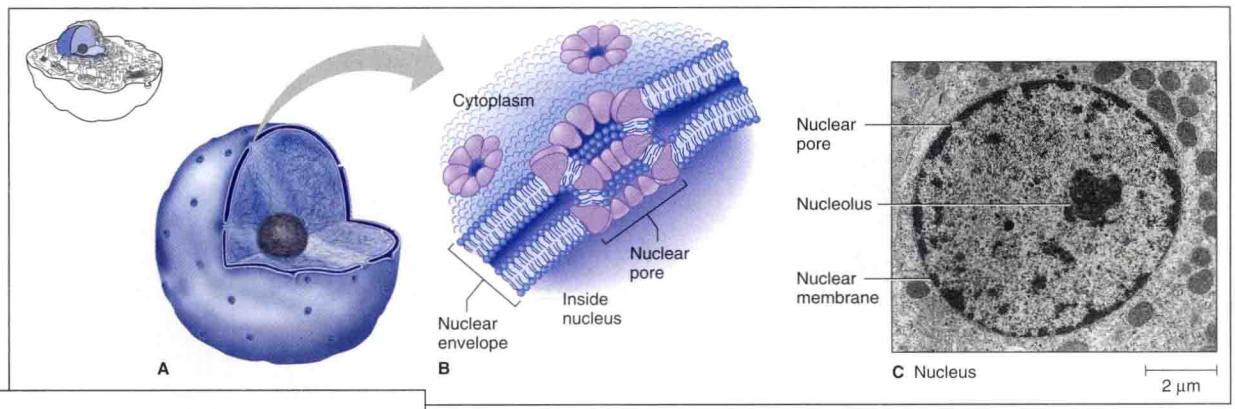


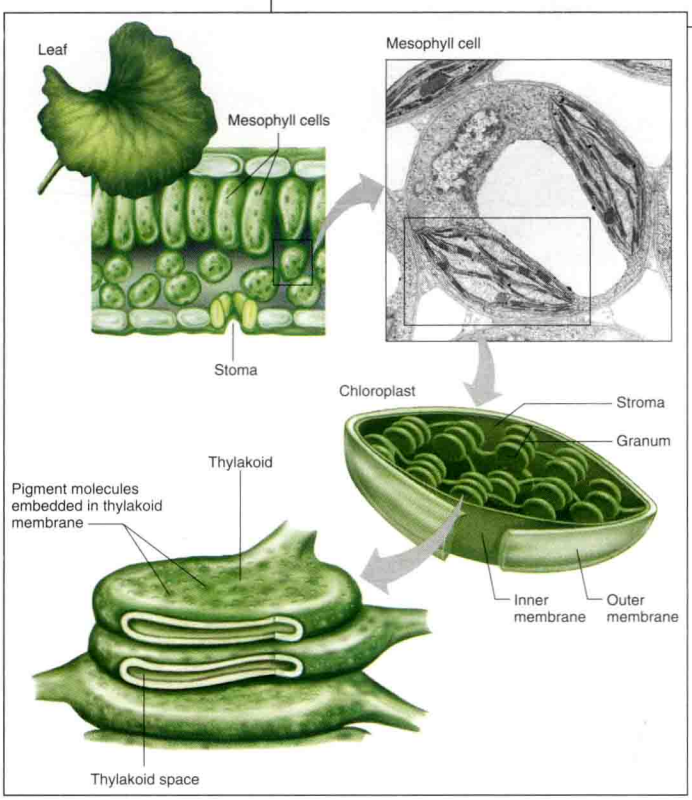
- **Process Figures** include step-by-step descriptions that walk the reader through a compact summary of important concepts.



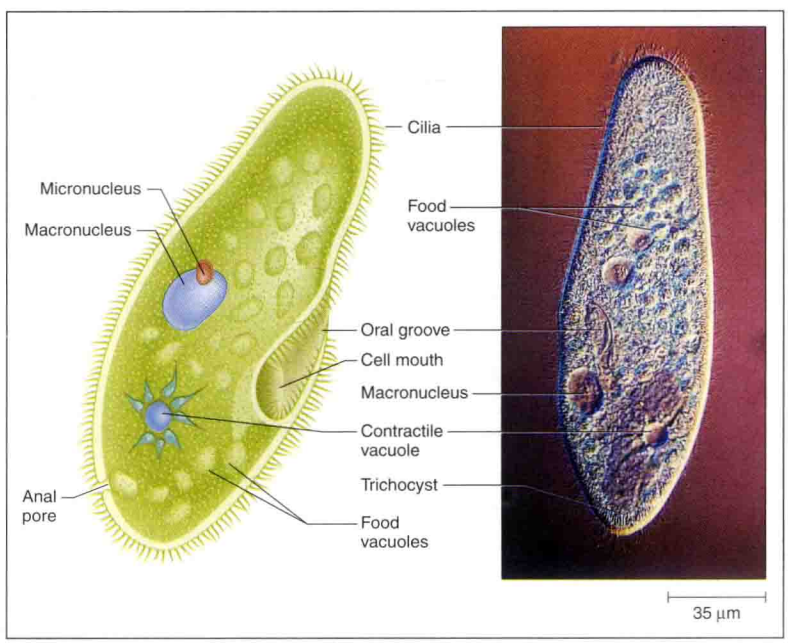
Art Program

- **Zoom Figures** put structures into context by providing a macroscopic to microscopic view of life and its processes.



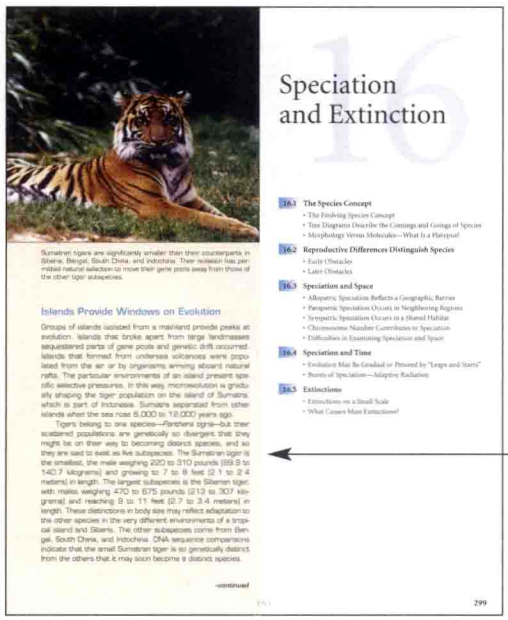


- **Combination Figures** combine the features that can be illustrated by an artist with the appearnace of structures and organisms in the real world.



The Learning System

These pages show you the tools found throughout *Life* to help you in your study of biology.



Chapter Opening Vignettes

Each chapter begins with a compelling vignette describing a real-life scientific issue related to the chapter topic.

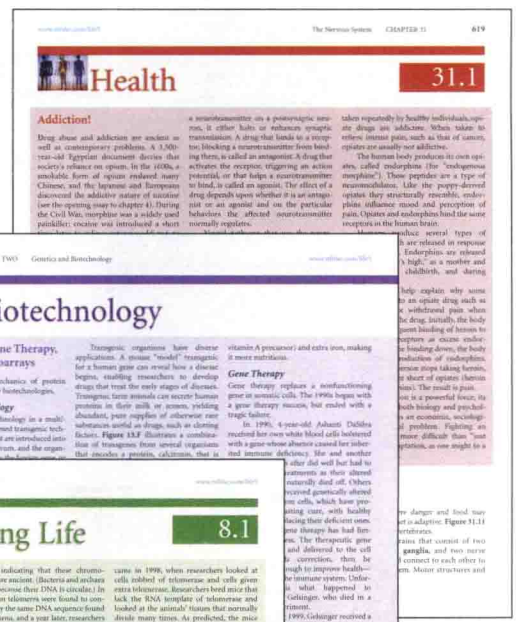
Boxed Readings

These readings highlight the relevance of chapter contents to health, biotechnology, and scientific inquiry.

Health readings discuss health issues of interest to the student.

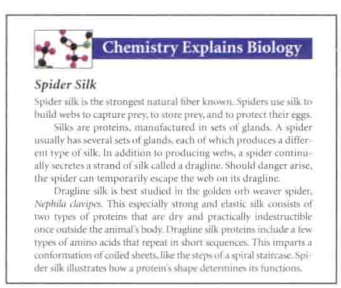
Biotechnology boxes reveal at a glance how science segues into practical applications.

Investigating Life features help remove some of the mystique of science, leading the reader through ways that scientists think when carrying out real experiments and investigations.



Chemistry Explains Biology

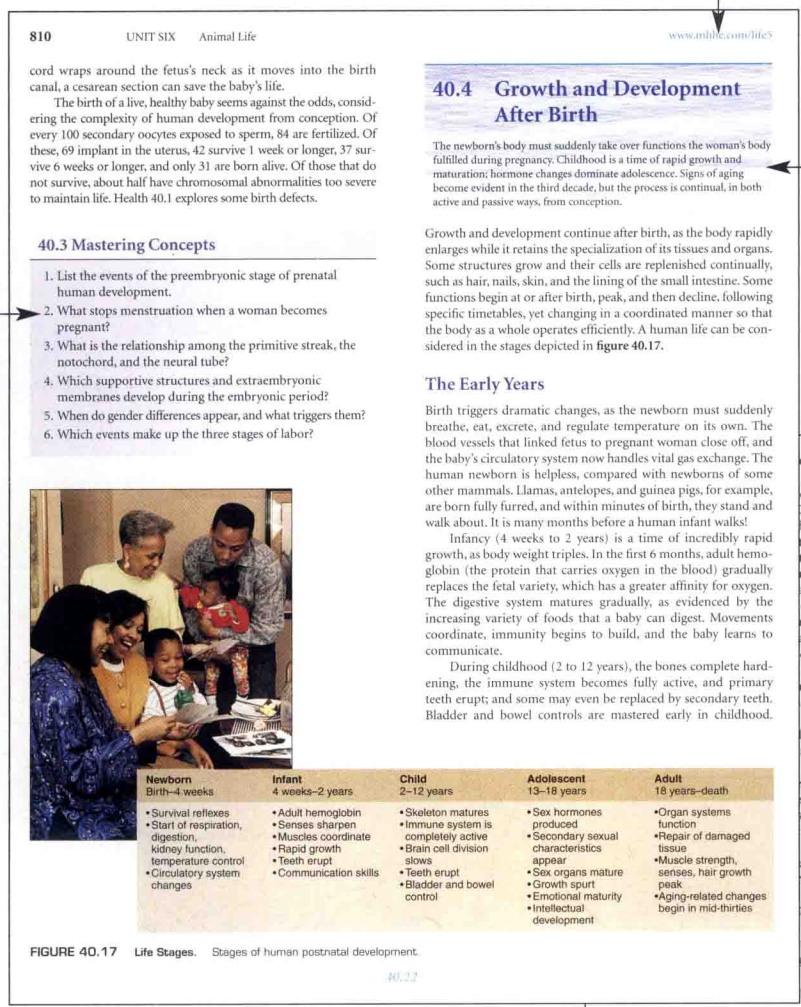
These brief readings, unique to the chemistry chapter, facilitate understanding of chemical concepts.



The Learning System

Online Learning Center

Directions to the *Life* Online Learning Center, which provides self-quizzing, interactive activities, and many other learning tools.



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cord wraps around the fetus's neck as it moves into the birth canal, a cesarean section can save the baby's life.

The birth of a live, healthy baby seems against the odds, considering the complexity of human development from conception. Of every 100 secondary oocytes exposed to sperm, 84 are fertilized. Of these, 69 implant in the uterus, 42 survive 1 week or longer, 37 survive 6 weeks or longer, and only 31 are born alive. Of those that do not survive, about half have chromosomal abnormalities too severe to maintain life. Health 40.1 explores some birth defects.

40.3 Mastering Concepts

1. List the events of the preembryonic stage of prenatal human development.
2. What stops menstruation when a woman becomes pregnant?
3. What is the relationship among the primitive streak, the notochord, and the neural tube?
4. Which supportive structures and extraembryonic membranes develop during the embryonic period?
5. When do gender differences appear, and what triggers them?
6. Which events make up the three stages of labor?

40.4 Growth and Development After Birth

The newborn's body must suddenly take over functions the woman's body fulfilled during pregnancy. Childhood is a time of rapid growth and maturation; hormone changes dominate adolescence. Signs of aging become evident in the third decade, but the process is continual, in both active and passive ways, from conception.

Growth and development continue after birth, as the body rapidly enlarges while it retains the specialization of its tissues and organs. Some structures grow and their cells are replenished continually, such as hair, nails, skin, and the lining of the small intestine. Some functions begin at or after birth, peak, and then decline, following specific timetables, yet changing in a coordinated manner so that the body as a whole operates efficiently. A human life can be considered in the stages depicted in **figure 40.17.**

The Early Years

Birth triggers dramatic changes, as the newborn must suddenly breathe, eat, excrete, and regulate temperature on its own. The blood vessels that linked fetus to pregnant woman close off, and the baby's circulatory system now handles vital gas exchange. The human newborn is helpless, compared with newborns of some other mammals. Llamas, antelopes, and guinea pigs, for example, are born fully furred, and within minutes of birth, they stand and walk about. It is many months before a human infant walks!

Infancy (4 weeks to 2 years) is a time of incredibly rapid growth, as body weight triples. In the first 6 months, adult hemoglobin (the protein that carries oxygen in the blood) gradually replaces the fetal variety, which has a greater affinity for oxygen. The digestive system matures gradually, as evidenced by the increasing variety of foods that a baby can digest. Movements coordinate, immunity begins to build, and the baby learns to communicate.

During childhood (2 to 12 years), the bones complete hardening, the immune system becomes fully active, and primary teeth erupt; and some may even be replaced by secondary teeth. Bladder and bowel controls are mastered early in childhood.

Newborn Birth–4 weeks	Infant 4 weeks–2 years	Child 2–12 years	Adolescent 13–18 years	Adult 18 years–death
• Survival reflexes • Start of respiration, digestion, kidney function, temperature control • Circulatory system changes	• Adult hemoglobin • Senses sharpen • Muscles coordinate • Rapid growth • Teeth erupt • Communication skills	• Skeleton matures • Immune system is completely active • Brain cell division slows • Teeth erupt • Bladder and bowel control	• Sex hormones produced • Secondary sexual characteristics appear • Sex organs mature • Growth spurt • Emotional maturity • Intellectual development	• Organ systems function • Repair of damaged tissue • Muscle strength, senses, hair growth peak • Aging-related changes begin in mid-thirties

FIGURE 40.17 **Life Stages.** Stages of human postnatal development.

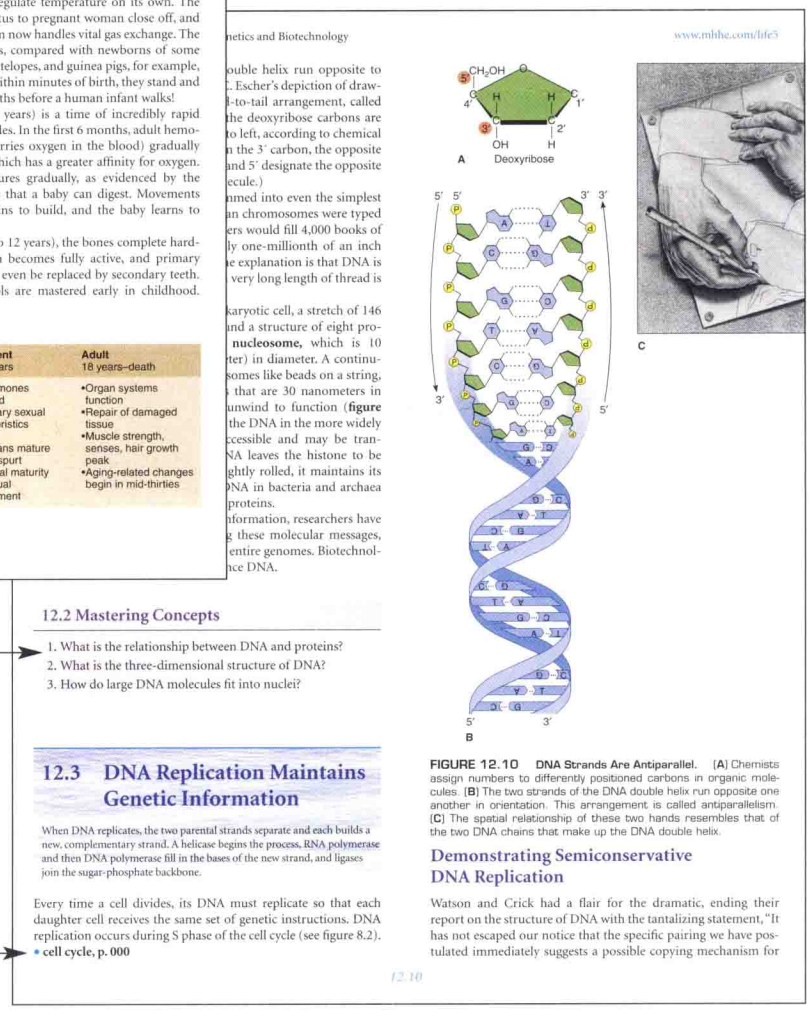
40.22

Summary Statements

Each major section of the chapter begins with a brief synopsis of the section's material.

Mastering Concepts

A short list of questions follows each major text section, to help you review and understand what was just covered.



netics and Biotechnology www.mhhe.com/life5

ouble helix run opposite to
. Escher's depiction of draw-
d-to-tail arrangement, called
the deoxyribose carbons are
to left, according to chemical
n the 3′ carbon, the opposite
and 5′ designate the opposite
ecule.)
nmed into even the simplest
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ers would fill 4,000 books of
ly one-millionth of an inch
e explanation is that DNA is
very long length of thread is

karyotic cell, a stretch of 146
nd a structure of eight pro-
nucleosome, which is 10
ter) in diameter. A continu-
somes like beads on a string,
that are 30 nanometers in
unwind to function (**figure**
the DNA in the more widely
ccessible and may be tran-
NA leaves the histone to be
ghtly rolled, it maintains its
NA in bacteria and archaea
proteins.
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entire genomes. Biotechnol-
nce DNA.

12.2 Mastering Concepts

1. What is the relationship between DNA and proteins?
2. What is the three-dimensional structure of DNA?
3. How do large DNA molecules fit into nuclei?

12.3 DNA Replication Maintains Genetic Information

When DNA replicates, the two parental strands separate and each builds a new, complementary strand. A helicase begins the process, RNA polymerase and then DNA polymerase fill in the bases of the new strand, and ligases join the sugar-phosphate backbone.

Every time a cell divides, its DNA must replicate so that each daughter cell receives the same set of genetic instructions. DNA replication occurs during S phase of the cell cycle (see figure 8.2).

• **cell cycle, p. 000**

12.10

FIGURE 12.10 **DNA Strands Are Antiparallel.** (**A**) Chemists assign numbers to differently positioned carbons in organic molecules. (**B**) The two strands of the DNA double helix run opposite one another in orientation. This arrangement is called antiparallelism. (**C**) The spatial relationship of these two hands resembles that of the two DNA chains that make up the DNA double helix.

Demonstrating Semiconservative DNA Replication

Watson and Crick had a flair for the dramatic, ending their report on the structure of DNA with the tantalizing statement, "It has not escaped our notice that the specific pairing we have postulated immediately suggests a possible copying mechanism for

Cross References

References direct readers to material elsewhere in the text with additional background to support the concepts mentioned within a paragraph.

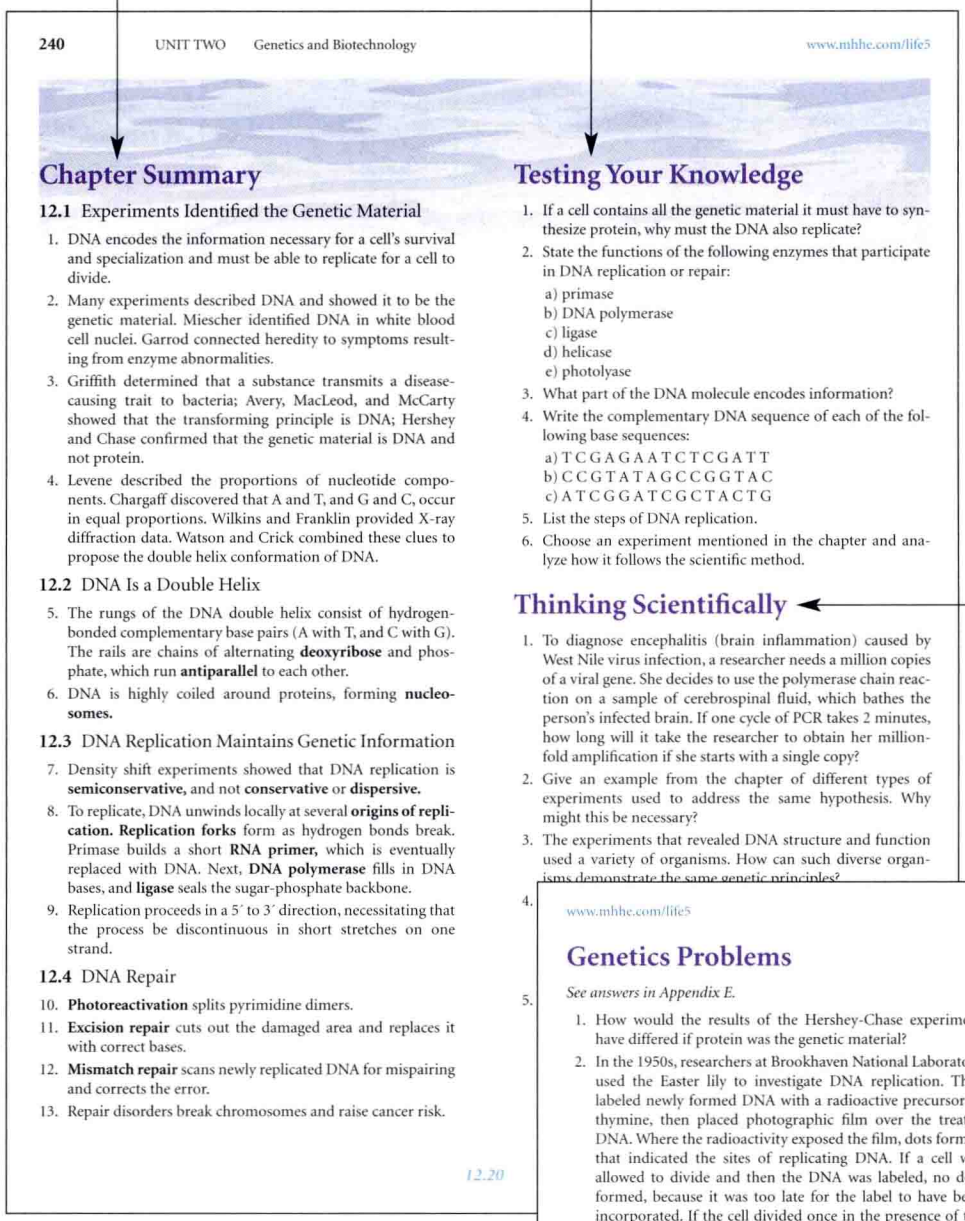
The Learning System

Chapter Summary

The list format of the end of chapter summary makes it easy to identify and review key concepts

Testing Your Knowledge

This feature at the end of the chapter tests your recall of chapter material. The answers are found on the Online Learning Center.



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Chapter Summary

12.1 Experiments Identified the Genetic Material

1. DNA encodes the information necessary for a cell's survival and specialization and must be able to replicate for a cell to divide.
2. Many experiments described DNA and showed it to be the genetic material. Miescher identified DNA in white blood cell nuclei. Garrod connected heredity to symptoms resulting from enzyme abnormalities.
3. Griffith determined that a substance transmits a disease-causing trait to bacteria; Avery, MacLeod, and McCarty showed that the transforming principle is DNA; Hershey and Chase confirmed that the genetic material is DNA and not protein.
4. Levene described the proportions of nucleotide components. Chargaff discovered that A and T, and G and C, occur in equal proportions. Wilkins and Franklin provided X-ray diffraction data. Watson and Crick combined these clues to propose the double helix conformation of DNA.

12.2 DNA Is a Double Helix

5. The rungs of the DNA double helix consist of hydrogen-bonded complementary base pairs (A with T, and C with G). The rails are chains of alternating **deoxyribose** and phosphate, which run **antiparallel** to each other.
6. DNA is highly coiled around proteins, forming **nucleosomes.**

12.3 DNA Replication Maintains Genetic Information

7. Density shift experiments showed that DNA replication is **semiconservative,** and not **conservative** or **dispersive.**
8. To replicate, DNA unwinds locally at several **origins of replication. Replication forks** form as hydrogen bonds break. Primase builds a short **RNA primer,** which is eventually replaced with DNA. Next, **DNA polymerase** fills in DNA bases, and **ligase** seals the sugar-phosphate backbone.
9. Replication proceeds in a 5′ to 3′ direction, necessitating that the process be discontinuous in short stretches on one strand.

12.4 DNA Repair

10. **Photoreactivation** splits pyrimidine dimers.
11. **Excision repair** cuts out the damaged area and replaces it with correct bases.
12. **Mismatch repair** scans newly replicated DNA for mispairing and corrects the error.
13. Repair disorders break chromosomes and raise cancer risk.

12.20

Testing Your Knowledge

1. If a cell contains all the genetic material it must have to synthesize protein, why must the DNA also replicate?
2. State the functions of the following enzymes that participate in DNA replication or repair:
   a) primase
   b) DNA polymerase
   c) ligase
   d) helicase
   e) photolyase
3. What part of the DNA molecule encodes information?
4. Write the complementary DNA sequence of each of the following base sequences:
   a) T C G A G A A T C T C G A T T
   b) C C G T A T A G C C G G T A C
   c) A T C G G A T C G C T A C T G
5. List the steps of DNA replication.
6. Choose an experiment mentioned in the chapter and analyze how it follows the scientific method.

Thinking Scientifically

1. To diagnose encephalitis (brain inflammation) caused by West Nile virus infection, a researcher needs a million copies of a viral gene. She decides to use the polymerase chain reaction on a sample of cerebrospinal fluid, which bathes the person's infected brain. If one cycle of PCR takes 2 minutes, how long will it take the researcher to obtain her million-fold amplification if she starts with a single copy?
2. Give an example from the chapter of different types of experiments used to address the same hypothesis. Why might this be necessary?
3. The experiments that revealed DNA structure and function used a variety of organisms. How can such diverse organisms demonstrate the same genetic principles?

4.

5.

Thinking Scientifically

These critical thinking questions challenge you to use concepts of the chapter to solve problems.

References and Resources

These suggested resources can be used for further study of topics covered in the chapter.

www.mhhe.com/life5 DNA Structure and Replication CHAPTER 12 241

Genetics Problems

See answers in Appendix E.

1. How would the results of the Hershey-Chase experiment have differed if protein was the genetic material?
2. In the 1950s, researchers at Brookhaven National Laboratory used the Easter lily to investigate DNA replication. They labeled newly formed DNA with a radioactive precursor of thymine, then placed photographic film over the treated DNA. Where the radioactivity exposed the film, dots formed that indicated the sites of replicating DNA. If a cell was allowed to divide and then the DNA was labeled, no dots formed, because it was too late for the label to have been incorporated. If the cell divided once in the presence of the radioactive label and was examined after the DNA had replicated again, both sister chromatids of each replicated chromosome were labeled. If a cell divided once in the presence of the label, then was removed and allowed to divide again without the label, one sister (half) of each replicated chromosome was labeled. Which of the three possible mechanisms of DNA replication did the Easter lily experiments reveal? Explain how the results would have differed if either

References and Resources

Holmes, Frederic Lawrence. 2001. *Meselson, Stahl, and the Replication of DNA: A History of "The Most Beautiful Experiment in Biology."* New Haven: Yale University Press. DNA replication is semiconservative.

Maas, Werner. 2001. *Gene action.* New York: Oxford University Press. A highly readable account of the discovery that DNA is the genetic material, and how DNA replicates and encodes information.

Mullis, Kary B. April 1990. The unusual origin of the polymerase chain reaction. *Scientific American.* How PCR arose from a brainstorm.

Piper, Anne. April 1998. Light on a dark lady. *Trends in Biological Sciences,* vol. 23. A tribute to Rosalind Franklin, by her best friend.

Watson, James D. 1968. *The Double Helix.* New York: New American Library. An exciting, personal account of the discovery of DNA structure.

Genetics Problems

Engaging practical situations provide additional practice in solving genetics problems.

Brief Contents

Detailed Contents