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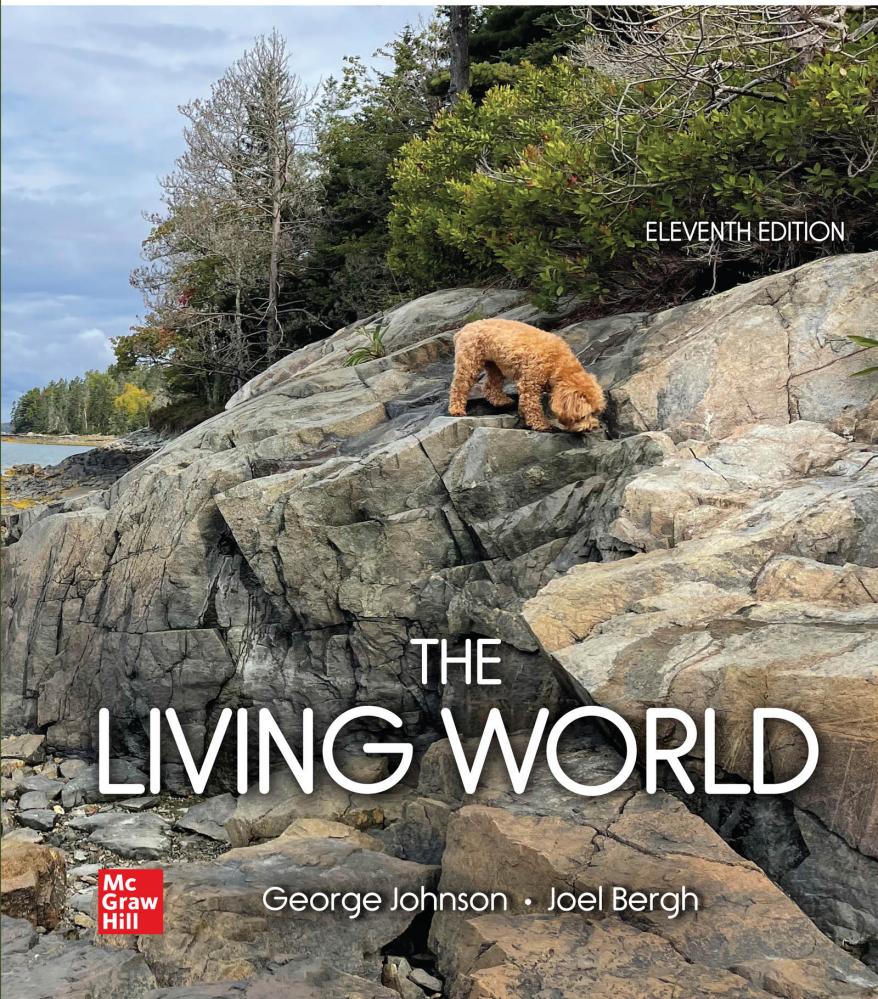

ELEVENTH EDITION

THE LIVING WORLD

George Johnson · Joel Bergh

Mc Graw Hill

ELEVENTH EDITION

The Living World

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Brief Contents

Preface

Teaching Science as a Process

Day in and day out, we make observations, form hypotheses, and draw conclusions. The COVID-19 pandemic, in particular, underlined the importance of making observations and being scientifically literate. For instance, does wearing a mask reduce the risk of infection? Which treatments are effective, and which ones are not? With news (and disinformation) coming at us from around the globe, on our televisions, our phones, and through social media, how can we determine what is accurate and correct? The first step is to clearly grasp how science is carried out. This book highlights essential biological concepts that help you understand science and the scientific method.

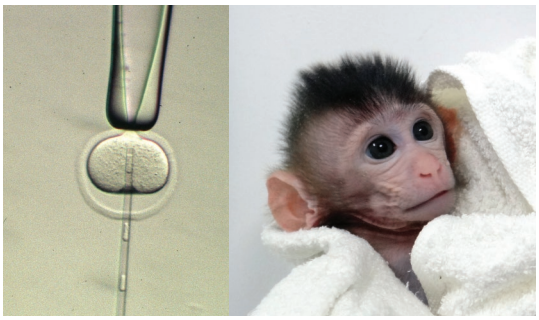
Analyzing Important Experiments Biology is at its core a detective story. Over many years, scientists have performed experiments to solve mysteries. Faced with a question, they have, like Sherlock Holmes, devised ways to test alternative possibilities. And it doesn't stop there. Learning the answer to one question has led scientists to other questions, addressed by other experiments. Every major concept taught to students taking a biology course is the result of a chain of experiments. In this text, you will analyze many of the most important experiments that have taught us what we know. By seeing how scientists conducted the experiments, you can see how scientists think and how ideas are tested.

Take, for example, the scientific question faced by a biologist named Peter Agre. Scientists had learned that plasma membranes, the skin of cells, are double layers of an oily substance called lipid. Water cannot pass through oil, so how can water enter cells? On page 80, you can follow the experiments Agre used to solve this mystery, experiments that won him the Nobel Prize. Often, a chain of experiments underlie our understanding. In chapter 11, you will follow a chain of experiments by Griffith, Avery, Hershey and Chase, Wilkins, and Meselson and Stahl that led to an ever-clearer understanding of DNA as the hereditary material. In *The Living World,* you will take a detailed look at over 60 experiments that have formed the conceptual framework of modern biology.

Inquiry and Analysis One of the most important things you will take away from this course is the ability to judge scientific claims you will encounter as a citizen long after college is over. Studying past experiments that have taught us what we know about biology is one step in this direction. Another way of learning this important skill is to actually do the analysis yourself. Every chapter of this text ends with an *Inquiry & Analysis* feature, a full-page presentation of an actual scientific investigation that requires you to formulate an experiment, analyze the data, and reach conclusions. The best way to learn how science is done is to do it.

Linking Biology to Everyday Life

Biology isn't all dry stuff, complex chemical pathways to memorize, and strange-sounding terms to learn. Biology affects you personally, in your own everyday life. As you proceed through



(a) Handout/Getty Images; (b) Courtesy Yongchang Chen, PhD of the following study: Niu Y, Shen B, Cui Y, Chen Y, Wang J, Wang L, Kang Y, Zhao X, Si W, Li W, Xiang AP, Zhou J, Guo X, Bi Y, Si C, Hu B, Dong G, Wang H, Zhou Z, Li T, Tan T, Pu X, Wang F, Ji S, Zhou Q, Huang X, Ji W, Sha J. "Generation of gene-modified cynomolgus monkey via Cas9 /RNA-mediated gene targeting in one-cell embryos." Cell. 2014 Feb 13; 156(4):836–43.

The Living World, you will encounter a variety of features linking a chapter's contents to your everyday world.

Relevancy Readings Throughout *The Living World* are full-page features devoted to how today's biology affects you:

Answering Your Questions About A lot of today's biology affects you directly, raising a variety of interesting questions concerning matters such as the effects of vaping and energy drinks on your body, how effective masks are at preventing the spread of COVID-19, and climate change.

Biology and Staying Healthy Many aspects of biology will impact your own health, and are worth a closer look. They include what you eat—diets like the currently popular Paleo diet, and chemicals like the bisphenol A found in the clear plastic of plastic bottles. Protecting your genes from DNA-attacking chemicals in cigarettes and DNA-damaging UV radiation in tanning booths is very important for your healthy future.

Today's Biology Many of today's advances in biology are affecting society in important and interesting ways. They allow you to trace your family history with DNA, eat test-tube hamburgers, meet babies with three parents, and look for life on other planets.

A Closer Look Sometimes it's fun to take a closer look. *A Day In the Life of Your Body,* for example, lets you see how often your heart beats and how much blood it pumps, how often your lungs inhale and how much air moves in and out, how fast your hair and fingernails grow, and other fascinating events. *A Sense of Where You Are* teaches you how basketball star LeBron James is able to sink a jump shot without looking at the basket.

Relevancy Modules A series of relevancy modules, available as a supplementary eBook to the existing text within Connect, have been designed to accompany *The Living World* content. These modules demonstrate the connections between biological content and topics that are of interest to society as a whole. Each module consists of an introduction to the topic, an overview of basic relevant scientific concepts, and then a closer look at the application of these concepts back to the topic. An infographic at the end of each module may be easily used in the lecture environment to

initiate discussion of the topic. Discussion and assessment questions, specific to the modules, are available at the end of the module, and for automatic assessment in the Connect platform.

A new "Thinking Scientifically" feature in each module uses a fake blog post about the module topic, similar to what students may encounter in their social media feeds, to increase science literacy. Assessments, available in the module or assignable in Connect, encourage the reader to analyze the author's credentials, consider potential conflicts of interest, and look for unscientific thinking and data misinterpretation. The reader is then challenged to determine what conclusions are appropriate.

Relevancy Videos: BioNOW Like the *Inquiry & Analysis* feature at the end of each chapter of *The Living World, BioNOW* videos narrated and produced by educator Jason Carlson provide a relevant, applied approach that allows students to feel they can actually do and learn biology themselves. While tying directly to the content of your course, the series of videos helps you relate your daily life to the biology you are learning.

McGraw Hill

Each video provides an engaging and entertaining story about applying the science of biology to a real situation or problem. Attention is given to using tools and techniques that the average person would have access to, so you can see science has something you yourself can do and understand.

Relevancy Readings

Answering Your Questions About…

Biology and Staying Healthy

Today's Biology

A Closer Look

New to This Edition

The Coronavirus Pandemic

During our lifetimes, nothing has changed the world quite like the global COVID-19 pandemic. The opening essay of chapter 1 on page 15 describes how the virus that causes COVID-19 grew into a global pandemic, while the closely related SARS and MERS coronaviruses that appeared in the last decade were more contained.

Earth's Polar Icecaps Are Disappearing

Scientists have been fearfully watching the amount of ice at our planet's poles. With atmospheric CO_2 levels at an all-time high and the world struggling to reduce emissions, the planet is warming. As described in chapter 1 on page 26, Antarctica is feeling the brunt of this warming. The ice in Antarctica took millions of years to form, but with summer temperatures reaching 70 degrees Fahrenheit, it is becoming more unstable. In 2019, an iceberg the size of Houston, Texas, broke free of the continent. Our main hope for reversing global warming lies with every country's active participation in the Paris Climate Accord.

Cancer and COVID

The health of a person is never more fragile than it is when someone is undergoing cancer treatments. When the COVID pandemic began, doctors saw a dramatic decrease in common cancer screening appointments. As described in chapter 8 on page 174, the delay in cancer screenings because of the pandemic is expected to increase the number of cancer deaths. The delay in screening gives any tumor that may be present more time to grow and spread. Patients receiving chemotherapy are already in an immune-compromised state and their body will have a harder time getting rid of any infection. This highlights why it is so important to try to prevent the spread of the virus.

Testing for COVID-19

When the 2020 coronavirus pandemic began, it was a guessing game as to who had COVID and who was sick for some other reason. It was important to develop a sensitive and accurate test to determine if someone had the virus. Chapter 13, page 271, explores the different types of tests that have become available. PCR and antigen tests can determine if a person actively has COVID, whereas antibody tests can determine if they already had an infection.

Cloning Your Dog

In 1997, the world was introduced to Dolly, the first mammal ever cloned from a somatic cell. Since then, horses, hamsters, and even a cow have been successfully cloned. But could you clone your pet? As described in Chapter 13 on page 279, the technology to clone your pet, or any mammal, currently exists. The DNA preserved in dinosaur fossils, as popularized by the movie *Jurassic Park,* has shown to be too fragmented to clone. DNA from more recent animals offers a greater chance of cloning success. But should the procedure be performed?

The SARS-CoV-2 Life Cycle

Researchers have worked hard to identify COVID's genetic code and the mechanism through which it infects humans. As described in chapter 16 on page 368, they have determined how COVID gets into our cells and what happens once it does. The spike protein of COVID binds to receptors on the surface of our cells. Then, its viral RNA uses our own ribosomes to produce more viral proteins. It even codes for an RNA polymerase that it can use to generate thousands of copies of this viral RNA. Together, the viral proteins and viral RNA will be packaged and fill the cytoplasm with more coronavirus particles.

Masks Prevent the Spread of Coronavirus

To slow the spread of the pandemic, health-care experts recommended we all wear facemasks. But are masks effective at preventing the spread of the coronavirus? This question is explored in chapter 16 on page 372. When you cough or sneeze, water droplets carry viral particles up to 10 feet away. Wearing a simple cloth mask reduces this spread to less than a foot, keeping more of your water droplets to yourself. Wearing a mask also reduces the likelihood you will inhale the virus that was just exhaled by someone else. Wearing a mask has some pronounced benefits, but studies have shown that wearing one also increases risky behavior because wearers feel more protected.

Mycoremediation to Rid the World of Plastic Waste

Use of plastic has grown exponentially across the globe. With this increase in the amount of plastic, there is an ever-growing concern about how to dispose of the waste. As described in chapter 18 on page 413, researchers are looking for other

methods to complement incineration and recycling to reduce the amount of plastic that pollutes our world. With the discovery of a unique species of fungi, *Pestalotiopsis microspore,* researchers have found another potential tool. These fungi have the ability to secrete digestive enzymes that can degrade the plastic, absorbing the plastic particles into mycelium. The fungi actually uses the plastic as a food source, thus reducing plastic waste in the environment.

Marijuana as a Cash Crop

Marijuana is derived from the *cannabis* plant. In 1996, California was the first state to legalize *cannabis* and, since then, more than 32 states have followed suit. The sale and cultivation of *cannabis* has grown to become a $1-billion-a-year industry. As described in chapter 20 on page 452, there is more to *cannabis* than just its psychoactive effects. There are two groups of *cannabis* plants, marijuana and hemp, and they are distinguished by the amount of cannabinoid compounds in each.

A Vaccine for COVID-19

COVID-19 caused a global pandemic because we did not have a naturally occurring defense to the virus, nor were there initially any successful treatments. To end the pandemic, the race was on to develop a vaccine. As described in chapter 30 on page 666, companies were using both traditional methods, such as live attenuated virus vaccines and inactivated virus vaccines, as well as new approaches, such as the nucleic acid vaccines. The first two vaccines to make it to the public were both RNA vaccines. The RNA for the spike protein of SARS-CoV-2 was placed inside a lipid carrier and injected into patients. With more vaccine options being readied for the public, there is hope the pandemic can be ended.

Why Is There No HIV Vaccine?

It took scientists less than a year to begin clinical trials for a vaccine for SARS-CoV-2, yet there have been no successful HIV trials since the virus was first discovered over 30 years ago. As described in chapter 30 on page 668, the differences between the viruses that cause COVID-19 and AIDS have a direct role in why one vaccine has been developed quickly and the other is still under development. HIV replicates very quickly and imperfectly. Additionally, HIV-infected cells not only do not present much to illicit an immune response, they also infect those cells (white blood cells) that start the response. These combinations of factors make producing a vaccine extraordinarily difficult.

Reflecting the Diverse World Around Us

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About the Authors

Dr. George B. Johnson taught biology and genetics at Washington University in Saint Louis for over three decades and now serves as a Professor Emeritus of Biology. An English major at Dartmouth College before obtaining his PhD in Biology at Stanford University, Dr Johnson has long been involved in innovative efforts to incorporate interactive learning into our nation's classrooms. He continues to be at the forefront of adapting new modalities to learning biology. Over three million students have been taught from biology textbooks authored by Dr. Johnson. His college textbooks include *Biology, Understanding Biology, The Living World,* and this text, *Essentials of the Living World*. He has also authored two widely used high school biology texts. For many years, he has written a weekly column "On Science" for the Saint Louis Post Dispatch (you can read them at his home page www.biologywriter.com). He has chronicled the recent coronavirus pandemic in a series of letters you can read at www.pandemicletter.com. Dr. Johnson lives in St. Louis, Missouri, with his wife Barbara and small dog Paddington.

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Dr. Joel Bergh is a Senior Lecturer in the Department of Biology at Texas State University in San Marcos, Texas. Dr. Bergh earned his BS in Biology from the University of Houston-Clear Lake. In 2003, he earned a PhD from the University of Delaware. His dissertation was focused on the role of vitamin D_3 on bone formation rates. Before coming to Texas State University, he taught at St. Edwards University in Austin, Texas. Dr. Bergh's teaching focuses on majors and nonmajors introductory biology, genetics, and cancer biology. When not in the classroom, he works on innovative new ways to make connections between the events students have experienced in their lives and advances in the scientific community. Dr. Bergh lives in Austin, Texas, with his wife Errin and their two children.

Joel Bergh/McGraw Hill

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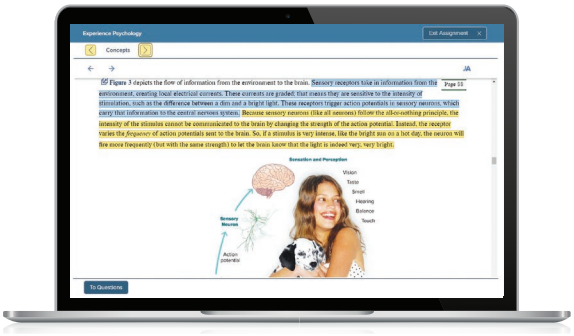

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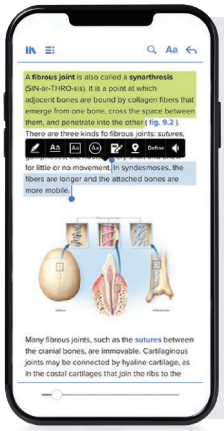

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"I really liked this app—it made it easy to study when you don't have your textbook in front of you."

- Jordan Cunningham,
  Eastern Washington University

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Contents

0 Studying Biology

This thoughtful porcupine, nibbling his breakfast, is covered by 30,000 long quills. They are not for decoration, as any animal approaching the porcupine soon learns. The quills are sharp, and tiny barbs coat the tips—touch them, and they come off the porcupine and into you! As forest creatures, porcupines live a solitary life, their woodland habitat increasingly encroached upon by human progress. The porcupine's fate, and that of all other creatures of the living world, will depend critically on the steps we humans take to protect and preserve our world's climate and resources. Your study of biology will provide you with a key tool to help. You are about to leap into the study of molecules, cells, and intricate body processes, of evolution and ecology. Rich with new ideas unknown to many of you, biology is a science course full of promise. This short "Chapter Zero" is intended to provide you with the tools to make the leap more strongly and with greater confidence. Good luck.

Bob Pool/Getty Images

Learning Objectives

Learning

0.1 How to Study

1. List the principal things you will need to do in order to study biology successfully.
2. Explain why it is important to recopy your lecture notes promptly.
3. Name two things you can do to slow down the forgetting process.
4. Identify three general means of rehearsal.
5. Describe three strategies to improve studying efficiency.

A Closer Look: Pulling an All-Nighter

0.2 Using Your Textbook

1. Describe how your text can be used to reinforce and clarify what you learn in lecture.
2. Identify the learning tools that the text provides to help you master the material.

0.3 Using Your Textbook's Internet Resources

1. Describe the three benefits of using *Connect*.
2. Describe how *SmartBook* tests how well you have learned.

0.4 Online Labs

1. Describe how virtual labs improve student learning.

Putting What You Learn to Work

0.5 Science Is a Way of Thinking

1. Describe how biological scientists have come to a conclusion when confronted with problems of major public importance.

0.6 How to Read a Graph

1. Define *independent variable,* and explain why correlation of dependent variables does not prove causation.
2. Differentiate between linear and logarithmic scales.
3. Explain how a regression line is drawn.
4. Differentiate between a line graph and a histogram.
5. Discuss the four distinct steps scientists use to analyze a graph.

0.1 How to Study

Learning Objective 0.1.1 List the principal things you will need to do in order to study biology successfully.

Some students will do well in this course, others poorly. One of the best predictors of how well you will do is how well you are prepared to learn. Entering an introductory science course like this one, do you know how to take lecture notes? Do you know how to use these notes effectively with your textbook? Can you read a graph? This edition of *The Living World* tackles this problem head-on by providing you with this "Chapter Zero" at the beginning of the text. It is intended to help you master these very basic but essential learning tools.

Taking Notes

Learning Objective 0.1.2 Explain why it is important to recopy your lecture notes promptly.

Listening to lectures and reading the text are only the first steps in learning enough to do well in a biology course. The key to mastering the mountain of information and concepts you are about to encounter is to take careful notes. Studying from poor-quality notes that are sparse, disorganized, and barely intelligible is not a productive way to approach preparing for an exam.

There are three simple ways to improve the quality of your notes:

1. **Take many notes.** Always attempt to take the most complete notes possible during class. If you miss class, take notes yourself from a tape of the lecture, if at all possible. It is the process of taking notes that promotes learning. Using someone else's notes is a poor substitute. When someone else takes the notes, that person tends to do most of the learning as well.
2. **Take paraphrased notes.** Develop a legible style of abbreviated note taking. Obviously, there are some things that cannot be easily paraphrased (referred to in a simpler way), but using abbreviations and paraphrasing will permit more comprehensive notes. Attempting to write complete organized sentences in note taking is frustrating and too time-consuming—people just talk too fast!
3. **Revise your notes.** As soon as possible after lecture, you should decipher and revise your notes. Nothing else in the learning process is more important, because this is where most of your learning will take place. By revising your notes, you meld the information together and put it into a context that is understandable to you. As you revise your notes, organize the material into major blocks of information with simple "heads" to identify each block. Add ideas from your reading of the text and note links to material in other lectures. Clarify terms and concepts that might be confusing with short notes and definitions. Thinking through the ideas of the lecture in this organized way will crystallize them for you, which is the key step in learning.

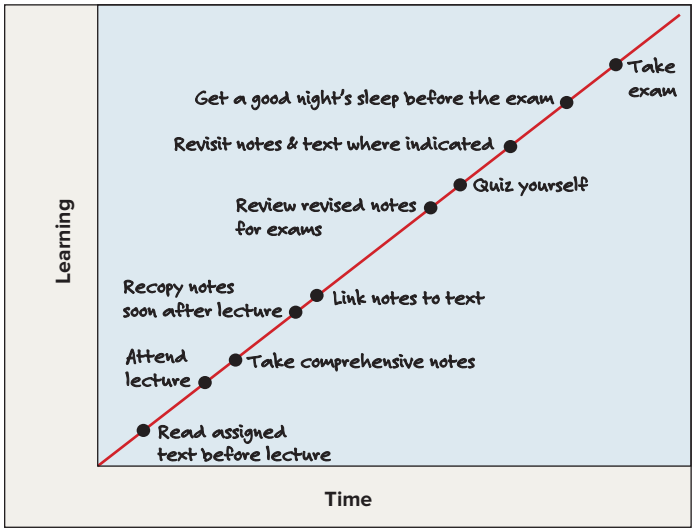


Figure 0.1 A learning timeline.

Remembering and Forgetting

Learning Objective 0.1.3 Name two things you can do to slow down the forgetting process.

Learning is the process of placing information in your memory. Just as in your computer, there are two sorts of memory. The first, *short-term memory,* is analogous to the RAM (random access memory) of a computer, holding information for only a short period of time. Just as in your computer, this memory is constantly being "written over" as new information comes in. The second kind of memory, *long-term memory,* consists of information you have stored in your memory banks for future retrieval, like storing files on your computer's hard drive. In its simplest context, learning is the process of transferring information to your hard drive.

Forgetting is the loss of information stored in memory. Most of what we forget when taking exams is the natural consequence of short-term memories not being effectively transferred to long-term memory. Forgetting occurs very rapidly, dropping to below 50% retention within one hour after learning and leveling off at about 20% retention after 24 hours.

There are many things you can do to slow down the forgetting process (**figure 0.1**). Here are two important ones:

1. **Recopy your notes as soon as possible after lecture.** Remember, there is about a 50% memory loss in the first hours. Optimally, you should use your textbook as well while recopying your notes.

2. **Establish a purpose for reading.** When you sit down to study your textbook, have a definite goal to learn a particular concept. Each chapter begins with a preview of its key concepts—let them be your guides. Do not try to learn the entire contents of a chapter in one session; break it up into small, "easily digested" pieces.

Learning

Learning Objective 0.1.4 Identify three general means of rehearsal.

Learning may be viewed as the efficient transfer of information from your short-term memory to your long-term memory. This transfer is referred to as *rehearsal* by learning strategists. As its name implies, rehearsal always involves some form of repetition. There are three general means of rehearsal in the jargon of education called "critical thinking skills" (**figure 0.2**).

Repeating The most obvious form of rehearsal is repetition. To learn facts, the sequence of events in a process, or the names of a group of things, you write them down, say them aloud, and mentally repeat them over and over until you have "memorized" them. This often is a first step on the road to learning. Many students mistake this as the only step. It is not, because it involves only rote memory instead of understanding. If all you do in this course is memorize facts, you will not succeed.

Organizing It is important to organize the information you are attempting to learn because the process of sorting and ordering increases retention. For example, if you place a sequence of events in order, like the stages of mitosis, the entire sequence can be recalled if you can remember what gets the sequence started.

Connecting You will learn biology much more effectively if you relate what you are learning to the world around you. The many challenges of living in today's world are often related to the information presented in this course, and understanding these relationships will help you learn. In each chapter of this textbook, you will encounter full-page Connection essays that allow you to briefly explore a "real-world" topic related to what you are learning. One appears on page 5. Read these essays. You may not be tested on these essays, but reading them will provide you with another "hook" to help you learn the material on which you will be tested.

Studying to Learn

Learning Objective 0.1.5 Describe three strategies to improve studying efficiency.

If I have heard it once, I have heard it a thousand times, "Gee, Professor, I studied for 20 hours straight and I still got a D." By now, you should be getting the idea that just throwing time at the material does not necessarily ensure a favorable outcome.

Studying, said simply, is putting your learning skills to work. It should come as no surprise to you that how you set about doing this matters. Three simple strategies can make your study sessions more effective:

Figure 0.2 Learning requires work.
Learning is something you do, not something that happens to you.
Image Source/DigitalVision/Getty Images

1. **Study at intervals.** The length of time you spend studying and the spacing between study or reading sessions directly affect how much you learn. If you had 10 hours to spend studying, you would be better off if you broke it up into 10 one-hour sessions than spend it all in one or two sessions. There are two reasons for this:

   First, we know from formal cognition research (as well as from our everyday life experiences) that we remember "beginnings" and "endings" but tend to forget "middles." Thus, the learning process can benefit from many "beginnings" and "endings."

   Second, unless you are unusual, after 30 minutes or an hour, your ability to concentrate is diminished. Concentration is a critical component of studying to learn. Many short, topic-focused study sessions maximize your ability to concentrate effectively.
2. **Avoid distractions.** It makes a surprising amount of difference *where* you study. Why? Because effective studying requires concentration. For most of us, effective concentration requires a comfortable, quiet environment with no outside distractions like loud music or conversations.

It is for this reason that studying in front of a loudly playing television or stereo or at a table in a busy cafeteria is a recipe for failure. A quiet room, a desk in the library, outside on a sunny day—all these study locations are quiet, offering few distractions and allowing you to focus your concentration on what you are trying to learn. Keep your mobile phone off; texting while studying is as distracting as it is while driving and as much to be avoided.

3. **Reward yourself.** At the end of every study interval, schedule something fun, if only to get away from studying for a bit. This "carrot and stick" approach tends to make the next study interval more palatable.

Learning Is an Active Process

It is important to realize that learning biology is not something you can do passively. Many students think that simply possessing a lecture video or a set of class notes will get them through. In and of themselves, videos and notes are no more important than the Nautilus machine an athlete works out on. It is not the machine per se but what happens when you use it effectively that is of importance.

Common sense will have a great deal to do with your success in learning biology, as it does in most of life's endeavors. Your success in this biology course will depend on doing some simple, obvious things (**figure 0.3**):

- *Attend class.* Go to all the lectures and be on time.
- *Read the assigned readings before lecture.* If you have done so, you will hear things in lecture that will be familiar to you, a recognition that is a vital form of learning reinforcement. Later, you can go back to the text to check details.
- *Take comprehensive notes.* Recognizing and writing down lecture points is another form of recognition and reinforcement. Later, studying for an exam, you will have already forgotten lecture material you did not record, and so even if you study hard, you will miss exam questions on this material.
- *Revise your notes soon after lecture.* Actively interacting with your class notes while you still hold much of the lecture in short-term memory provides perhaps the most powerful form of reinforcement and will be a key to your success.

The process of revising your lecture notes can and should be a powerful learning tool. For the best results, don't simply transcribe more legibly what you scribbled down so rapidly in class. Instead, focus on how the lecture was organized, and use that framework to organize your revised notes. Most lectures are organized much like each chapter is in this textbook, with three or four main topics, each covered in a series of steps. To revise your class lecture notes most effectively, you should try to *outline* what was said in lecture: First write down the three or four main headings, and then under each heading, place the block of lecture material that addressed that topic.

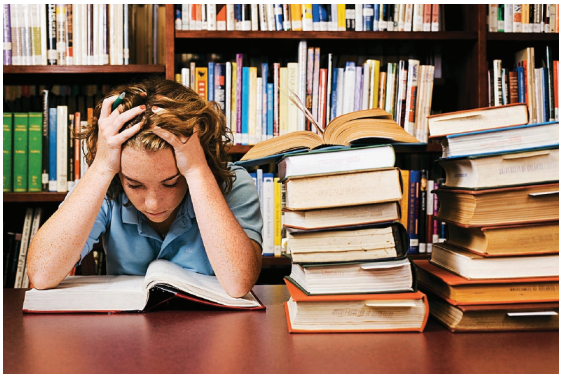
Perhaps more than you have realized, a lecture in a biology course is a network of ideas. Going through your class lecture notes and identifying the main topics is a powerful first step in sorting these ideas out in your mind. The second step, laying out the material devoted to each topic in a logical order (which is, hopefully, the order in which it was presented), will make clearer to you the ideas that link the material together—and this is, in the final analysis, much of what you are trying to learn.

Figure 0.3 Critical learning occurs in the classroom.
Learning occurs in at least four distinct stages: attending class; doing assigned textbook readings before lecture; listening and taking notes during lecture; and recopying notes shortly after lecture. If you are diligent in these steps, then studying lecture notes and text assignments before exams is much more effective. Skipping any of these stages makes successful learning far less likely.
Fuse/Getty Images

As you proceed through this textbook, you will encounter a blizzard of terms and concepts. Biology is a field rich with ideas and the technical jargon needed to describe them. What you discover reading this textbook is intended to support the lectures that provide the core of your biology course. Integrating what you learn here with what you learn in lecture will provide you with the strongest possible tool for successfully mastering the basics of biology. The rest is just hard work.

Key Learning Outcome 0.1 Studying biology successfully is an active process. To do well, you should attend lectures, do assigned readings before lecture, take complete class notes, rewrite those notes soon after class, and study for exams in short, focused sessions.

Pulling an All-Nighter



Randy Faris/Getty Images

At some point in the next months, you will face that scary rite, the first exam in this course. As a university professor, I get to give the exams rather than take them, but I can remember with crystal clarity when the shoe was on the other foot. I didn't like exams a bit as a student. What student does? But in my case, I was often practically paralyzed with fear. What scared me about exams was the possibility of unanticipated questions. No matter how much I learned, there was always something I didn't know, some direction from which my teacher could lob a question that I had no chance of answering.

I lived and died by the all-nighter. Black coffee was my closest friend in final exam week, and sleep seemed a luxury I couldn't afford. My parents urged me to sleep more, but I was trying to cram enough in to meet any possible question and couldn't waste time sleeping.

Now I find I did it all wrong. Over the last two decades, researchers at Harvard Medical School have demonstrated that our memory of newly learned information improves only after sleeping at least six hours. If I wanted to do well on final exams, I could not have chosen a poorer way to prepare. The gods must look after the ignorant, as I usually passed.

Learning is, in its most basic sense, a matter of forming memories. The Harvard researchers' experiments showed that a person trying to learn something does not improve their knowledge until after they have had more than six hours of sleep (preferably eight). It seems the brain needs time to file new information and skills away in the proper slots so they can be retrieved later. Without enough sleep to do all this filing, new information does not get properly encoded into the brain's memory circuits.

To sort out the role of sleep in learning, the Harvard Medical School researchers used Harvard undergrads as guinea pigs. The undergraduates were trained to look for particular visual targets on a computer screen and to push a button as soon as they were sure they had seen one. At first, responses were relatively sluggish: It typically took 400 milliseconds for a target to reach a student's conscious awareness. With an hour's training, however, many students were hitting the button correctly in 75 milliseconds.

How well had they learned? When they were retested from 3 to 12 hours later on the same day, there was no further improvement past a student's best time in the training session. If the researchers let a student get a little sleep, but less than six hours, then retested the next day, the student still showed no improvement. For students who slept more than six hours, the story was very different. Sleep greatly improved performance. Students who achieved 75 milliseconds in the training session would reliably perform the target identification in 62 milliseconds after a good night's sleep! After several nights of ample sleep, they often got even more proficient.

Why six or eight hours and not four or five? The sort of sleeping you do at the beginning of a night's sleep and the sort you do at the end are different, and both, it appears, are required for efficient learning.

The first two hours of sleeping are spent in deep sleep, what psychiatrists call slow wave sleep. During this time, certain brain chemicals become used up, which allows information that has been gathered during the day to flow out of the memory center of the brain, the hippocampus, and into the cortex, the outer covering of the brain, where long-term memories are stored. Like moving information in a computer from active memory to the hard drive, this process preserves experience for future reference. Without it, long-term learning cannot occur.

Over the next hours, the cortex sorts through the information it has received, distributing it to various locations and networks. Particular connections between nerve cells become strengthened as memories are preserved, a process that is thought to require the time-consuming manufacture of new proteins.

If you halt this process before it is complete, the day's memories do not get fully "transcribed," and you don't remember all that you would have, had you allowed the process to continue to completion. A few hours are just not enough time to get the job done. Four hours, the Harvard researchers estimate, is a minimum requirement.

The last two hours of a night's uninterrupted sleep are spent in rapid-eye-movement (REM) sleep. This is when dreams occur. The brain shuts down the connection to the hippocampus and runs through the data it has stored over the previous hours. This process is also important to learning, because it reinforces and strengthens the many connections between nerve cells that make up the new memory. Like a child repeating a refrain to memorize it, the brain goes over things until practice makes perfect.

That's why my college system of getting by on 3 or 4 hours of sleep during exam week and crashing for 12 hours on weekends didn't work. After a few days, all of the facts I had memorized during one of my "all-nighters" faded away. Of course, they did. I had never given them a chance to integrate properly into my memory circuits.

As I look back, I see now that how well I did on my exams probably had far less to do with how hard I studied than with how much I slept. It doesn't seem fair.

0.2 Using Your Textbook

A Textbook Is a Tool

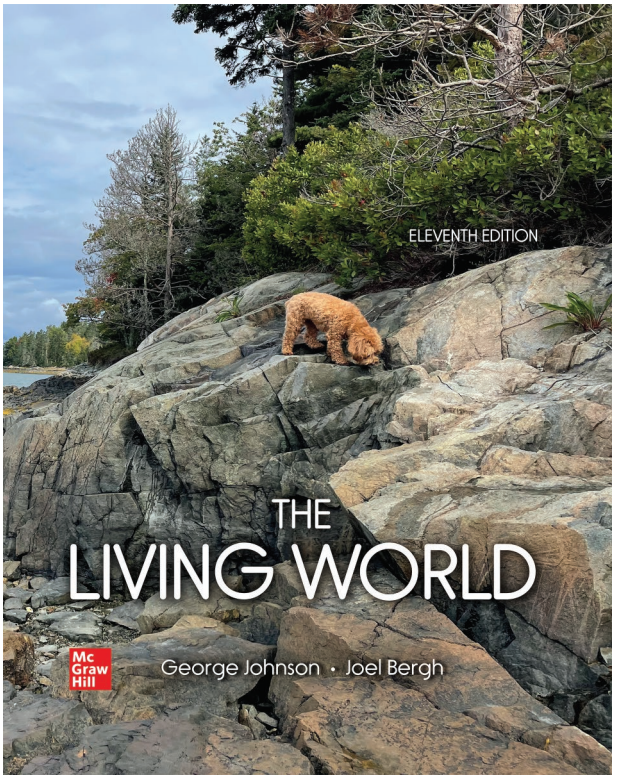
Learning Objective 0.2.1 Describe how your text can be used to reinforce and clarify what you learn in lecture.

A student enrolled in an introductory biology course, as you are, almost never learns everything from the textbook. Your text is a tool to explain and amplify what you learn in lecture. No textbook is a substitute for attending lectures, taking notes, and studying them. Success in your biology course is like a stool with three legs: lectures, class notes, and text reading—all three are necessary. Used together, they will take you a long way toward success in the course.

When to Use Your Text While you can glance at your text at any time to refresh your memory, your use of your text should focus on providing support for the other two "legs" of course success: lectures and class notes.

Do the Assigned Reading. Many instructors assign reading from the text, reading that is supposed to be done before lecture. The timing here is very important: If you already have a general idea of what is being discussed in lecture, it is easier to follow the discussion and take better notes.

Link the Text to Your Lecture Notes. Few lectures cover exactly what is in the text, and much of what is in the text may not be covered in lecture. That said, much of what you will hear in lecture *is* covered in your text. This coverage provides you with a powerful tool to reinforce ideas and information you encounter in lecture. Text illustrations and detailed explanations can pound home an idea quickly grasped in lecture and answer any questions that might occur to you as you sort through the logic of an argument. Thus, it is absolutely essential that you follow along with your text as you recopy your lecture notes, keying your notes to the textbook as you go. Annotating your notes in this way will make them better learning tools as you study for exams later.



George B. Johnson

Review for Exams. It goes without saying that you should review your recopied lecture notes to prepare for an exam. But that is not enough. What is often missed in gearing up for an exam is the need to also review that part of the text that covers the same material. Reading the chapter again, one last time, helps place your lecture notes in perspective, so that it will be easier to remember key points when faced with any topic on your exam.

How to Use Your Text The single most important way to use your text is to read it. As your biology course proceeds and you move through the text, read each assigned chapter all the way through at one sitting. This will give you valuable perspective. Then, guided by your lecture notes, go back through the chapter one topic at a time and focus on learning that one topic as you recopy your notes. As discussed earlier, building a bridge between text and lecture notes is a very powerful way to learn. Remember, your notes don't take the exam, and neither does the textbook; you do, and the learning that occurs as you integrate text pages and lecture notes in your mind will go a long way toward you doing well on the exam.

Learning Tools at Your Disposal

Learning Objective 0.2.2 Identify the learning tools that the text provides to help you master the material.

Learning Objectives Every chapter begins by telling you precisely what each section of the chapter is attempting to teach you. Called "Learning Objectives," these items describe what you are intended to know after studying that section. Use them. They are a road map to success in the course.

Openers and Capstones When you have finished studying a chapter of your text, it will be very important for you to be able to assess how good a job you have done. Waiting until a class exam to find out if you have mastered the key points of a chapter is neither necessary nor wise. The key to understanding the material is to link all of the concepts together. The chapters of this book are organized in such a way that you are first presented with an issue and a series of questions. By learning the material in the chapter, you will gain the knowledge to answer those questions. After you learn the material, review the capstone section at the end of each chapter. Here, we will walk through how the chapter material can help you answer those initial questions. Application is the key to understanding.

One of the easiest mistakes to make in studying a chapter is to slide over its figures as if they were simply decoration. In fact, they often illustrate key ideas and processes. At the end of the capstone, you will see a set of questions for you to answer. By design, these questions are attempting to have you engage the material in a manner that is beyond just simple memorization. The goal is to have you take the information, process the material in a new way, and use this to answer

questions that go beyond the material in the book. If you can answer these questions, you will be able to better answer those questions you could have never anticipated.

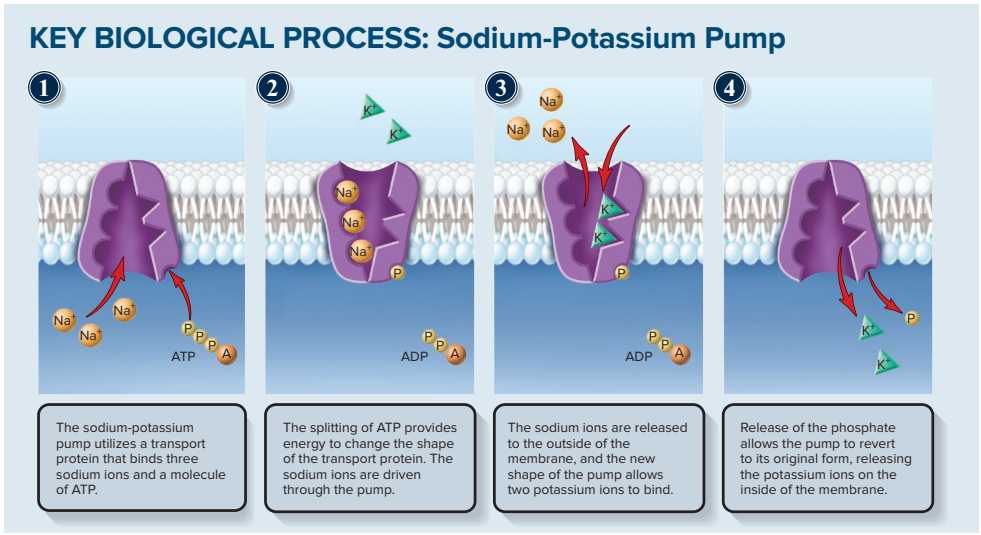
Let the Illustrations Teach You All introductory biology texts are rich with colorful photographs and diagrams. They are not there to decorate but to aid your comprehension of ideas and concepts. When the text refers you to a specific figure, look at it: The visual link will help you remember the idea much better than restricting yourself to cold words on a page.

Three sorts of illustrations offer particularly strong reinforcement:

Key Biological Processes. While you will be asked to learn many technical terms in this course, learning the names of things is not your key goal. Your goal is to master a small set of concepts. A few dozen key biological processes explain how organisms work the way they do. When you have understood these processes, much of the heavy lifting in learning biology is done. Every time you encounter one of these key biological processes in the text, you will be provided with an illustration to help you better understand it. These illustrations break the process down into easily understood stages so you can grasp how the overall process works without being lost in a forest of details (**figure 0.4*a***).

Bubble Links. Illustrations teach best when they are simple. Unfortunately, some of the structures and processes being illustrated just aren't simple. Every time you encounter a complex diagram in the text, it will be "predigested" for you, the individual components of the diagram each identified with a number in a colored circle, or bubble. This same number is also placed in the text narrative right where that component is discussed. These bubble links allow the text to step you through the illustration, explaining what is going on at each stage—the illustration is a feast you devour one bite at a time.

Phylum Facts. Not all of what you will learn are concepts. Sometimes you will need to soak up a lot of information, painting a picture with facts. Nowhere is this more true than when you study animal diversity. In chapter 22, you will encounter a train of animal phyla (a phylum is a major category of organisms) with which you must become familiar. In such a sea of information, what should you learn? Every time you encounter a phylum in chapter 22, you will be provided with a *Phylum Facts* illustration that selects the key bits of information about the body and lifestyle of that kind of animal (**figure 0.4*b***). If you learned and understood only the items highlighted there, you would have mastered much of what you need to know.



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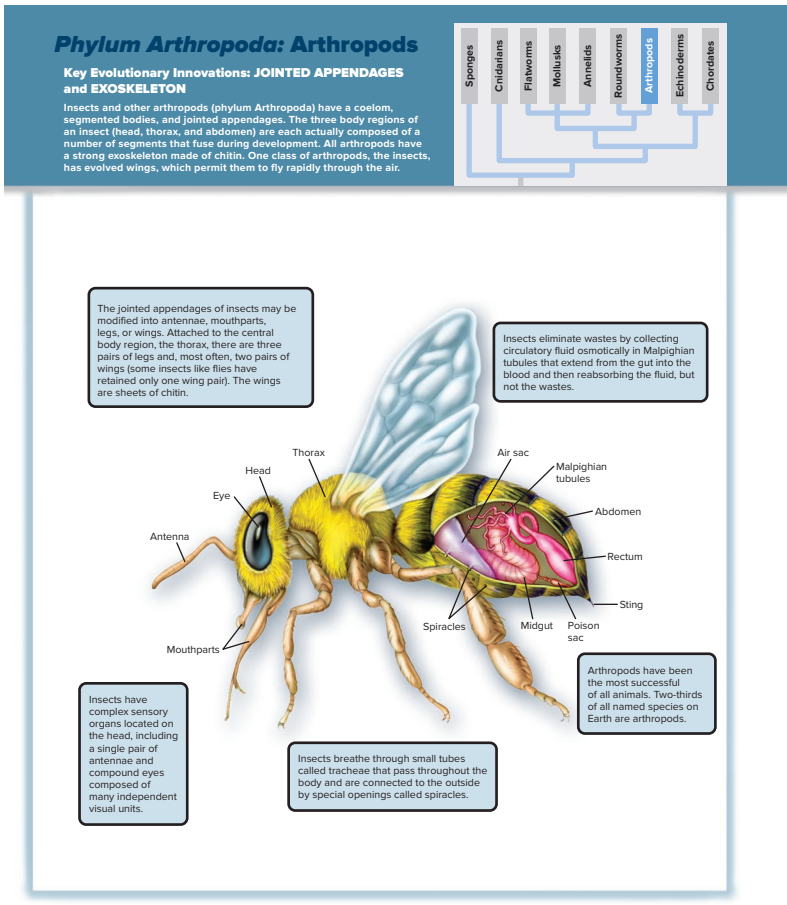

(b)

Figure 0.4 Visual learning tools.

(*a*) An example of a Key Biological Process illustration. (*b*) An example of a Phylum Facts illustration.

0.3 Using Your Textbook's Internet Resources

Some of the most powerful learning tools this text provides are delivered over the Internet.

Connect

Learning Objective 0.3.1 Describe the three benefits of using *Connect*.

It probably came as no surprise to you that you were instructed in section 0.2 to read your text in order to learn the material on which you will be tested, using its illustrations to fortify your understanding. It thus came as something of a surprise to education researchers when they found that most successful students do exactly the opposite. Watching how college students actually use their textbooks, they repeatedly observed students going first to the illustrations, then to the captions beneath them, and only later to the words of the text, using the text to clarify their understanding of the illustrations! Said simply, successful students are often interactive learners.

This type of learner is best tested with interactive questions and resources. If your class is utilizing an instructor-guided learning program called *Connect*, just such an approach is available to you. As a platform for tackling such interactive assessment of how you are doing, *Connect* provides you with a fully interactive *eBook* version of this text, with embedded animations, as well as notes and highlights added by your instructor. For each class assignment, the instructor then assigns you a series of interactive questions. *Connect* grades each answer for you. If you have trouble with a question, the program connects that question to the learning objective in the *eBook* where the question is answered.

How* Connect *Helps You to Learn *Connect* is not simply a testing machine used by the instructor to look over your shoulder and spy on how you are studying. Far from it. It is a powerful learning platform you can use to help understand instructor-assigned material. By the time you have successfully navigated the series of questions assigned by your instructor, you will be well on the way to mastering the assignment. *Connect* is no substitute for reading your text and linking it to your lecture notes. Make no mistake about it—your text and lecture notes are the only sure road to success in this course. The great utility of *Connect* is that it provides a way for you to check how you are doing. The interactive questions you access through *Connect* are self-study questions fully integrated with the text. They provide you with a powerful—and fun—way to identify holes in your understanding of an assignment and the means to fill them in. Why wait until an exam to find out what you don't know? Your course grade will be far superior if you find and solve these problems before the exam.

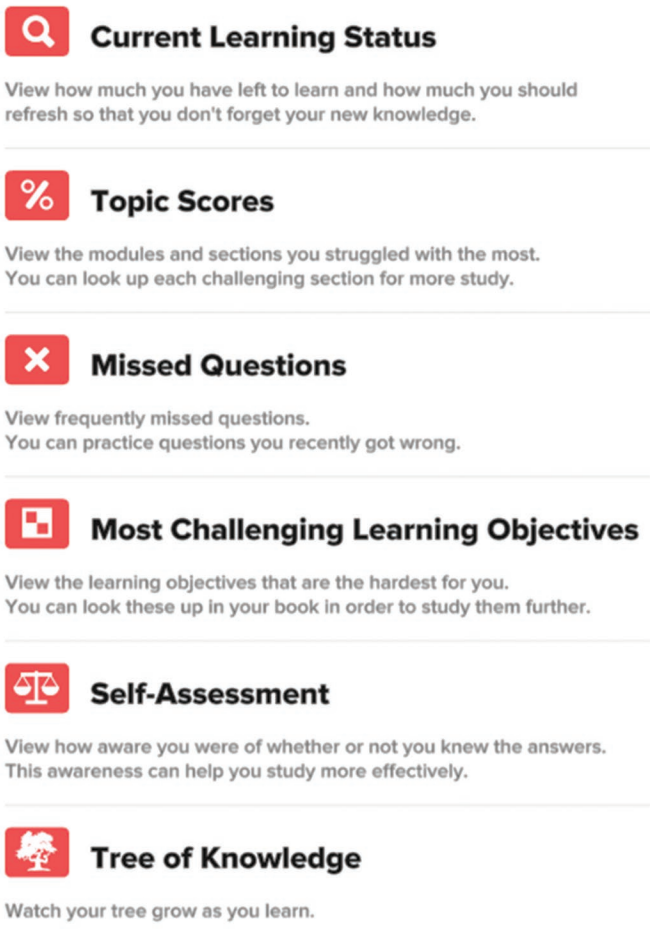

Figure 0.5 Using *SmartBook* reports.

SmartBook reports provide you with six tools to help you identify what you do not yet understand, so you can better focus your available study time.

Adaptive Learning

Learning Objective 0.3.2 Describe how *SmartBook* tests how well you have learned.

Not all students come to a biology class with the same level of preparation or remember equally well what they learned in high school. *SmartBook,* delivered through *Connect,* addresses this problem in a direct way, tailoring a learning plan to each student individually.

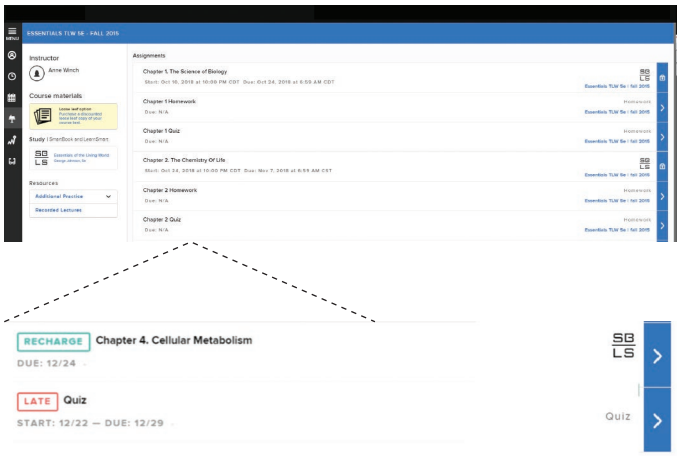

Figure 0.6 Recharge to retain knowledge longer.

SmartBook predicts when you are in danger of forgetting previously learned content and adds a reminder in your To Do list so you can make time to refresh your knowledge.

Figure 0.7 *Virtual Lab* simulations.

Connect Virtual Labs allow you to put your knowledge to work in real-world settings, helping you deepen your understanding.

McGraw Hill

Smartbook Adapts to Each Learner The power of *SmartBook* is that it adapts directly to you. As you read, yellow highlights focus your attention on the concepts you need to learn at that moment in time. After reading a while, you are prompted to *Practice* what you have learned. As you answer questions correctly, highlights turn green to indicate mastery and new content is highlighted. If you answer incorrectly or if you've been in *Practice* mode for a while, you'll be directed to go back to *Read* mode. In both *Read* and *Practice* modes, *Learning Resources* offer videos and other tools to clarify concepts you are struggling to master. This process of going back and forth between reading and quizzing will help you learn more effectively.

Reports Show Your Progress and Identify Knowledge Gaps *Use SmartBook* reports like the one you see in **figure 0.5** to track your progress and see where you need to focus your study time.

- **Current Learning Status** shows how many items you have left to learn in a chapter and the approximate time you will need to take to learn them, as well as items you need to revisit from earlier chapters.
- **Missed Questions and Most Challenging Learning Outcomes (LOs)** can help make your study time more efficient by focusing your attention on the questions and learning outcomes that were difficult for you to master. These reports can be used before a test or exam for additional practice.
- **Self-Assessment** provides insight into how aware you are of what you know and what you don't know. Being able to identify your knowledge gaps helps you focus your study where you need it.
- **Tree of Knowledge** illustrates what portions of the chapter's web of concepts you have mastered and which others still need attention.

Recharge to Retain Knowledge Throughout the Semester *SmartBook* uses your response data to predict when you are in danger of forgetting previously learned content. These *Recharge* reminders appear in the "To Do" section of *Connect* to prompt you to plan time to review (**figure 0.6**).

0.4 Online Labs

One of the best ways to retain newly learned information is to put it into practice.

Virtual Labs and Lab Simulations

Learning Objective 0.4.1 Describe how virtual labs improve student learning.

Biology is a hands-on discipline, and many instructors will choose to augment your course with laboratory experience. At the end of every chapter of this text you will find an Inquiry & Analysis feature that walks you through a real biology experiment, so you can learn how an experiment is designed and analyzed.

Even better, *Connect* provides you with Virtual Lab Simulations that allow you to carry out an experiment yourself, virtually (**figure 0.7**). As you proceed, the simulation will check your understanding and provide feedback. In addition, your instructor can customize each lab assignment to you using adaptive prelab and postlab assessments.

These lab simulations provide a valuable connection between the lecture environment and your own hands-on experience, helping you to visualize complex scientific processes by putting them to work.

Key Learning Objective 0.2 Your text is a tool to reinforce and clarify what you learn in lecture. The Internet resources give you access to your course material from any smart device. *Smartbook* provides a tailored set of questions to close the learning gaps specific to you, while Virtual Labs provides valuable feedback as you put what you have learned into practice. Together, your text, *Smartbook,* and the Virtual Labs provide a coordinated set of resources to give you the opportunity to learn and practice the material you covered in lecture.