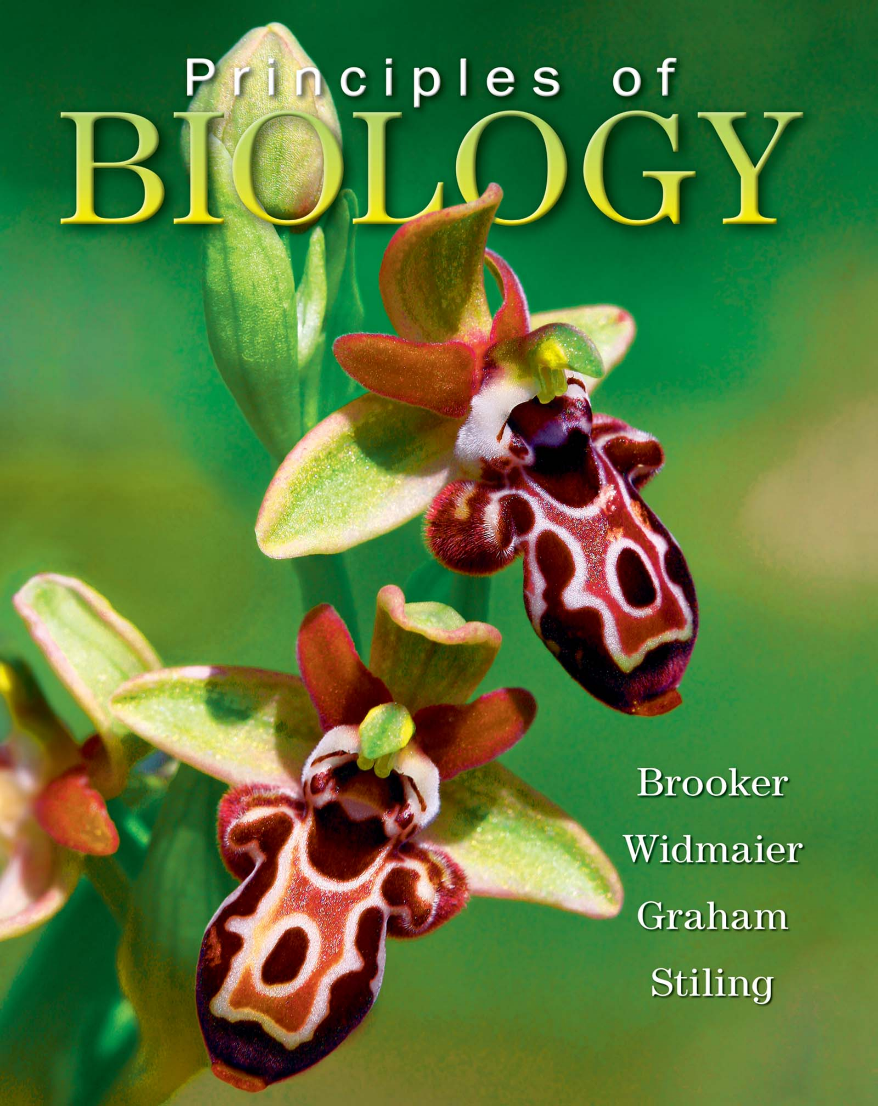

Principles of BIOLOGY

Brooker

Widmaier

Graham

Stiling

Principles of BIOLOGY

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PRINCIPLES OF BIOLOGY

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Peter Stiling obtained his Ph.D. from University College, Cardiff, Wales, in 1979. Subsequently, he became a postdoctoral fellow at Florida State University and later spent two years as a lecturer at the University of the West Indies, Trinidad. During this time, he began photographing and writing about butterflies and other insects, which led to publication of several books on local insects. Dr. Stiling is currently a Professor of Biology at the University of South Florida at Tampa. His research interests include plant-insect relationships, parasite-host relationships, biological control, restoration ecology, and the effects of elevated carbon dioxide levels on plant–herbivore interactions. He teaches graduate and undergraduate courses in ecology and environmental science as well as introductory biology. He has published many scientific papers and is the author of *Ecology: Global Insights and Investigations*, 2nd edition, copyright 2015, and is coauthor of *Biology*, 3rd edition, copyright 2014, both published by McGraw-Hill Education.

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A Note about *Principles of Biology* . . .

A recent trend in science education is the phenomenon that is sometimes called "*flipping the classroom*." This phrase refers to the idea that some of the activities that used to be done in class are now done out of class, and vice versa. For example, instead of spending the entire class time lecturing about textbook and other materials, some of the class time is spent engaging students in various activities, such as problem solving, working through case studies, and designing experiments. This approach is called *active learning*. For many instructors, the classroom has become more learner-centered rather than teacher-centered. A learner-centered classroom provides a rich environment in which students can interact with each other and with their instructors. Instructors and fellow students often provide formative assessment—immediate feedback that helps each student understand if his or her learning is on the right track.

What are some advantages of active learning? Educational studies reveal that active learning usually promotes greater learning gains. In addition, active learning often focuses on skill development rather than the memorization of facts that are easily forgotten. Students become trained to "think like scientists" and to develop a skill set that enables them to apply scientific reasoning.

A common concern among instructors who are beginning to try out active learning is that they think they will have to teach their students less material. However, this may not be the case. Although students may be provided with online lectures, "flipping the classroom" typically gives students more responsibility for understanding the textbook material on their own. Along these lines, *Principles of Biology* is intended to provide students with a resource that can be effectively used out of the classroom. Several key pedagogical features include the following:

- **Focus on Core Concepts:** Although it is intended for majors in the biological sciences, *Principles of Biology* is a shorter textbook that emphasizes core concepts. Twelve principles of biology are enunciated in Chapter 1 and those principles are emphasized throughout the textbook with specially labeled figures. An effort has also been made to emphasize some material in bulleted lists and numbered lists, so students can more easily see the main points.
- **Learning Outcomes:** Each section of every chapter begins with a set of learning outcomes. These outcomes help students understand what they should be able to do if they have mastered the material in that section.
- **Formative Assessment:** When students are expected to learn textbook material on their own, it is imperative that they be given regular formative assessments so they can gauge whether or not they are mastering the material. Formative assessment is a major feature of this textbook and is bolstered by McGraw-Hill Connect®—a state-of-the-art digital assignment and assessment platform. In *Principles of Biology*, formative assessment is provided in multiple ways.

  1. Each section of every chapter ends with multiple-choice questions.
  2. Most figures have concept check questions so students can determine if they understand the key points in the figure.
  3. End-of-chapter questions continue to provide students with feedback regarding their mastery of the material.
  4. Further assessment tools are available in Connect. Question banks, Test banks, and Quantitative Question banks can be assigned by the professor. McGraw-Hill LearnSmart® allows for individual study as well as assignments from the professor.

- **Quantitative Analysis:** Many chapters have a subsection that emphasizes quantitative reasoning, an important skill for careers in science and medicine. In these subsections, the quantitative nature of a given topic is described, and then students are asked to solve a problem related to that topic.
- **BioConnections and Evolutionary Connections:** To help students broaden their understanding of biology, two recurring features are BioConnections and Evolutionary Connections. BioConnections are placed in key figure legends in each chapter and help students relate a topic they are currently learning to another topic elsewhere in the textbook, often in a different unit. Evolutionary Connections provide a framework for understanding how a topic in a given chapter relates to evolution, the core unifying theme in Biology.

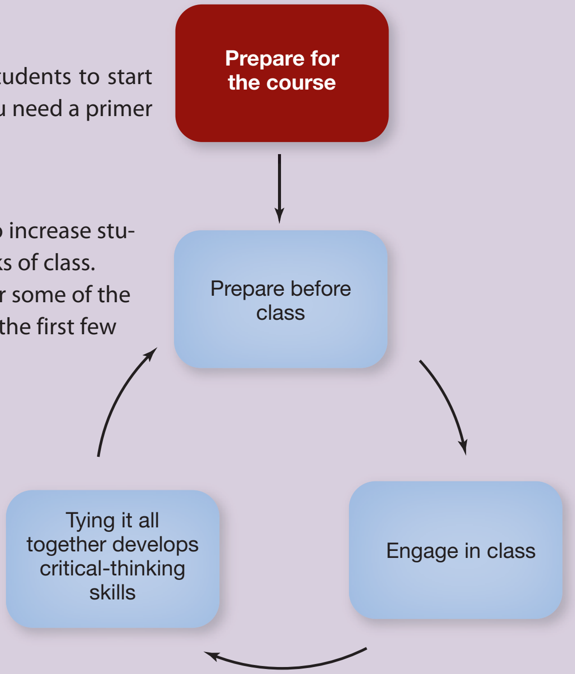
Overall, the pedagogy of *Principles of Biology* has been designed to foster student learning. Instead of being a collection of "facts and figures," *Principles of Biology* is intended to be an engaging and motivating textbook in which formative assessment allows students to move ahead and learn the material in a productive way. We welcome your feedback so we can make future editions even better!

Rob Brooker
Eric Widmaier
Linda Graham
Peter Stiling

GUIDING YOU THROUGH *PRINCIPLES OF BIOLOGY*

Principles of Biology and its online assets have been carefully crafted to help you, the student, work efficiently and effectively through the material in the course, making the most of your study time. This *Guiding You Through Principles of Biology* section explains how you can use the text and online resources to help you succeed in Majors Biology.

Prepare for the Course



Many biology students struggle the first few weeks of class. Many institutions expect students to start majors biology having a working knowledge of basic chemistry and cellular biology. If you need a primer to help you get up to speed, consider McGraw-Hill's new program, *LearnSmart Prep*.

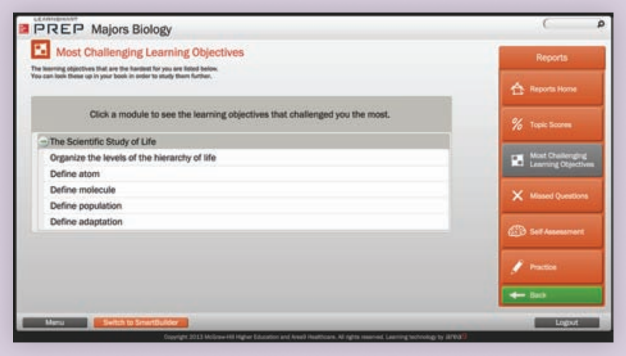
LEARNSMART PREP™

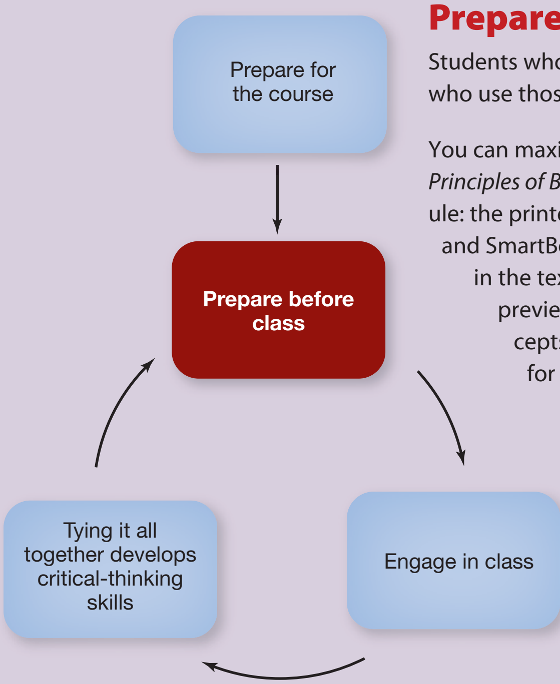
LearnSmart Prep is an adaptive learning tool designed to increase student success and aid retention through the first few weeks of class. Using this digital tool, Majors Biology students can master some of the most fundamental and challenging principles of biology before they begin to struggle in the first few weeks of class.

1 A diagnostic establishes your baseline comprehension and knowledge; then the program generates a learning plan tailored to your academic needs and schedule.

2 As you work through the learning plan, the program asks you questions and tracks your mastery of concepts. If you answer questions about a particular concept incorrectly, the program will provide a learning resource (ex. animation or tutorial) on that concept, then ensure that you understand the concept by asking you more questions. Didn't get it the first time? Don't worry—*LearnSmart Prep* will keep working with you!

3 Using *LearnSmart Prep*, you can identify the content you don't understand, focus your time on content you need to know but don't, and therefore improve your chances of success in your majors biology course.

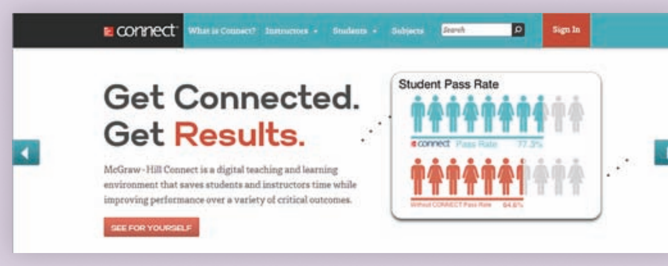




Prepare Before Class

Students who are most successful in college are those who have developed effective study skills and who use those skills, before, during, and after class.

You can maximize your time in class by previewing the material before stepping into the lecture hall. *Principles of Biology* is available in several formats that allow you to fit studying into your busy schedule: the printed text as well as online offerings that include the interactive eBook in ConnectPlus+ and SmartBook. All three formats deliver the chapter material and valuable learning aids presented in the text, but the online options offer additional resources. Use any or all of these options to preview the material before lecture. Familiarizing yourself with terminology and basic concepts will allow you to follow along in class and engage in the content in a way that allows for better retention.

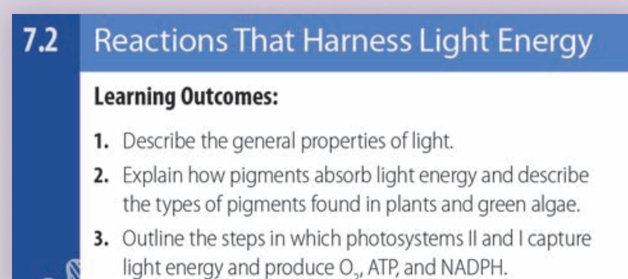


The gateway to your online Resources

1 The traditional printed text offers many embedded study aids.

Guiding You Through *Principles of Biology*

Every chapter opens with a Chapter Outline that walks through the main concepts and organizes the material in the chapter and provides a story that puts the topic of the chapter into context.



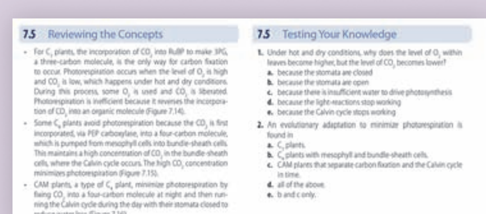
7.2 Reactions That Harness Light Energy

Learning Outcomes:

1. Describe the general properties of light.
2. Explain how pigments absorb light energy and describe the types of pigments found in plants and green algae.
3. Outline the steps in which photosystems II and I capture light energy and produce O_2, ATP, and NADPH.

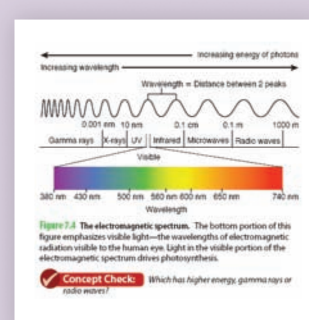
Chapters are broken down into sections that cover skills or ideas you should master. Learning Outcomes at the beginning of each section tell you exactly what you should be able to do by the end of the section.

Reviewing the Concepts provides a summary of the key concepts presented in the section.



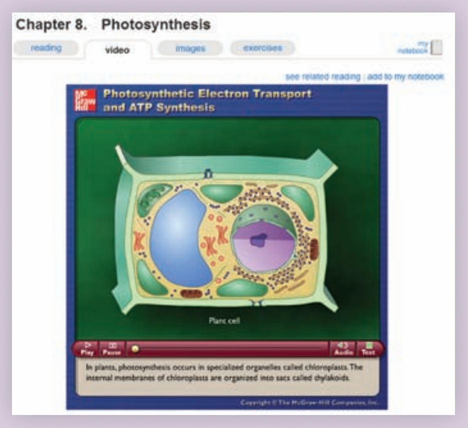
Testing Your Knowledge allows you to check your understanding of key concepts in the section before moving on. Additional questions are available at the end of the chapter.

Many figures throughout the text are supported with *Concept Check* questions that test your understanding of the concept illustrated in the figure.

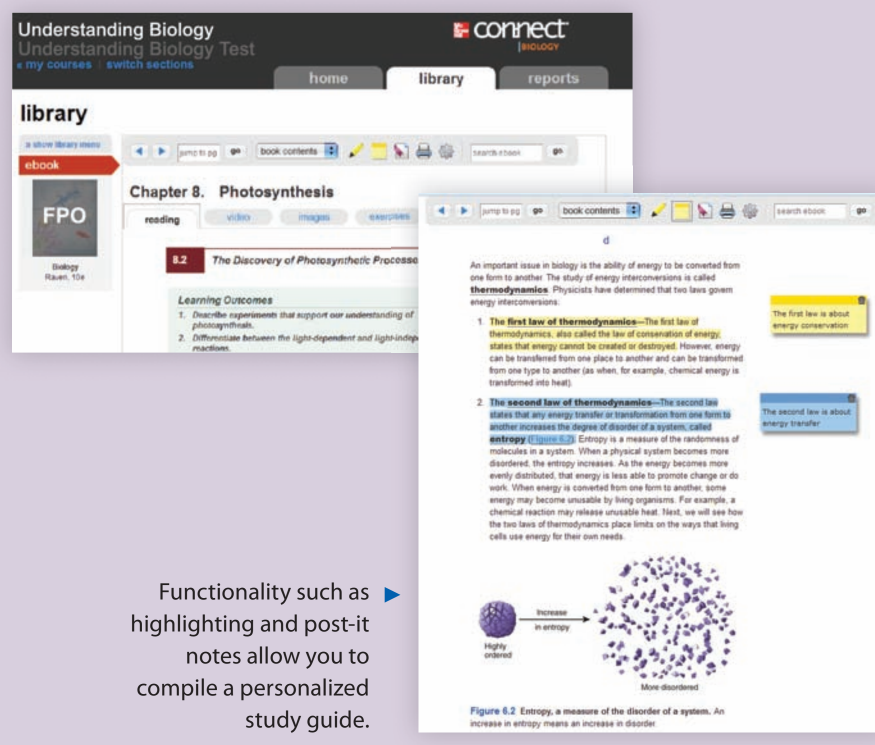


2 Online interactive eBook in ConnectPlus+ offers additional animations and study aids.

Enhancements found in the interactive eBook



▲ The interactive eBook takes the reading experience to a new level with links to animations and videos that supplement the text.



Functionality such as highlighting and post-it notes allow you to compile a personalized study guide. ▶

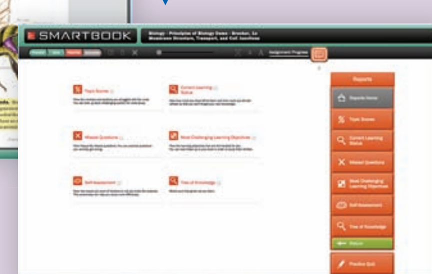
3 SmartBook provides a personalized, adaptive reading experience.

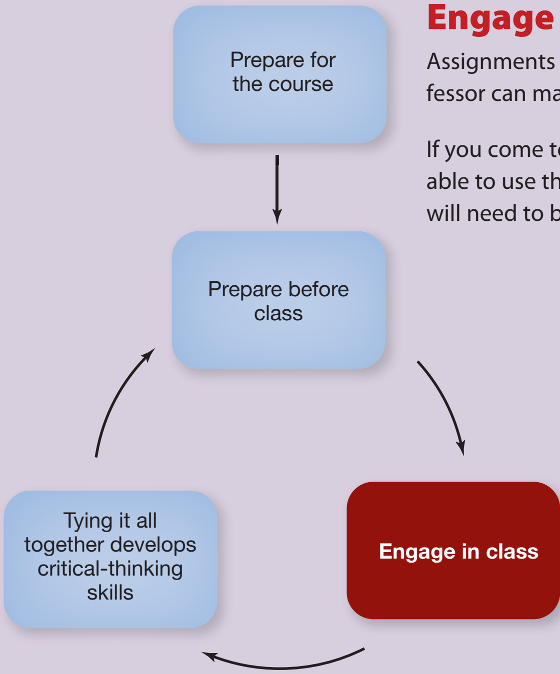
Powered by an intelligent diagnostic and adaptive engine, **SmartBook** facilitates the reading process by identifying what content a student knows and doesn't know through adaptive assessments.

▲ The SmartBook experience starts by previewing key concepts from the chapter and ensuring that you understand the big ideas.

▲ SmartBook asks you questions that identify gaps in your knowledge. The reading experience then continuously adapts in response to the assessments—highlighting the material you need to review based on what you don't know.

The reports in SmartBook help identify topics where you need more work. ▼





Engage in Class

Assignments in Connect and LearnSmart will help you understand concepts so that you and your professor can make the most of in-class time.

If you come to class having a working knowledge of concepts and terminology, the professor will be able to use the class period to help you develop critical thinking and analytical skills—skills that you will need to be successful in upper level courses and in your career.

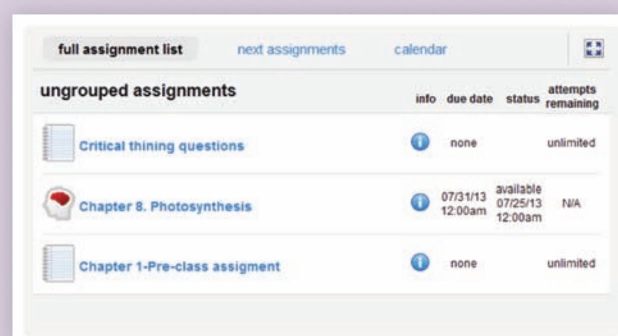
LEARNSMART®

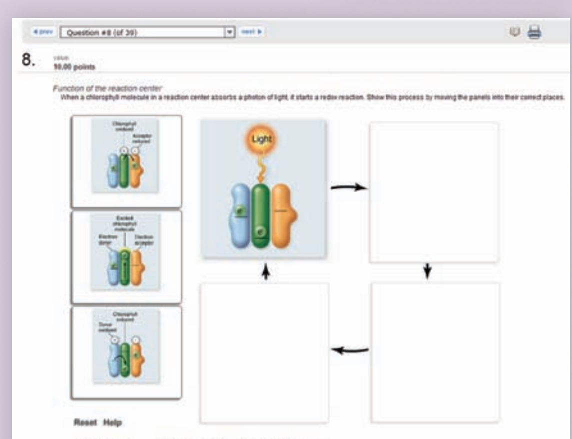
McGraw-Hill LearnSmart™ is available as an integrated feature of McGraw-Hill Connect Biology. It is an adaptive learning system designed to help students learn faster, study more efficiently, and retain more knowledge for greater success. LearnSmart assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. This innovative study tool also has features that allow students access to rich reporting and provides instructors with a built-in assessment tool for grading assignments. Visit www.mhlearnsmart.com for a demonstration.

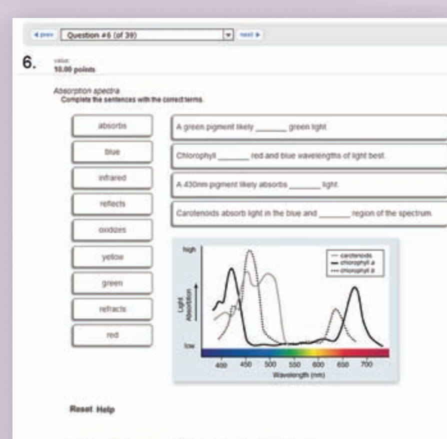
1 Your professor may make pre-class assignments to help you engage in the content during class.

connect® plus+ BIOLOGY

Assignments are accessed through Connect and could include homework assignments, quizzes, reading assignments, LearnSmart assignments, and other resources. ▶

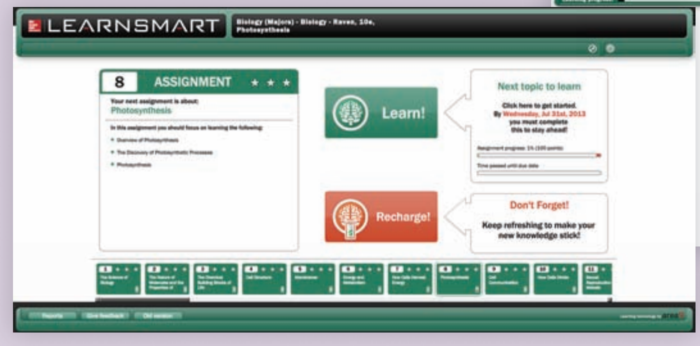


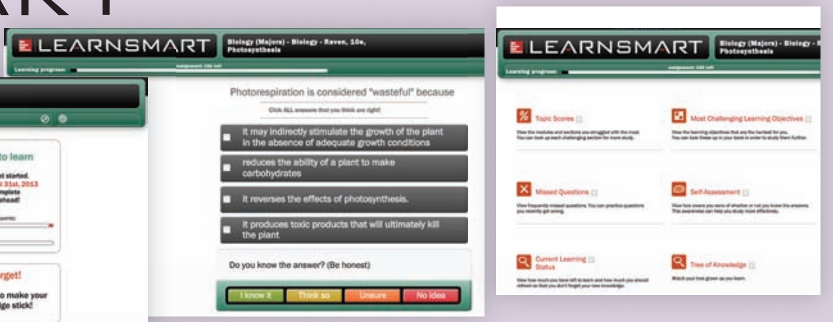




◀ Interactive and traditional questions help assess your knowledge of the material.

2 Your professor can assign modules in LearnSmart, which are also available in Connect or on your mobile device for self-study.



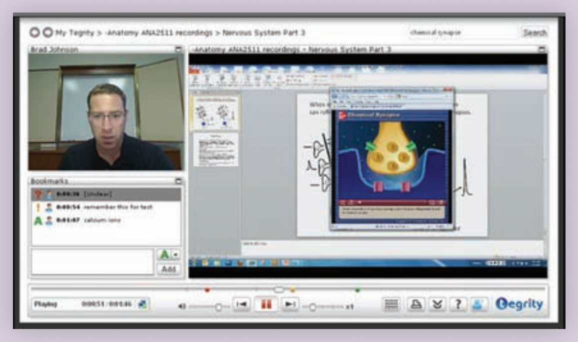


◄ Study with LearnSmart by working through modules and using LearnSmart's reporting to better understand your strengths and weaknesses.

▲ The Tree of Knowledge tracks your progress, reporting on short term successes and long term retention.

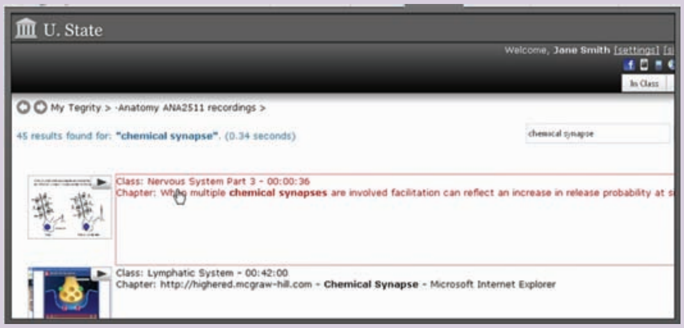
◄ Download the LearnSmart app from iTunes or Google Play and work on LearnSmart from anywhere!

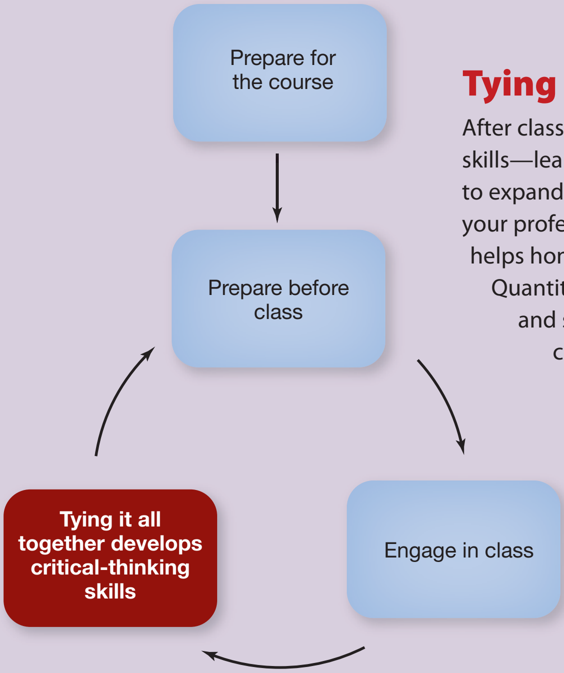
3 Your professor may record his or her lectures. If your professor is using Tegrity, you can review the lecture after class along with the corresponding PowerPoint® presentations. A Search function allows quick access to the content you want to review.



▲ More than just a recorded lecture, Tegrity lets you search and bookmark content, take notes, and work with fellow class-mates in order to make learning incredibly efficient.

To save time, search through the Tegrity lecture using key terms—all PowerPoint slides that contain the term are identified for a quick review.
▼





Tying It All Together Develops Critical-Thinking Skills

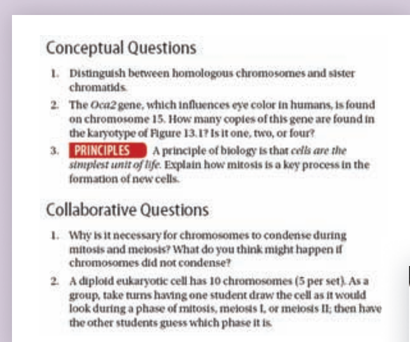
After class, put your new-found knowledge to work by developing your critical thinking skills—learning to apply, analyze, and synthesize information. There are many opportunities to expand your skills. End-of-chapter questions in the book and online assignments from your professor challenge your understanding, revisiting LearnSmart/SmartBook modules helps hone your understanding, and Feature Investigations, Evolutionary Connections, and Quantitative Analysis are features in the book that encourage you to think past the facts and start putting your understanding to work. The Quantitative Analysis features are complemented by an online component to help you develop data analysis skills. BioConnection questions and *Principles of Biology* figures help you see how topics in biology are interconnected. All of these help develop critical-thinking and analytical skills.

1 Working through problems and questions that develop critical-thinking skills is key to understanding the concepts at a higher level.

Questions that challenge your comprehension

Following lecture, you should be able to answer Conceptual and Collaborative questions at the end of the chapter. A "Principles" question tests your understanding of how chapter concepts relate to the principles of biology that provide a framework for organizing concepts in biology.

Quantitative questions assigned in Connect allow you to practice answering mathematically-based biological problems—with hints and guided solutions to help you along the way. Numerical values in these questions change so that you can keep practicing until you understand the concept.

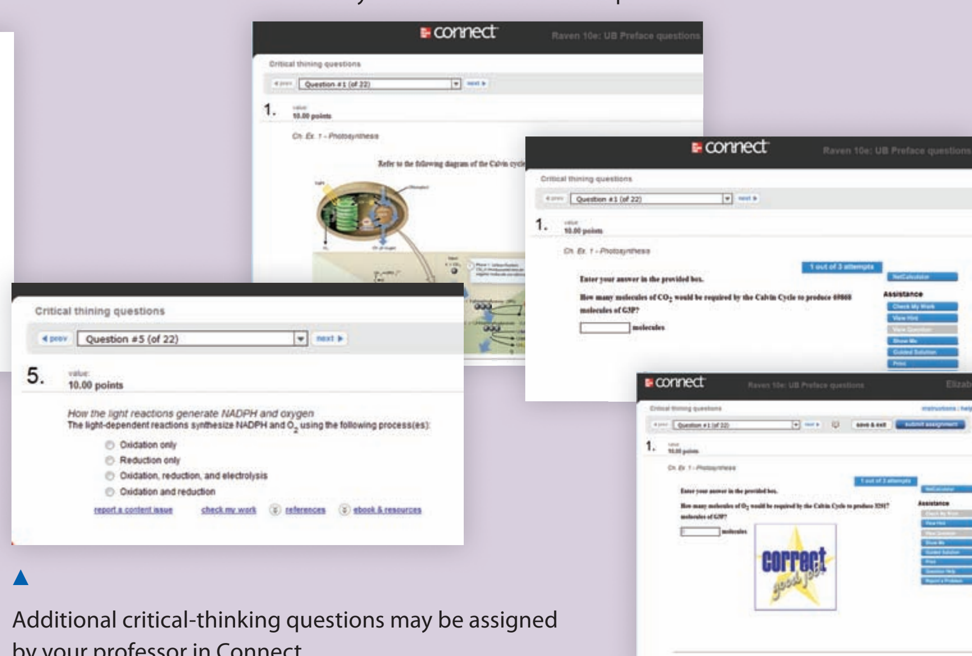


Conceptual Questions

1. Distinguish between homologous chromosomes and sister chromatids.
2. The *Oca2* gene, which influences eye color in humans, is found on chromosome 15. How many copies of this gene are found in the karyotype of Figure 13.1? Is it one, two, or four?
3. PRINCIPLES A principle of biology is that *cells are the simplest unit of life*. Explain how mitosis is a key process in the formation of new cells.

Collaborative Questions

1. Why is it necessary for chromosomes to condense during mitosis and meiosis? What do you think might happen if chromosomes did not condense?
2. A diploid eukaryotic cell has 10 chromosomes (5 per set). As a group, take turns having one student draw the cell as it would look during a phase of mitosis, meiosis I, or meiosis II; then have the other students guess which phase it is.



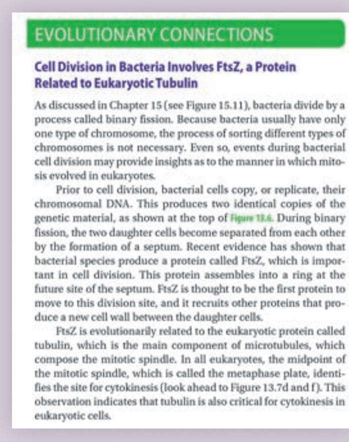
▲ Additional critical-thinking questions may be assigned by your professor in Connect.

2 The development of critical thinking and analytical tools is also achieved by analyzing scientific research.

Think like a scientist

Feature Investigations walk you through a scientific investigation looking at the experimental and conceptual aspects. The Investigation lays out the hypothesis, test procedures, data, and conclusion. Experimental questions test your understanding of the experiment, data, and conclusions.

▼



EVOLUTIONARY CONNECTIONS

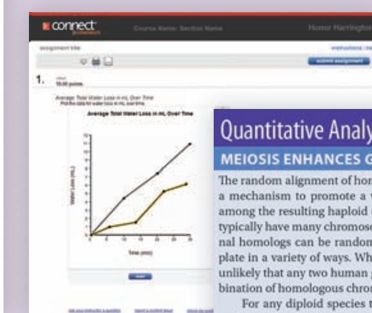
Cell Division in Bacteria Involves FtsZ, a Protein Related to Eukaryotic Tubulin

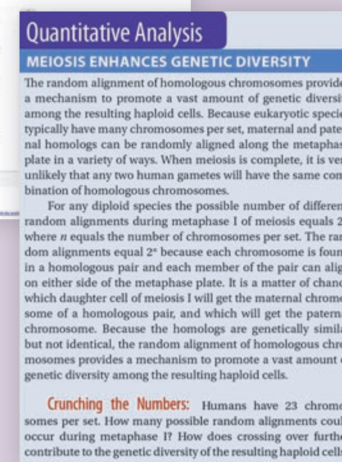
As discussed in Chapter 15 (see Figure 15.11), bacteria divide by a process called binary fission. Because bacteria usually have only one type of chromosome, the process of sorting different types of chromosomes is not necessary. Even so, events during bacterial cell division may provide insights as to the manner in which mitosis evolved in eukaryotes.

Prior to cell division, bacterial cells copy, or replicate, their chromosomal DNA. This produces two identical copies of the genetic material, as shown at the top of Figure 15.6. During binary fission, the two daughter cells become separated from each other by the formation of a septum. Recent evidence has shown that bacterial species produce a protein called FtsZ, which is important in cell division. This protein assembles into a ring at the future site of the septum. FtsZ is thought to be the first protein to move to this division site, and it recruits other proteins that produce a new cell wall between the daughter cells.

FtsZ is evolutionarily related to the eukaryotic protein called tubulin, which is the main component of microtubules, which compose the mitotic spindle. In all eukaryotes, the midpoint of the mitotic spindle, which is called the metaphase plate, identifies the site for cytokinesis (look ahead to Figure 13.7d and f). This observation indicates that tubulin is also critical for cytokinesis in eukaryotic cells.

◀ The Evolutionary Connections feature examines the evolutionary implications of scientific research.





Quantitative Analysis

MEIOSIS ENHANCES GENETIC DIVERSITY

The random alignment of homologous chromosomes provides a mechanism to promote a vast amount of genetic diversity among the resulting haploid cells. Because eukaryotic species typically have many chromosomes per set, maternal and paternal homologs can be randomly aligned along the metaphase plate in a variety of ways. When meiosis is complete, it is very unlikely that any two human gametes will have the same combination of homologous chromosomes.

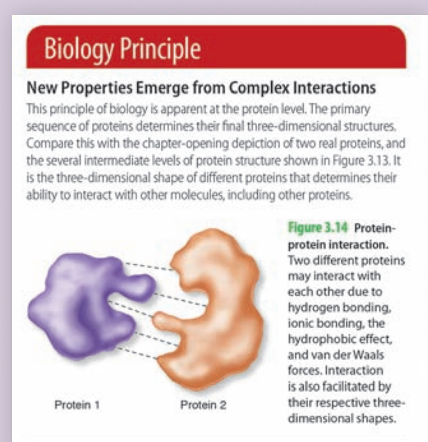
For any diploid species the possible number of different, random alignments during metaphase I of meiosis equals 2^n, where n equals the number of chromosomes per set. The random alignments equal 2^n because each chromosome is found in a homologous pair and each member of the pair can align on either side of the metaphase plate. It is a matter of chance which daughter cell of meiosis I will get the maternal chromosome of a homologous pair, and which will get the paternal chromosome. Because the homologs are genetically similar but not identical, the random alignment of homologous chromosomes provides a mechanism to promote a vast amount of genetic diversity among the resulting haploid cells.

Crunching the Numbers: Humans have 23 chromosomes per set. How many possible random alignments could occur during metaphase I? How does crossing over further contribute to the genetic diversity of the resulting haploid cells?

The Quantitative Analysis feature explores the quantitative aspect of the study of biology. The features walk you through biological concepts that have a quantitative component. The Crunching the Numbers provides a sample problem that tests your understanding. Associated online activities can help you practice your data analysis skills. ▶

3 A key component to learning is understanding the underlying principles of biology and making connections between different topics.

Biology principles and making connections



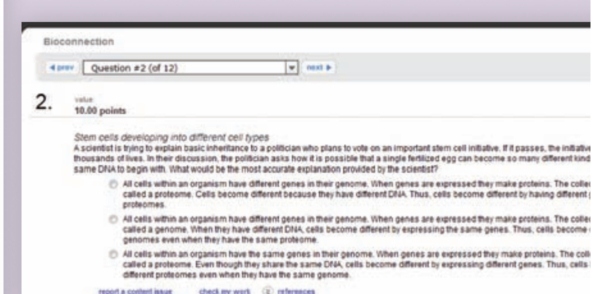
Biology Principle

New Properties Emerge from Complex Interactions

This principle of biology is apparent at the protein level. The primary sequence of proteins determines their final three-dimensional structures. Compare this with the chapter-opening depiction of two real proteins, and the several intermediate levels of protein structure shown in Figure 3.13. It is the three-dimensional shape of different proteins that determines their ability to interact with other molecules, including other proteins.

Figure 3.14 **Protein-protein interaction.** Two different proteins may interact with each other due to hydrogen bonding, ionic bonding, the hydrophobic effect, and van der Waals forces. Interaction is also facilitated by their respective three-dimensional shapes.

▲ Figures that are highlighted as Biology Principles discuss not only how the figure relates to the topic under consideration, but also how that figure illustrates a biological principle. Biology Principles provide a framework for organizing concepts in biology.



Bioconnection

◀ prev | Question #2 (of 12) | next ▶

2. value 10.00 points

Stem cells developing into different cell types

A scientist is trying to explain basic inheritance to a politician who plans to vote on an important stem cell initiative. If it passes, the initiative … thousands of lives. In their discussion, the politician asks how it is possible that a single fertilized egg can become so many different kind… same DNA to begin with. What would be the most accurate explanation provided by the scientist?

- All cells within an organism have different genes in their genome. When genes are expressed they make proteins. The colle… called a proteome. Cells become different because they have different DNA. Thus, cells become different by having different … proteomes.
- All cells within an organism have different genes in their genome. When genes are expressed they make proteins. The colle… called a genome. When they have different DNA, cells become different by expressing the same genes. Thus, cells become … genomes even when they have the same proteome.
- All cells within an organism have the same genes in their genome. When genes are expressed they make proteins. The coll… called a proteome. Even though they share the same DNA, cells become different by expressing different genes. Thus, cells … different proteomes even when they have the same genome.

report a content issue | check my work | references

▲

Additionally, your professor may assign questions in Connect that require you to pull together and synthesize information from various chapters to address a more complex issue.

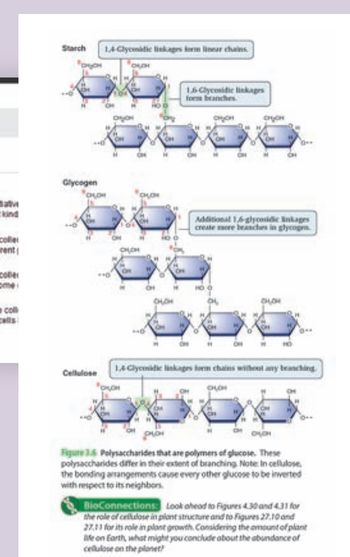


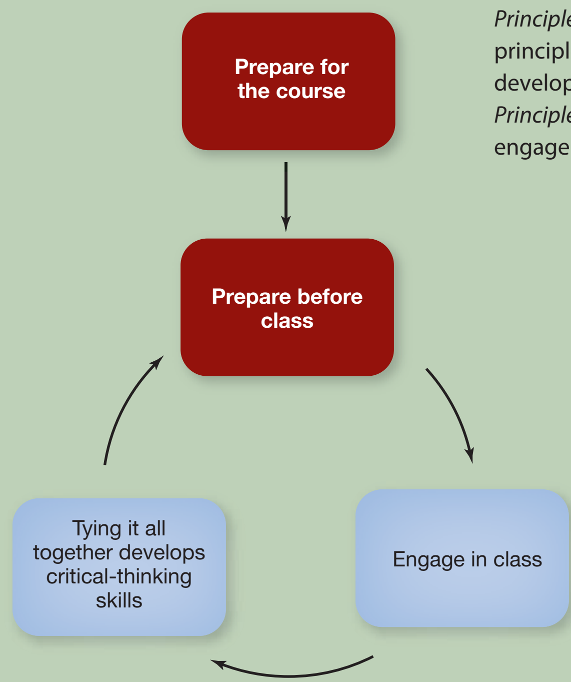
Figure 3.6 **Polysaccharides that are polymers of glucose.** These polysaccharides differ in their extent of branching. Note: In cellulose, the bonding arrangements cause every other glucose to be inverted with respect to its neighbors.

BioConnections: *Look ahead to Figures 4.30 and 4.31 for the role of cellulose in plant structure and to Figures 27.10 and 27.11 for its role in plant growth. Considering the amount of plant life on Earth, what might you conclude about the abundance of cellulose on the planet?*

▲

BioConnections in figure legends direct you to figures in other chapters that are related to the topic or concept being illustrated. Although material is presented in separate chapters, many concepts in biology are related. BioConnections help you examine connections between seemingly unrelated concepts.

GUIDE YOUR STUDENTS THROUGH *PRINCIPLES OF BIOLOGY*



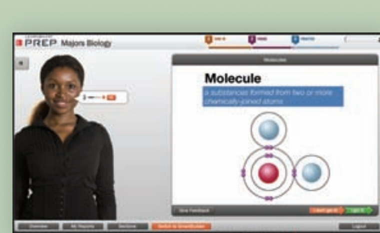
Principles of Biology offers professors a text focused on developing an understanding of the core principles that provide a foundation for students intending to pursue a degree in biology and developing critical thinking skills that will serve them well into the future. This *Guide Through Principles of Biology* explains how professors can use the text and online resources to help engage their students and maximize their instructional time.

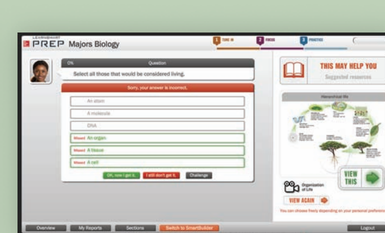
Prepare for the Course and for the Class

The Majors Biology class is changing in new and exciting ways, with more emphasis on active learning. Digital resources can help you achieve your instructional goals—making your students more responsible for learning outside of class by meeting your students where they live: on the go and online. Use the text and digital tools to empower students to come to class more prepared and ready to engage!

To help your students get up to speed, assign *LearnSmart Prep* at the beginning of the course. ***LearnSmart***™ *Prep* is an adaptive learning tool designed to increase student success and aid retention through the first few weeks of class. Using this digital tool, Majors Biology students can master some of the most fundamental and challenging principles of biology before they begin to struggle in the first few weeks of class.

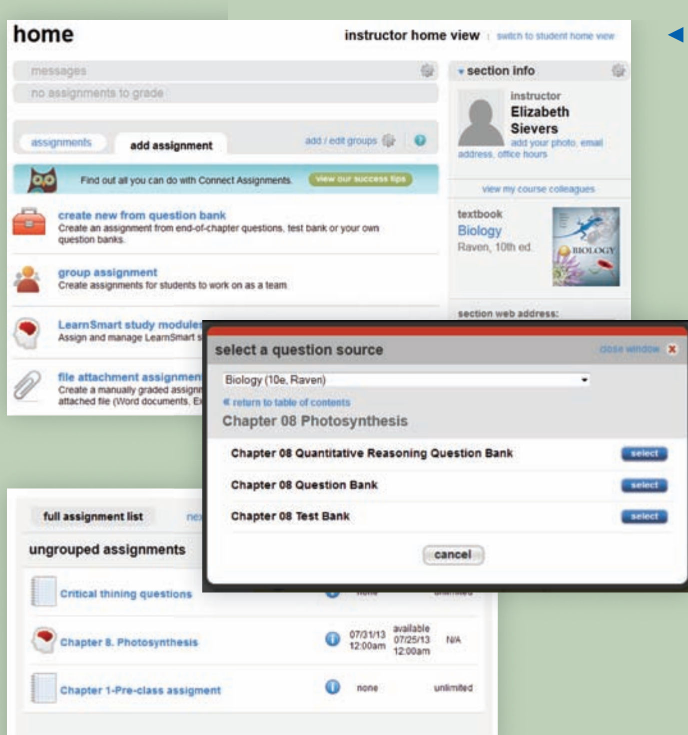
Assessment with timely learning resources helps students with foundational material that you want them to know coming into the course.



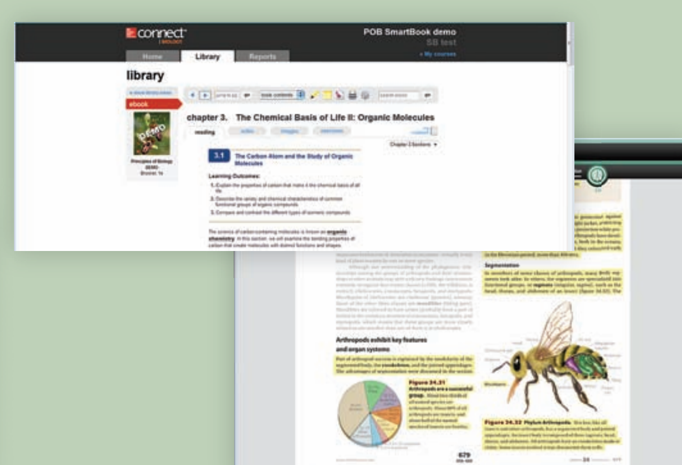


1 Create assignments and use adaptive resources to introduce terminology and basic concepts to students before class.

Help your students prepare for class by making assignments—reading, homework, and LearnSmart



◀ Assignments can include Reading assignments from the ConnectPlus eBook, homework or quizzes, LearnSmart, your own Web or short answer activities, and more.



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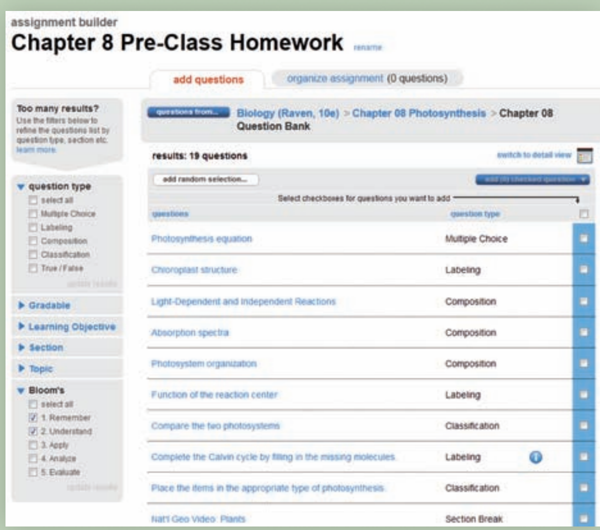
Reading assignments can be made using the ConnectPlus eBook, but students also have access to SmartBook or the standard printed text.

McGraw-Hill Connect Biology provides online presentation, assignment, and assessment solutions. It connects your students with the tools and resources they'll need to achieve success. With Connect Biology you can deliver assignments, quizzes, and tests online. A robust set of questions and activities are presented in the Question Bank and a separate set of questions to use for exams are presented in the Test Bank. As an instructor, you can edit existing questions and author entirely new problems. Track individual student performance—by question, assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems such as Blackboard and Canvas—and much more. ConnectPlus Biology provides students with all the advantages of Connect Biology plus 24/7 online access to an eBook. This media-rich version of the book is available through the McGraw-Hill Connect platform and allows seamless integration of text, media, and assessments.

To learn more, visit www.mcgrawhillconnect.com

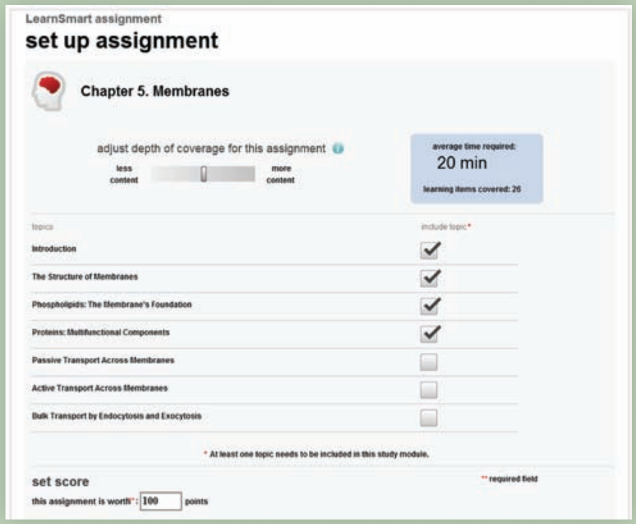
2 Customize Connect and LearnSmart assignments to address knowledge gaps so students can get the most out of class.

Customize your assignments using Connect filters

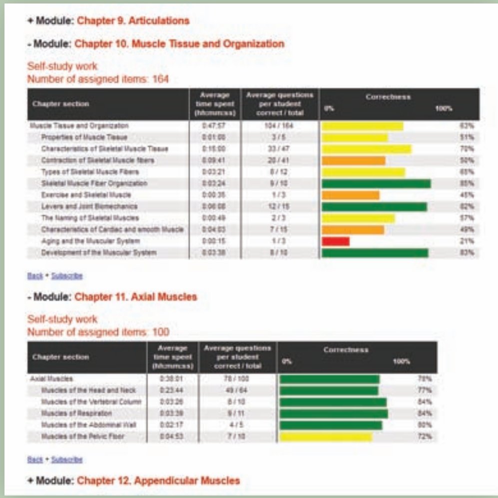


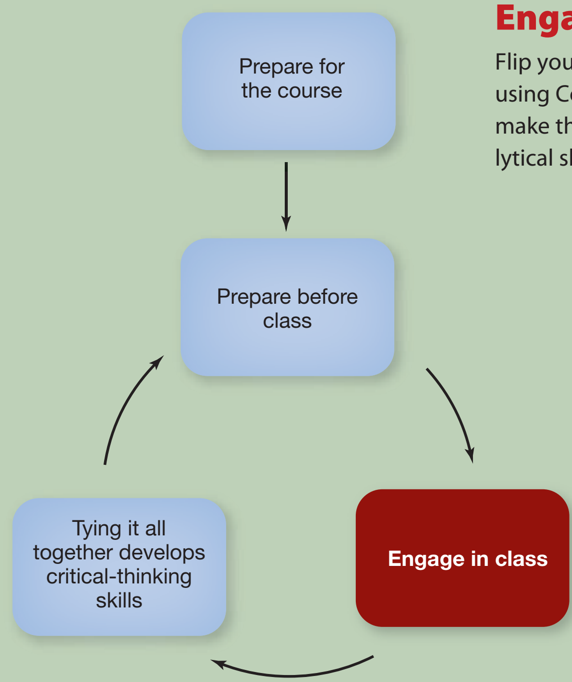
Use the filters in Connect to select questions that match your desired level of assessment—filter questions for lower-level Blooms to assess basic concepts and understanding prior to lecture. Filter using upper-level Blooms after class to develop critical-thinking and analytical skills.

You can customize your LearnSmart assignments by topic (selecting the sections in the chapter you will cover in class) and by the amount of time investment you expect from your students. Reducing the length of time focuses the LearnSmart questions on core concepts in the chapter.



Reports in Connect and LearnSmart help you monitor student assignments and performance, allowing for "just-in-time" teaching to clarify concepts that are more difficult for your students to understand.





Engage Your Students in Class

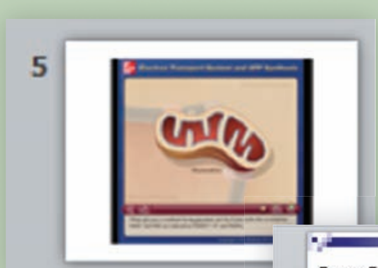
Flip your classroom and make time for active learning in class by creating preclass assignments using Connect and LearnSmart. Your students will come to class better prepared and you can make the most of your valuable class time to work on developing their critical thinking and analytical skills.

McGraw-Hill Tegrity® records and distributes your class activities or lectures with just a click of a button. Students can view the recorded videos anytime/anywhere via computer, iPod, or mobile device. Tegrity indexes your PowerPoint® presentations and anything shown on your computer so that students can use keywords to find exactly what they want to study. Tegrity is available as an integrated feature of McGraw-Hill Connect Biology and as a standalone resource.

1 Within Connect, you will find presentation materials to enhance your class.

Presentation Tools in Connect

The Presentation Tools in Connect provide everything you need for outstanding presentations all in one place.



◀ Animation PowerPoints contain full-color animations illustrating important processes, which are fully embedded in PowerPoint slides for easy use in your presentations.

FlexArt PowerPoints contain editable art from the text. For all figures, labels and leader lines are editable allowing you to customize your PowerPoint presentations.
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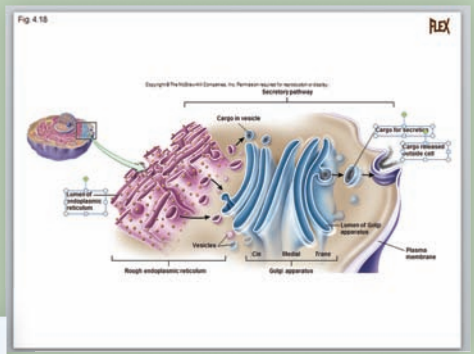

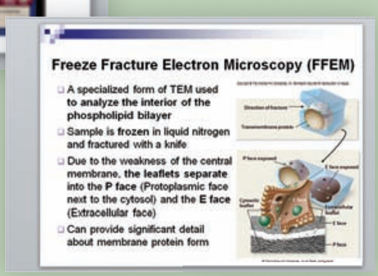

◀ Enhance your presentations with lecture PowerPoints with animations fully embedded.

3-D Animations bring biology to life with dynamic imagery and interesting presentation tools, such as the highlighting pen.
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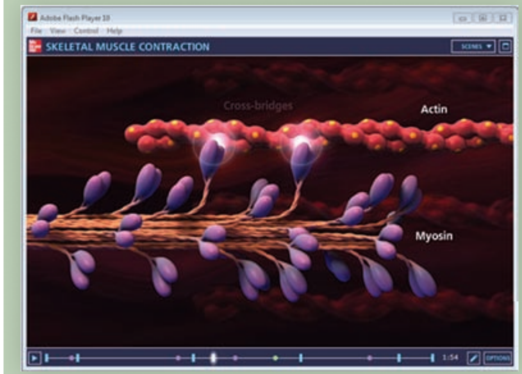
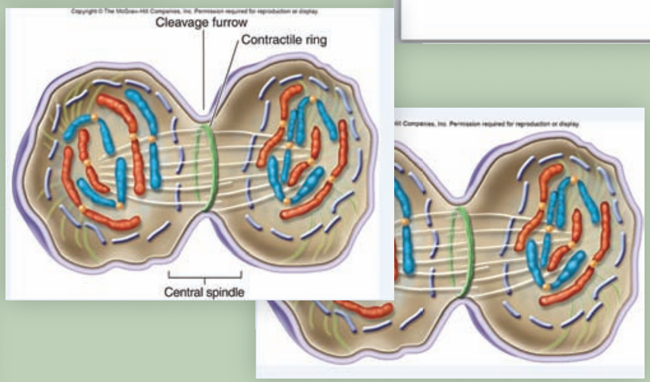




◀ Labeled and unlabeled JPEG files of all art and photos in the text can be readily incorporated into presentations, exams, or custom-made classroom materials.

2 Engage your students during class with Active Learning resources. Use Tegrity, the lecture-capture program in Connect, to reach your students outside of class.

Active Learning in Connect

Chapter	Guided Collaborative Activities	Minute Papers	Clicker Questions	Concept Mapping
All Chapters	Guided Collaborative Learning Activities (11986.0K)	Available soon	Available soon	Available soon
Ch01 An Introduction to Biology	Experimental Design - Metabo-Herb (91.0K) Hypothesis Testing (172.0K)	Ch01 Minute Papers PPT (324.0K)	Ch01 Clicker Questions PPT (350.0K)	Ch1 Concept Map Scientific Theory (296.0K)
Ch02 The Chemical Basis of Life I: Atoms, Molecules, and Water		Ch02 Minute Papers PPT (177.0K)	Ch02 Clicker Questions PPT (215.0K)	Ch2 Concept Map Chemistry (226.0K)
Ch03 The Chemical Basis of Life II: Organic Molecules	Fatty Acids, Nutrition, Health (432.0K) How Expensive Are You? (125.0K)	Ch03 Minute Papers PPT (175.0K)	Ch03 Clicker Questions PPT (221.0K)	Ch3 Concept Map Biomolecules (150.0K)
Ch04 General Features of Cells	Organelles and Illness (91.0K)	Ch04 Minute Papers PPT (168.0K)	Ch04 Clicker Questions PPT (227.0K)	Ch4 Concept Map Eukaryotic Cell Components (145.0K)

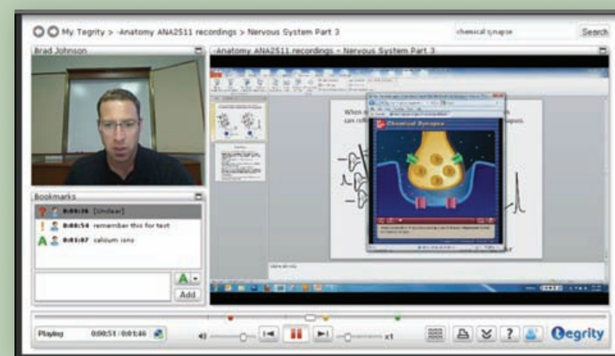
▲

Active-learning resources in Connect are sorted by chapter and designed to help you offer activities with varying degrees of participation: from Collaborative In-class Activities that are supported with instructor resources and prebuilt student assignments to Clicker Questions, Minute Papers, and Concept Maps.

Mc Graw Hill Education Tegrity

Use Tegrity to record your class activities. Your students can revisit your presentations and discussions after class with access to all the materials you covered.

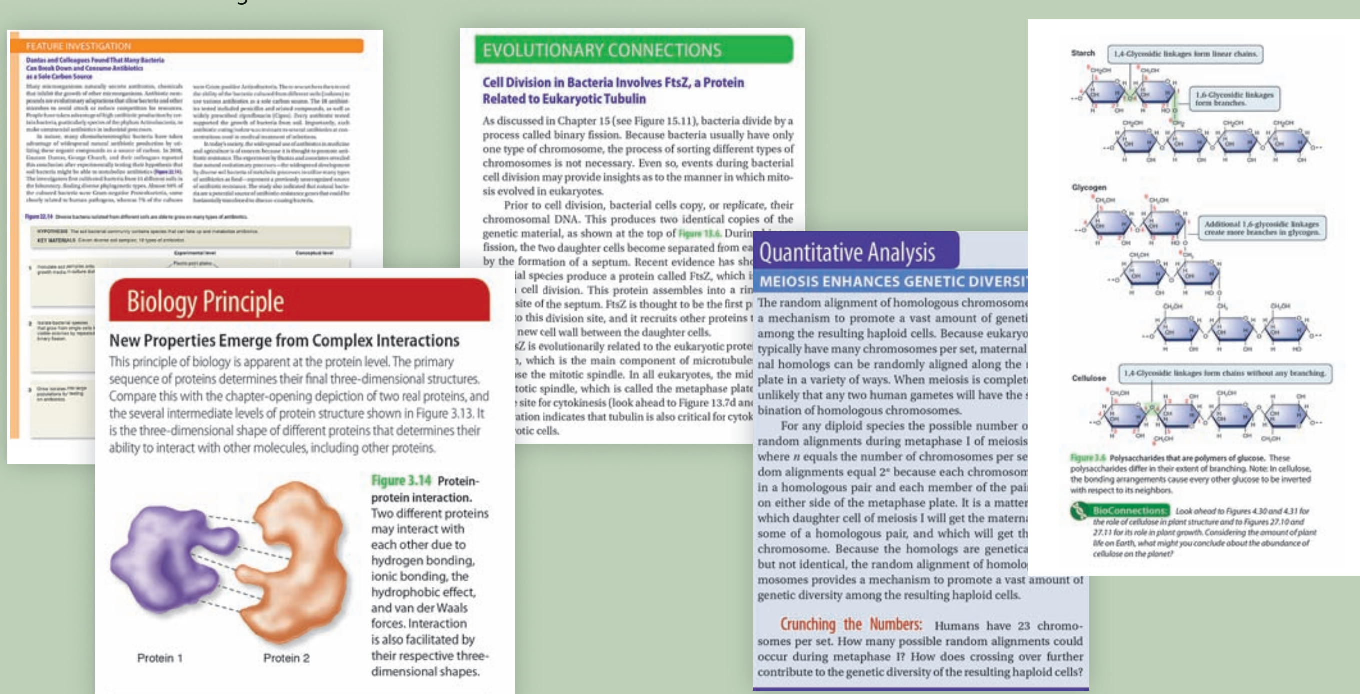
▼

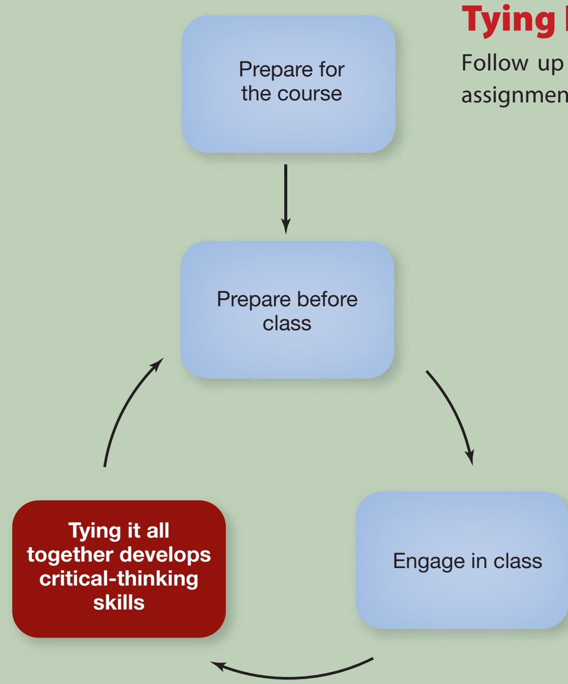


3 If your students are better prepared when they walk into class, you can expand your coverage beyond the scope of basic concepts, incorporating discussion sessions and working on critical thinking skills.

Challenge your students

The authors of *Principles of Biology* understand that today's biology majors need to move beyond memorization and content acquisition. Features in the text such as Feature Investigations, Quantitative Analysis, Biology Principles figures, Evolutionary Connections, and BioConnections questions challenge students to apply their knowledge. Assignable online assessments and activities support the development of critical-thinking skills.

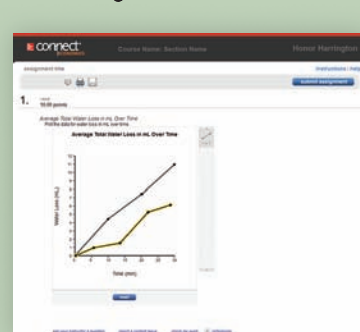




Tying It All Together for Your Students

Follow up your class with assessment that helps students develop critical-thinking skills. Set up assignments from the various assessment banks in Connect.

The Question and Test Banks contain higher order critical thinking questions that require students to demonstrate a more in-depth understanding of the concepts—as described on page xiii, you can quickly and easily filter the banks for these questions using higher level Blooms. BioConnections question banks provide questions that require students make connections among topics across chapters, developing critical-thinking skills.



◀ **Quantitative Analysis** features in the text have assignable online activities that encourage students to practice and strengthen their quantitative reasoning skills.

Many chapters also contain a **Quantitative Question Bank.** These are more challenging algorithmic questions, intended to help your students practice their quantitative reasoning skills. Hints and guided solution options step students through a problem. ▶

LEARNSMART LABS™

Based on the same world-class superadaptive technology as LearnSmart, McGraw-Hill LearnSmart-Labs is a must-see, outcomes-based lab simulation. It assesses a student's knowledge and adaptively corrects deficiencies, allowing the student to learn faster and retain more knowledge with greater success. Whether your need is to overcome the logistical challenges of a traditional lab, provide better lab prep, improve student performance, or create an online experience that rivals the real world, LabSmart accomplishes it all.

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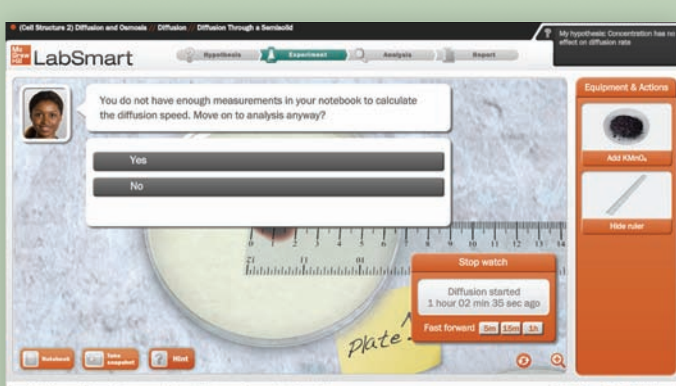
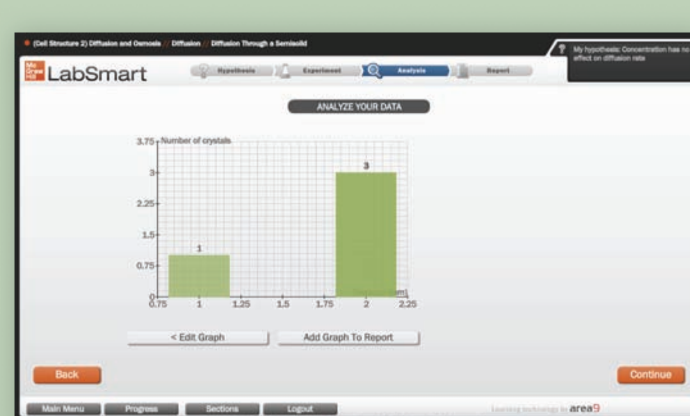


LearnSmart Labs can be used to help students apply the scientific process, thinking and doing like scientists via rich simulations.



ACKNOWLEDGMENTS

The lives of most science-textbook authors do not revolve around an analysis of writing techniques. Instead, we are people who understand science and are inspired by it, and we want to communicate that information to our students. Simply put, we need a lot of help to get it right.

Editors are a key component that help the authors modify the content of their book so it is logical, easy to read, and inspiring. The editorial team for *Principles of Biology* has been a catalyst that kept this project rolling. The members played various roles in the editorial process. Rebecca Olson, Brand Manager for Majors Biology, did an outstanding job of overseeing the development of this new text. Her insights with regard to pedagogy, content, and organization have been invaluable. Elizabeth Sievers, Director of Development—Biology, has been the master organizer. Liz's success at keeping us on schedule is greatly appreciated.

Our Freelance Developmental Editor, Joni Fraser, worked directly with the authors to greatly improve the presentation of the textbook's content. She did a great job of editing chapters and advising the authors on improvements. We would also like to acknowledge our copy editor, Linda Davoli, for keeping our grammar on track.

Another important aspect of the editorial process is the actual design, presentation, and layout of materials. It's confusing if the text and art aren't near each other or if a figure is too large or too small. We are indebted to the tireless efforts of Sandy Wille, Content Project Manager, and David Hash, Senior Designer at McGraw-Hill Education. Likewise, our production company, Lachina Publishing Services, did an excellent job with the paging, extensive revisions of the art, and the creation of new art. Their artistic talents, ability to size and arrange figures, and attention to the consistency of the figures has been remarkable.

We would like to acknowledge the ongoing efforts of the superb marketing staff at McGraw-Hill Education. Special thanks to Patrick Reidy, Executive Marketing Manager—Life Sciences, for his ideas and enthusiasm for this book.

Other staff members at McGraw-Hill Education have ensured that the authors and editors were provided with adequate resources to achieve the goal of producing a superior textbook. These include Kurt Strand, Senior Vice President, Products & Markets; Marty Lange, Vice President, General Manager, Products & Markets; Michael Hackett, Managing Director for Life Science; and Lynn Breithaupt, Director for Biology.

We would like to thank the subject matter experts who helped in the development of the digital assets in Connect that support *Principles of Biology*. Finally, we need to thank our reviewers. Instructors from across the country are continually invited to share their knowledge and experience with us through reviews and focus groups. The feedback we received shaped this new text. All of these people took time out of their already busy lives to help us build a text to reach out to introductory biology students, and they have our heartfelt thanks.

The authors are grateful for the help, support, and patience of their families, friends, and students: Deb, Dan, Nate, and Sarah Brooker; Maria, Rick, and Carrie Widmaier; Jim, Michael, and Melissa Graham; and Jacqui, Zoe, Leah, and Jenna Stiling.

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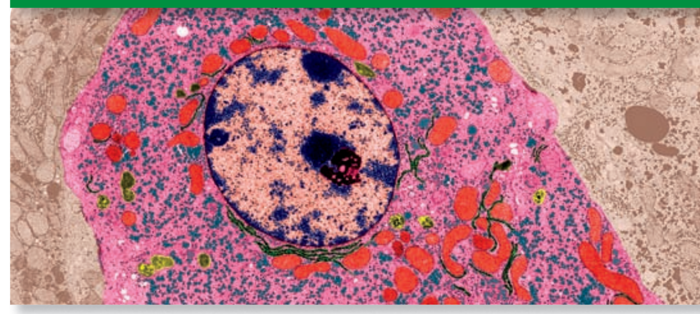

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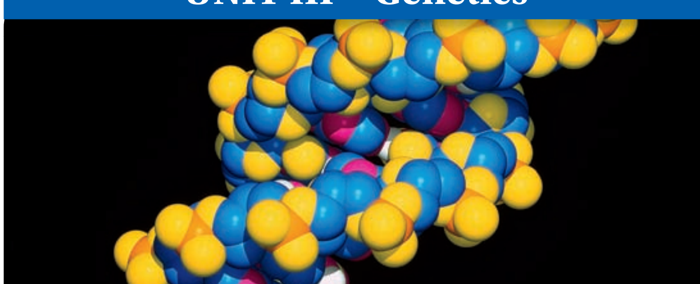

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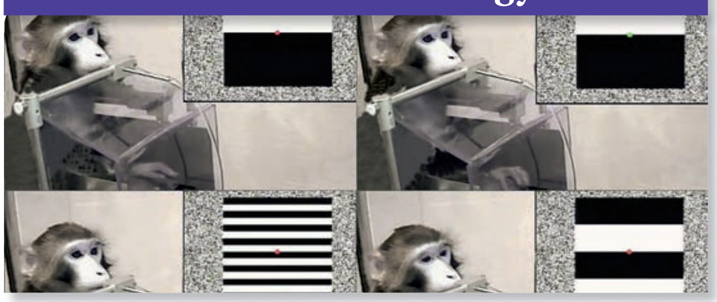
UNIT VIII Ecology



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1

An Introduction to Biology

The bee orchid (*Ophrys apifera*). This orchid produces a pheromone that attracts male bees, thereby aiding in its pollination.

Chapter Outline

1.1 Principles of Biology and the Levels of Biological Organization

1.2 Unity and Diversity of Life

1.3 Biology as a Scientific Discipline

Assess and Discuss

Biology is the study of life. The diverse forms of life found on Earth provide biologists with an amazing array of organisms to study. In many cases, the investigation of living things leads to discoveries with far-reaching benefits. Certain ancient civilizations, such as the Greeks, Romans, and Egyptians, discovered that the bark of the white willow tree (*Salix alba*) could be used to fight fever. Chemists determined that willow bark contains a substance called salicylic acid, which led to the development of the related compound acetylsalicylic acid, more commonly known as aspirin (**Figure 1.1**). Today, aspirin is taken not only for fever and pain relief, but is also recommended for the prevention of heart attacks and strokes.

As a more recent example, researchers determined that the venom from certain poisonous snakes contains a chemical that lowers blood pressure in humans. By analyzing that chemical, scientists have developed drugs called ACE inhibitors that treat high blood pressure (**Figure 1.2**).

These are just a couple of the many discoveries that make biology an intriguing discipline. The study of life not only reveals the fascinating characteristics of living species but also leads to the development of medicines and research tools that benefit the lives of people.

To make new discoveries, biologists view life from many different perspectives. What is the composition of living things? How is life organized? How do organisms reproduce? Sometimes the questions posed by biologists are fundamental and even philosophical in nature. How did living organisms originate? Can we live forever? What is the physical basis for memory? Can we save endangered species?

Future biologists will continue to make important advances. Biologists are scientific explorers looking for answers to some of life's most enduring mysteries. Unraveling these mysteries presents an exciting challenge to the best and brightest minds. The rewards of a career in biology include the excitement of forging into uncharted territory, the thrill of making discoveries that can improve the health and lives of people, and the goal of trying to preserve the environment and protect endangered species. For these and many other compelling reasons, students seeking challenging and rewarding careers may wish to choose biology as a lifelong pursuit.

In this chapter, we will begin our survey of biology by examining the basic principles that underlie the characteristics of all living organisms and the fields of biology. We then take a deeper look at the process of evolution and how it explains the unity and diversity that we observe among living species. Finally, we will explore the general approaches that scientists follow when making new discoveries.

Figure 1.1 The white willow (*Salix alba*) and aspirin. Modern aspirin, acetylsalicylic acid, was developed after analysis of a chemical found in the bark of the white willow tree.

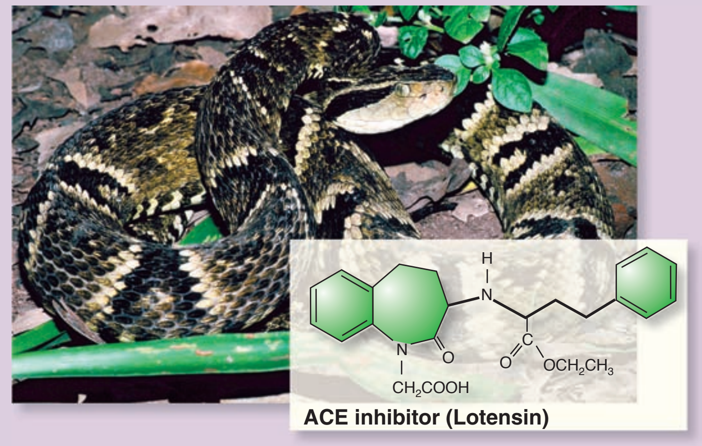


Figure 1.2 The Brazilian arrowhead viper and inhibitors of high blood pressure. Originally found in the venom of the Brazilian arrowhead viper (*Bothrops jararaca/jararacussa*), angiotensin-converting enzyme (ACE) inhibitors, including benazepril (Lotensin, chemical structure shown here), are commonly used to treat high blood pressure.

1.1 Principles of Biology and the Levels of Biological Organization

Learning Outcomes:

1. Describe the principles of biology.
2. Explain how life can be viewed at different levels of biological complexity.

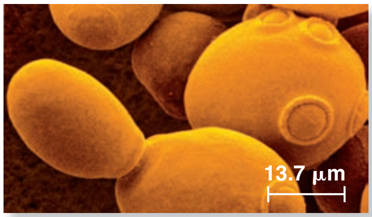
Because biology is the study of life, a good way to begin a biology textbook is to distinguish living organisms from nonliving objects. At first, the distinction might seem obvious. A person is alive, but a rock is not. However, the distinction between living and nonliving may seem less obvious when we consider microscopic entities. Is a bacterium alive? What about a virus or a chromosome? In this section, we will examine the principles that underlie the characteristics of all forms of life and explore other broad principles in biology. We will then consider the levels of organization that biologists study, ranging from atoms and small molecules to very large geographical areas.

The Study of Life Has Revealed a Set of Unifying Principles

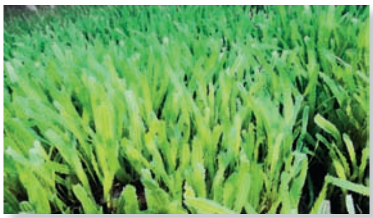
In the course of studying a vast number of species, biologists have learned that a set of principles applies to all fields of biology. Twelve broad principles are described in Figure 1.3. The first eight principles are often used as criteria for defining the basic features of life. You will see these 12 principles at many points as you progress through this textbook. In particular, we will draw your attention to them at the beginning of each unit, and we will refer to them within particular figures in Chapters 2 through 47. It should be noted that the principles of biology are also governed by the laws of chemistry and physics, which are discussed in Chapters 2, 3, and 6.

Principle 1: Cells are the simplest unit of life. The term **organism** can be applied to all living things. Organisms maintain an internal order that is separated from the environment (Figure 1.3a). The simplest unit of such organization is the cell, which we will examine in Unit II. One of the foundations of biology is the **cell theory,** which states that (1) all organisms are composed of one or more cells, (2) cells are the smallest units of life, and (3) new cells come from pre-existing cells by cell division. Unicellular organisms are composed of one cell, whereas multicellular organisms such as plants and animals contain many cells. In plants and animals, each cell has an internal order, and the cells within the body have specific arrangements and functions.

Principle 2: Living organisms use energy. The maintenance of organization requires energy. Therefore, all living organisms acquire energy from the environment and use that energy to maintain their internal order. Cells carry out a variety of chemical reactions that are responsible for the breakdown of energy-yielding



(a) Cells are the simplest unit of life:
Organisms maintain an internal order. The simplest unit of organization is the cell. Yeast cells are shown here.



(b) Living organisms use energy:
Organisms need energy to maintain internal order. These algae harness light energy via photosynthesis. Energy is used in chemical reactions collectively known as metabolism.

(c) Living organisms interact with their environment:
Organisms respond to environmental changes. These plants are growing toward the light.

(d) Living organisms maintain homeostasis:
Organisms regulate their cells and bodies, maintaining relatively stable internal conditions, a process called homeostasis.

(e) Living organisms grow and develop:
Growth produces more or larger cells, whereas development produces organisms with a defined set of characteristics.

(f) The genetic material provides a blueprint for reproduction:
To sustain life over many generations, organisms must reproduce. Due to the transmission of genetic material, offspring tend to have traits like their parents.

(g) Populations of organisms evolve from one generation to the next:
Populations of organisms change over the course of many generations. Evolution results in traits that promote survival and reproductive success.

(h) All species (past and present) are related by an evolutionary history:
The three mammal species shown here share a common ancestor, which was also a mammal.

(i) Structure determines function:
In the example seen here, webbed feet (on ducks) function as paddles for swimming. Nonwebbed feet (on chickens) function better for walking on the ground.

(j) New properties of life emerge from complex interactions:
Our ability to see is an emergent property due to interactions among many types of cells in the eye and neurons that send signals to the brain.

(k) Biology is an experimental science:
The discoveries of biology are made via experimentation, which leads to theories and biological principles.

(l) Biology affects our society:
Many discoveries in biology have had major effects on our society. For example, biologists developed Bt-corn, which is resistant to insect pests and is widely planted by farmers.

Figure 1.3 Twelve principles of biology. The first eight principles are often used as criteria for defining the basic features of life. Note: The principles described here are considered very broad. Biologists have determined many others that have a more defined focus.

BioConnections: *Look ahead to Figure 4.11. Which of these principles is this figure emphasizing?*

nutrients. Such reactions often release energy in a process called **cellular respiration.** The energy may be used to synthesize the components that make up individual cells and living organisms. Chemical reactions involved with the breakdown and synthesis of cellular molecules are collectively known as **metabolism.** Plants, algae, and certain bacteria directly harness light energy to produce their own nutrients in the process of **photosynthesis** (Figure 1.3b). They are the primary producers of food on Earth. In contrast, some organisms, such as animals and fungi, are consumers—they must use other organisms as food to obtain energy.

Principle 3: Living organisms interact with their environment. To survive, living organisms must interact with their environment, which includes other organisms they may encounter. All organisms must respond to environmental changes. For example, bacterial cells have mechanisms to detect that certain nutrients in the environment are in short supply, whereas others are readily available. In the winter, many species of mammals develop a thicker coat of fur that protects them from the cold temperatures. Plants respond to changes in the angle of the Sun. If you place a plant in a window, it will grow toward the light (Figure 1.3c).

Principle 4: Living organisms maintain homeostasis. As we have just seen, living organisms respond to environmental variation. Although life is a dynamic process, living cells and organisms regulate their cells and bodies to maintain relatively stable internal conditions, a process called **homeostasis** (from the Greek, meaning to stay the same). The degree to which homeostasis is achieved varies among different organisms. For example, most mammals and birds maintain a relatively stable body temperature in spite of changing environmental temperatures (Figure 1.3d), whereas reptiles and amphibians tolerate a wider fluctuation in body temperature. By comparison, all organisms continually regulate their cellular metabolism so that nutrient molecules are used at an appropriate rate and new cellular components are synthesized when they are needed.

Principle 5: Living organisms grow and develop. All living organisms have an ability to grow and develop. **Growth** produces more or larger cells, which usually results in an increase in size and weight. Multicellular organisms, such as plants and animals, begin life at a single-cell stage (for example, a fertilized egg) and then undergo multiple cell divisions to develop into a complete organism with many cells. Among unicellular organisms such as bacteria, new cells are relatively small, and they increase in volume by the synthesis of additional cellular components. **Development** is a series of changes in the state of a cell, tissue, organ, or organism, eventually resulting in organisms with a defined set of characteristics (Figure 1.3e).

Principle 6: The genetic material provides a blueprint for reproduction. All living organisms have a finite life span. To sustain life, organisms must **reproduce,** or generate offspring (Figure 1.3f). A key feature of reproduction is that offspring tend to have characteristics that greatly resemble those of their parent(s). How is this possible? All living organisms contain genetic material composed of **deoxyribonucleic acid (DNA),** which provides a blueprint for the organization, development, and function of living things. During reproduction, a copy of this blueprint is transmitted from parent to offspring. DNA is **heritable,** which means that offspring inherit DNA from their parents.

As discussed in Unit III, **genes,** which are segments of DNA, govern the characteristics, or traits, of organisms. Most genes are transcribed into a type of **RNA (ribonucleic acid)** molecule called messenger RNA (mRNA) that is then translated into a **polypeptide** with a specific amino acid sequence. A **protein** is composed of one or more polypeptides. The structures and functions of proteins are largely responsible for the traits of living organisms.

Principle 7: Populations of organisms evolve from one generation to the next. The first six characteristics of life, which we have just considered, apply to individual organisms over the short run. Over the long run, another universal characteristic of life is **biological evolution,** or simply **evolution,** which refers to a heritable change in a population of organisms from generation to generation. As a result of evolution, populations become better adapted to the environment in which they live. For example, the long snout of an anteater is an adaptation that enhances its ability to obtain food, namely ants, from hard-to-reach places (Figure 1.3g). Over the course of many generations, the fossil record suggests that the long snout occurred via biological evolution in which modern anteaters evolved from populations of organisms with shorter snouts.

In many chapters of this textbook, you will find a subsection called "Evolutionary Connections," which focuses on the evolutionary aspects of the chapter's material.

Principle 8. All species (past and present) are related by an evolutionary history. Principle 7 considers evolution as an ongoing process that happens from one generation to the next. Evidence from a variety of sources, including the fossil record and DNA sequences, also indicates that all organisms on Earth share a common ancestry. For example, the three species of mammals shown in Figure 1.3h shared a common ancestor in the past, which was also a mammal. We will discuss evolutionary relationships further in Section 1.2.

Principle 9: Structure determines function. In addition to the preceding eight characteristics of life, biologists have identified other principles that are important in all fields of biology. The principle that structure determines function pertains to very tiny biological molecules as well as very large biological structures. For example, at the microscopic level, a cellular protein called actin naturally assembles into structures that are long filaments. The function of these filaments is to provide support and shape to cells. At the macroscopic level, let's consider the feet of different birds (Figure 1.3i). Aquatic birds have webbed feet that function as paddles for swimming. By comparison, the feet of nonaquatic birds are not webbed and are better adapted for grasping food, perching on branches, and running along the ground. In this case, the structure of a bird's feet, webbed versus nonwebbed, is a critical feature that affects their function.

Principle 10: New properties of life emerge from complex interactions. In biology, when individual components in an organism interact with each other or with the external environment to create novel structures and functions, the resulting characteristics are called **emergent properties.** For example, the human eye is composed of many different types of cells that are organized to sense incoming light and transmit signals to the brain (Figure 1.3j). Our ability to see is an emergent property of this complex arrangement of different cell types.

Principle 11: Biology is as an experimental science. Biology is an inquiry process. Biologists are curious about the characteristics of living organisms and ask questions about those characteristics.

For example, a cell biologist may wonder why a cell produces a specific protein when it is confronted with high temperature. An ecologist may ask herself why a particular bird eats insects in the summer and seeds in the winter. To answer such questions, biologists typically gather additional information and ultimately form a hypothesis, which is a proposed explanation for a natural phenomenon. The next stage is to design one or more experiments to test the validity of a hypothesis (Figure 1.3k).

Like evolution, experimentation is such a key aspect of biology that many chapters of this textbook include a "Feature Investigation"—an actual research study that showcases the experimental approach.

Principle 12. Biology affects our society. The influence of biology is not confined to textbooks and classrooms. The work of biologists has far-reaching effects in our society. For example, biologists have discovered drugs that are used to treat many different human diseases. Likewise, biologists have created technologies that have many uses. Examples include the use of microorganisms to make medical products, such as human insulin, and the genetic engineering of crops to make them resistant to particular types of insect pests (Figure 1.3l).

Living Organisms Are Studied at Different Levels of Organization

The organization of living organisms can be analyzed at different levels of biological complexity, starting with the smallest level of organization and progressing to levels that are physically much larger and more complex. **Figure 1.4** depicts a scientist's view of the levels of biological organization.

1. **Atoms:** An **atom** is the smallest unit of an element that has the chemical properties of the element. All matter is composed of atoms.
2. **Molecules and macromolecules:** As discussed in Unit I, atoms bond with each other to form **molecules.** Many smaller molecules bonded together to form a large polymer is called a **macromolecule.** Carbohydrates, proteins, and nucleic acids (for example, DNA and RNA) are important macromolecules found in living organisms.
3. **Cells:** Molecules and macromolecules associate with each other to form larger structures such as cells. A **cell** is surrounded by a membrane and contains a variety of molecules and macromolecules. As noted earlier, a cell is the simplest unit of life.
4. **Tissues:** In the case of multicellular organisms such as plants and animals, many cells of the same type associate with each other to form **tissues.** An example is muscle tissue.
5. **Organs:** In complex multicellular organisms, an **organ** is composed of two or more types of tissue. For example, the heart is composed of several types of tissues, including muscle, nervous, and connective tissue.
6. **Organism:** All living things can be called **organisms.** Biologists classify organisms as belonging to a particular **species,** which is a related group of organisms that share a distinctive form and set of attributes in nature. The members of the same species are closely related genetically. In Units VI and VII, we will examine plants and animals at the level of cells, tissues, organs, and complete organisms.
7. **Population:** A group of organisms of the same species that occupy the same environment is called a **population.**
8. **Community:** A biological **community** is an assemblage of populations of different species that live in the same environment. The types of species found in a community are determined by the environment and by the interactions of species with each other.
9. **Ecosystem:** Researchers may extend their work beyond living organisms and also study the physical environment. Ecologists analyze **ecosystems,** which are formed by interactions between a community of organisms and its physical environment. Unit VIII considers biology from populations to ecosystems.
10. **Biosphere:** The **biosphere** includes all of the places on the Earth where living organisms exist. Life is found in the air, in bodies of water, on the land, and in the soil.

1.1 Reviewing the Concepts

- Biology is the study of life. Discoveries in biology help us understand how life exists, and they also have many practical applications, such as the development of drugs to treat human diseases (Figures 1.1, 1.2).
- Eight principles underlie the characteristics that are common to all forms of life. All living things (1) are composed of cells as their simplest unit; (2) use energy; (3) interact with their environment; (4) maintain homeostasis; (5) grow and develop; and (6) have genetic material for reproduction. Also, (7) populations of organisms evolve from one generation to the next, and; (8) are connected by an evolutionary history (Figure 1.3).
- Additional important principles of biology are that (9) structure determines function; (10) new properties emerge from complex interactions; (11) biology is an experimental science; and (12) biology influences our society.
- Living organisms can be viewed at different levels of biological organization: atoms, molecules and macromolecules, cells, tissues, organs, organisms, populations, communities, ecosystems, and the biosphere (Figure 1.4).

1.1 Testing Your Knowledge

1. The wing of a bird, the wing of an insect, and the wing of a bat have similar shapes. Which principle of biology does this observation pertain to?

a. Living organisms use energy.
b. Living organisms maintain homeostasis.
c. Structure determines function.
d. Populations of organisms evolve from one generation to the next.
e. All of the above.

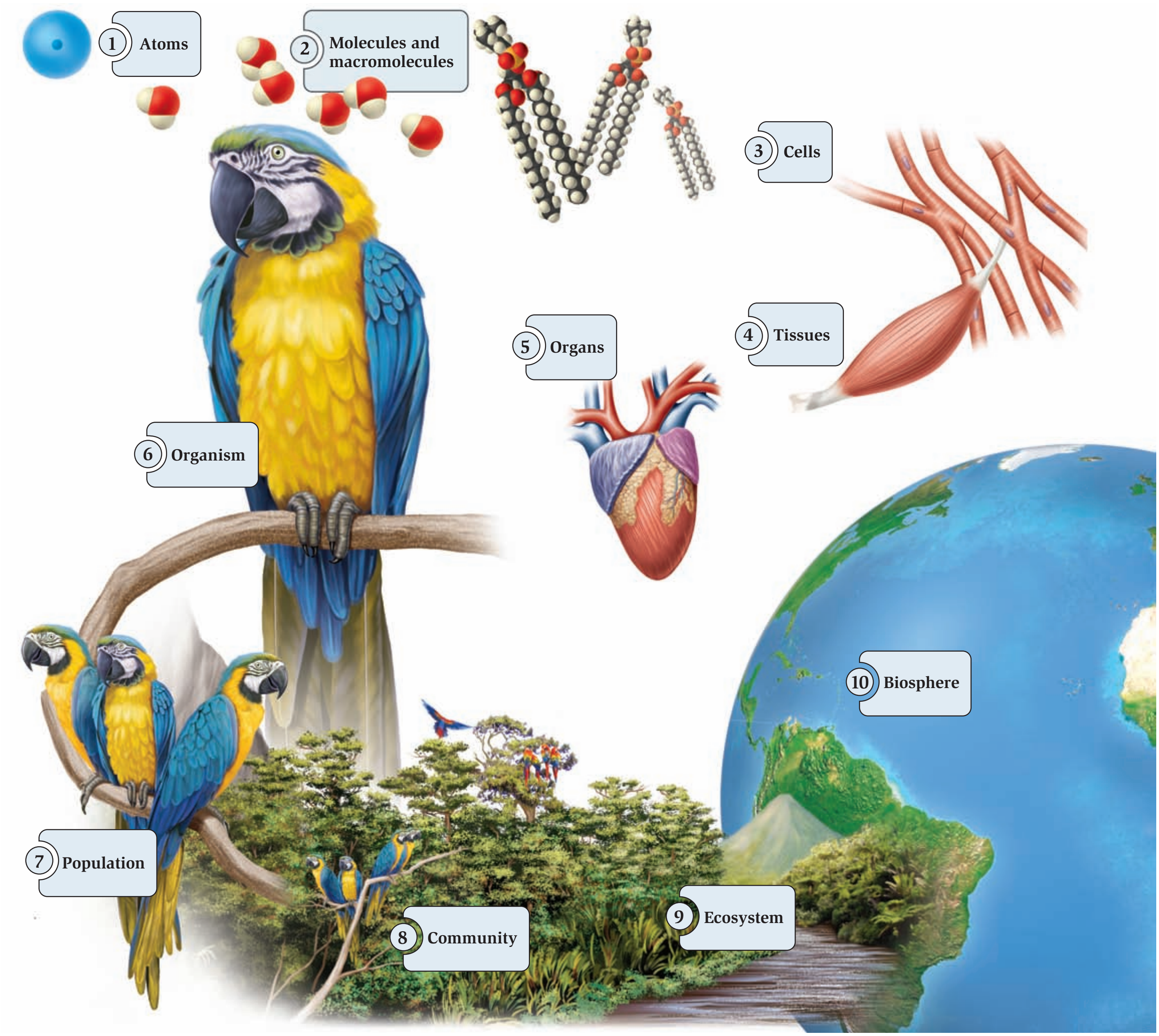


Figure 1.4 **The levels of biological organization.**

Concept Check: *At which level of biological organization would you place a herd of buffalo?*

2. Which of the following is the most complex level of biological organization?
   a. organism **b.** tissue **c.** community **d.** population

1.2 Unity and Diversity of Life

Learning Outcomes:

1. Explain the two basic mechanisms by which evolutionary change occurs: vertical descent with mutation and horizontal gene transfer.
2. Outline how organisms are classified (taxonomy).
3. Describe how evolution accounts for unity and diversity in biology.

Unity and diversity are two words that often are used to describe the living world. As we have seen, all modern forms of life display a common set of characteristics that distinguish them from nonliving objects. In this section, we will explore how this unity of common traits is rooted in the phenomenon of biological evolution. Life on Earth is united by an evolutionary past in which modern organisms have evolved from populations of pre-existing organisms.

Evolutionary unity does not mean that organisms are exactly alike. The Earth has many different types of environments, ranging from tropical rain forests to salty oceans, from hot and dry deserts to cold mountaintops. Diverse forms of life have evolved in ways that help them prosper in the different environments the Earth has to offer. In this section, we will begin to examine the unity and diversity that exists within the biological world.

Modern Forms of Life Are Connected by an Evolutionary History

Life began on Earth as primitive cells about 3.5–4 billion years ago (bya). Since that time, populations of living organisms underwent evolutionary changes that ultimately gave rise to the species we see today. Understanding the evolutionary history of species can provide key insights into an organism's structure and function, because evolutionary change frequently involves modifications of characteristics in pre-existing populations. Over long periods of time, populations may change so that structures with a particular function may become modified to serve a new function. For example, the wing of a bat is used for flying, and the flipper of a dolphin is used for swimming. Evidence from the fossil record indicates that both structures were modified from a limb that was used for walking in a pre-existing ancestor (**Figure 1.5**).

Evolutionary change occurs by two mechanisms: vertical descent with mutation and horizontal gene transfer. Let's take a brief look at each of these mechanisms.

Vertical Descent with Mutation The traditional way to study evolution is to examine a progression of changes in a series of ancestors. Such a series is called a **lineage.** Biologists have traditionally depicted such evolutionary change in a diagram like the one shown in **Figure 1.6**, which shows a portion of the lineage that gave rise to modern horses. In this mechanism of evolution, called **vertical evolution,** new species evolve from pre-existing ones by the accumulation of **mutations,** which are random changes in the genetic material of organisms. But why would some mutations accumulate in a population and eventually change the characteristics of an entire species? One reason is that a mutation may alter the traits of organisms in a way that increases their chances of survival and reproduction. When a mutation causes such a beneficial change, the frequency of the mutation may increase in a population from one generation to the next, a process called **natural selection.** This topic is discussed in Units IV and V. Evolution also involves the accumulation of neutral changes that do not benefit or harm a species, and evolution sometimes involves rare changes that may be harmful.

With regard to the horses shown in Figure 1.6, the fossil record has revealed adaptive changes in various traits such as size and tooth morphology. The first horses were the size of dogs, whereas modern horses typically weigh more than a half ton. The teeth of *Hyracotherium* were relatively small compared with those of modern horses. Over the course of millions of years, horse teeth have increased in size, and a complex pattern of ridges has developed on the molars. How do evolutionary biologists explain these changes in horse characteristics? They can be attributed to natural selection producing adaptations to changing global climates. Over North America, where much of horse evolution occurred, large areas changed from dense forests to grasslands. The horses' increase in size allowed them to escape predators and travel greater distances in search of food. The changes seen in horses' teeth are consistent with a dietary shift from eating tender leaves to eating grasses and other vegetation that are more abrasive and require more chewing.

Horizontal Gene Transfer The most common way for genes to be transferred is in a vertical manner. This can involve the transfer of genetic material from a mother cell to daughter cells, or it can occur via gametes—sperm and egg—that unite to form a new organism. However, as discussed in Chapter 21, genes are sometimes transferred between organisms by **horizontal gene transfer**—a process in which an organism incorporates genetic material from another organism without being the offspring of that organism. In some cases, horizontal gene transfer can occur between members of different species. For example, you may have heard in the news media that resistance to antibiotics among bacteria is a growing medical problem. This can occur by the transfer of an antibiotic resistance gene from one bacterial species to another via horizontal gene transfer.

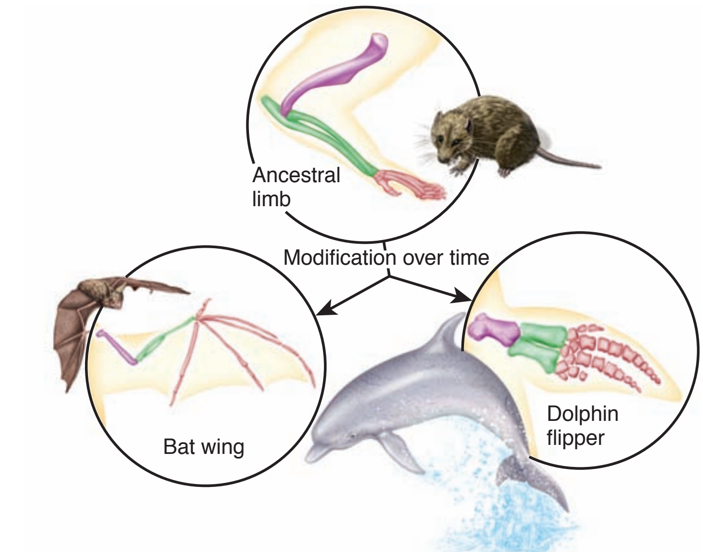


Figure 1.5 An example showing a modification that has occurred as a result of biological evolution. The wing of a bat and the flipper of a dolphin are modifications of a limb that was used for walking in a pre-existing ancestor.

Concept Check: *Among mammals, give two examples of how the tail has been modified and has different purposes.*

Traditionally, biologists have described evolution using diagrams such as that in Figure 1.6, which depict the vertical evolution of species over a long time scale. In this view, all living organisms evolved from a common ancestor, resulting in a "tree of life" that could describe the evolution that gave rise to all modern species. Now that we understand the great importance of horizontal gene transfer in the evolution of life on Earth, biologists have reevaluated the concept of evolution as it occurs over time. Rather than a tree of life, a more appropriate way to view the unity of living organisms is to describe it as a "web of life" (as discussed in Chapter 21, see Figure 21.12), which accounts for both vertical evolution and horizontal gene transfer.

The Classification of Living Organisms Allows Biologists to Appreciate the Unity and Diversity of Life

As biologists discover new species, they try to place them in groups based on their evolutionary history. This is a difficult task because researchers estimate that the Earth has between 10 and 100 million different species! The rationale for categorization is

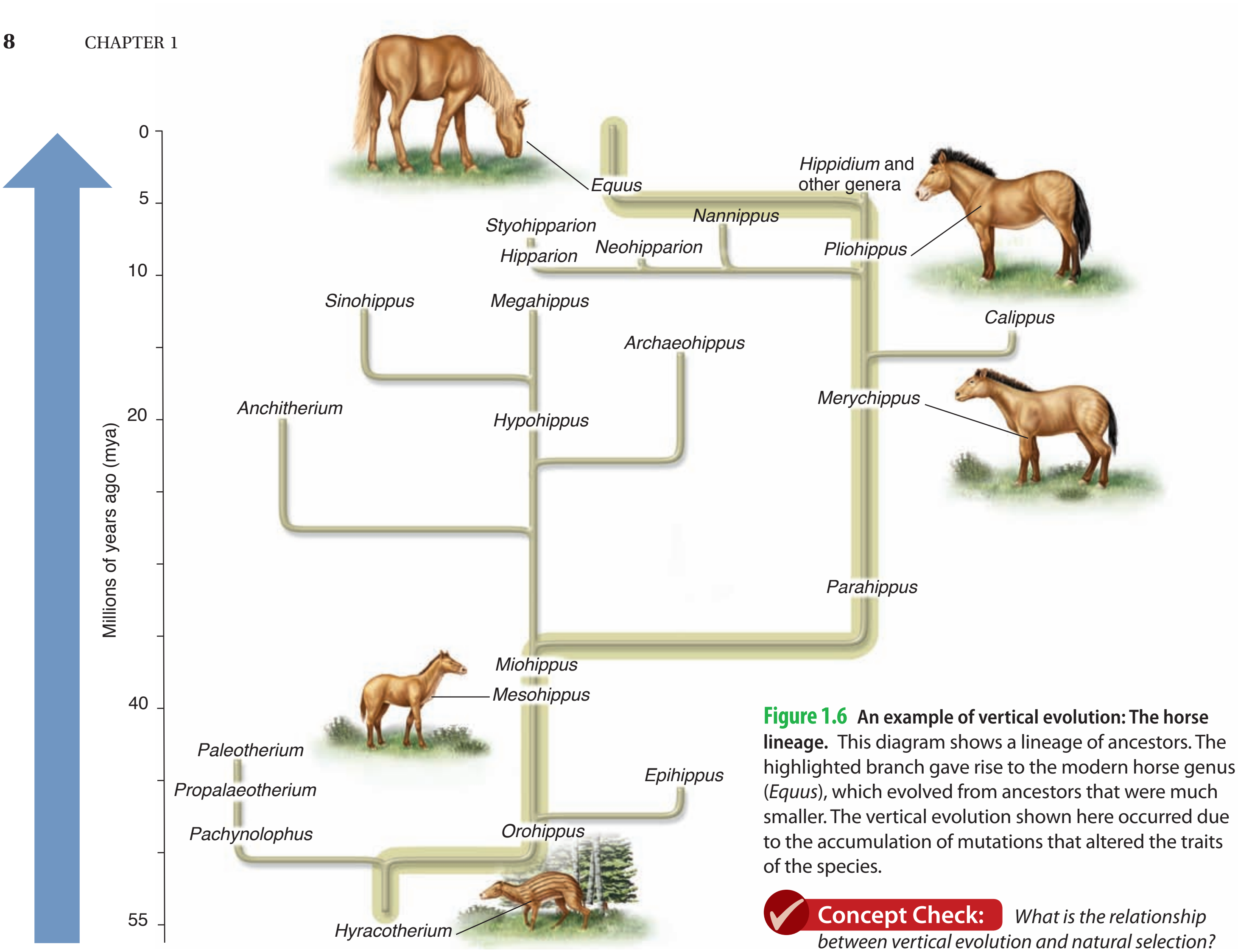


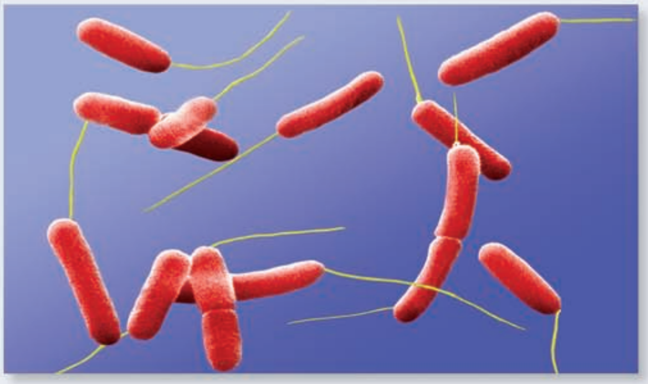
Figure 1.6 An example of vertical evolution: The horse lineage. This diagram shows a lineage of ancestors. The highlighted branch gave rise to the modern horse genus (*Equus*), which evolved from ancestors that were much smaller. The vertical evolution shown here occurred due to the accumulation of mutations that altered the traits of the species.

Concept Check: *What is the relationship between vertical evolution and natural selection?*

usually based on vertical evolution. Species with a recent common ancestor are grouped together, whereas species whose common ancestor was in the very distant past are placed into different groups. The grouping of species is termed **taxonomy.**

Let's first consider taxonomy on a broad scale. From an evolutionary perspective, all forms of life can be placed into three large categories, or **domains,** called **Bacteria, Archaea,** and **Eukarya** (Figure 1.7). Bacteria and archaea are microorganisms that are also termed **prokaryotic** because their cell structure is relatively simple. At the molecular level, bacterial and archaeal cells show significant differences in their compositions. By comparison, organisms in domain Eukarya are termed **eukaryotic;** they have larger cells with internal compartments that serve various functions. A defining distinction between prokaryotic and eukaryotic cells is that eukaryotic cells have a **nucleus** in which the genetic material is surrounded by a membrane. The organisms in domain Eukarya were once subdivided into four major categories, or kingdoms, called Protista (protists), Plantae (plants), Fungi, and Animalia (animals). However, as discussed in Chapter 21 and Unit V, this traditional view became invalid as biologists gathered new information regarding the evolutionary relationships of these organisms. We now know the protists do not form a single kingdom but instead are divided into seven broad categories called **supergroups.**

Taxonomy involves multiple levels in which particular species are placed into progressively smaller and smaller groups of organisms that are more closely related to each other evolutionarily. Such an approach emphasizes the unity and diversity of different species. As an example, let's consider clownfish, which are found in the Indian and Pacific Oceans and are popular among salt-water aquarium enthusiasts (Figure 1.8). Several species of clownfish have been identified. One species of clownfish, which is orange with white stripes, has several common names, including Ocellaris clownfish. The broadest grouping for this clownfish is the domain, namely, Eukarya, followed by progressively smaller divisions, from supergroup (Opisthokonta) to kingdom (Animalia) and eventually to species. In the animal kingdom, clownfish are part of a phylum, Chordata, the chordates, which is subdivided into classes. Clownfish are in a class called Actinopterygii, which includes all ray-finned fishes. The common ancestor that gave rise to ray-finned fishes arose about 420 million years ago (mya). Actinopterygii is subdivided into several smaller orders. The clownfish are in the order Perciformes (bony fish). The order is, in turn, divided into families; the clownfish belong to the family of marine fish called Pomacentridae, which are often brightly colored. Families are divided into genera (singular, genus). The genus *Amphiprion* is composed of 28 different species; these are various



(a) Domain Bacteria: Mostly unicellular prokaryotes that inhabit many diverse environments on Earth.

(b) Domain Archaea: Unicellular prokaryotes that often live in extreme environments, such as hot springs.

Protists: Unicellular and small multicellular organisms that are now subdivided into seven broad groups based on their evolutionary relationships.

Plants: Multicellular organisms that can carry out photosynthesis.

Fungi: Unicellular and multicellular organisms that have a cell wall but cannot carry out photosynthesis. Fungi usually survive on decaying organic material.

Animals: Multicellular organisms that usually have a nervous system and are capable of locomotion. They must eat other organisms or the products of other organisms to live.

(c) Domain Eukarya: Unicellular and multicellular organisms having cells with internal compartments that serve various functions.

Figure 1.7 The three domains of life. **(a)** Bacteria and **(b)** Archaea are domains consisting of prokaryotic cells. The third domain, **(c)** Eukarya, comprises species that are eukaryotes.

BioConnections: *Look ahead to Figure 21.1. Are fungi more closely related to plants or animals?*