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George Johnson

ESSENTIALS of the LIVING WORLD

6e

Mc Graw Hill Education

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ESSENTIALS OF THE LIVING WORLD, SIXTH EDITION

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Brief Contents

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About the Author

Dr. George B. Johnson is a researcher, educator, and author. Born in 1942 in Virginia, he went to college in New Hampshire (Dartmouth), attended graduate school in California (Stanford), and is Professor Emeritus of Biology at Washington University in St. Louis, where he has taught freshman biology and genetics to undergraduates for over 35 years. Also Professor of Genetics at Washington University's School of Medicine, Dr. Johnson is a student of population genetics and evolution, authoring more than 50 scientific journal publications. His laboratory work is renowned for pioneering the study of previously undisclosed genetic variability. His field research has centered on alpine butterflies and flowers, much of it carried out in the Rocky Mountains of Colorado, Wyoming, and, more lately, Montana. Other ecosystems he has explored in recent years include Brazilian and Costa Rican rain forests, the Florida Everglades, the seacoast of Maine, coral reefs off Belize, the ice fields and mountains of Patagonia, and, delightfully, vineyards in Tuscany.

A profilic writer and educator, Dr. Johnson is the author of seven nationally recognized college texts for McGraw-Hill, including the hugely successful majors texts *Biology* (with botanist Peter Raven) and three nonmajors texts: *Understanding Biology, The Living World*, and this text, *Essentials of the Living World*. He has also authored two widely used high school biology textbooks, *Holt Biology* and *Biology: Visualizing Life*. In the more than 30 years he has been authoring biology texts, over 3 million students have been taught from textbooks Dr. Johnson has written.

Dr. Johnson has been involved in innovative efforts to incorporate interactive learning and Internet experiences into our nation's classrooms. He has served on a National Research Council task force to improve high school biology teaching and as the founding director of The Living World, the education center at the St. Louis Zoo, where he was responsible for developing a broad range of innovative high-tech exhibits and an array of new educational programs.

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St. Louis students may be familiar with Dr. Johnson as the author of a weekly science column, "On Science," appearing for many years in the *St. Louis Post Dispatch*. Dedicated to educating the general public about today's science, Dr. Johnson continues to write new columns regularly on current issues in which science plays a key role, issues such as AIDS, the environment, cloning, genetic engineering, and evolution. The columns, focused on explaining how and why, are intended to give readers the tools to think about these issues as citizens and voters. You may follow his columns on his blog: *biologywriter.com*.

Dr. Johnson is best known for the clarity of his writing. "Most students are very interested in science," he points out, "but are put off by the terminology. When you don't know what the words mean, its easy to slip into thinking that the matter is difficult, when actually the ideas are simple, easy to grasp, and fun to consider. It's the terms that get in the way, that stand as a wall between students and science." In his writing, Dr. Johnson aims to turn those walls into windows, so that students can peer in and join the fun. Analogies are his tool. In each chapter, he looks for simple analogies that relate the matter at hand to things we all know. As science, analogies are not exact, trading precision for clarity. "But if I do my job right," Johnson explains, "the key idea is not compromised by the analogy I use to explain it, but rather revealed."

Preface

Focus on the Essentials

In preparing this new sixth edition of *Essentials of the Living World,* I have endeavored to focus more tightly on that first word, *Essentials*. In previous editions, I had fleshed out the core concepts with a good deal of background material. A well-intentioned approach, this has had an unfortunate consequence: While useful in a higher-level biology course, the added material gave struggling nonmajor students a lot to learn that they didn't need to know—and that their instructors were not teaching. An instructor teaching students majoring in biology needs to explain to them how the shape of *p* orbitals affects a covalent chemical bond; an instructor teaching nonmajors might not. My job as a text writer is to provide you, the instructor, with a tool, a text that helps you explain to students the core ideas of biology you are teaching. Anything you see in this new edition is indeed essential.

Breaking Up Material into Learnable Bites

A student sometimes looks in horror at a page of text, a dense field of words concealing something he or she needs to learn. In this edition, I have put a scalpel to work on these pages, trimming long sections of text into more bite-sized bits, with subheads to increase comprehension and retention. Each concept is introduced by a learning objective and bookended by a question requiring the student to put that concept to work. This results in a more precisely blocked-out text, with each bit you are teaching clearly identified and keyed to assessment.

A Brighter, More Open Look

This text has always been enriched by a wealth of art and photos. This edition has a snappy new design, with larger font sizes and more open spaces. The layout of this page, for example, makes the point clearly.

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Today's Biology Explained

While your students may not need to learn the details of molecular engineering, there is no getting around the fact that their future lives will be impacted in very tangible ways by what is going on today in biology. With that in mind, I have tried to give you, the instructor, a useful tool for explaining current discoveries to your students. Genetic engineering of crops is of interest to many students and needs careful explaining. An even more crucial challenge is the need to clearly explain to nonmajor biology students our new ability to edit genes. I have chosen to devote many pages to CRISPR in this edition, explaining how it was discovered (which explains its weird name), the many impacts it is already having on medicine, and its potential use in gene drives. The promise of gene drives to rapidly eliminate malaria is exciting—and a little scary. Teaching this is a lot of fun, and important, but needs a clear text to support your explanation.

Relevancy

The use of real-world examples to demonstrate the importance of biology in the lives of your students is widely recognized as an effective teaching strategy for the introductory biology classroom. Students want to learn about *their* stuff, the topics they encounter on Facebook, and the topics other students are interested in and talk

about. To give instructors tools to address this student interest, this edition offers several new relevancy-based resources.

Relevancy Readings

In many chapters, new **Answering Your Questions About…** readings directly address matters of immediate interest to students. Topics include vaping and e-cigarettes, energy drinks, how to read a food label, global warming, biological clocks, cloning your dog, LGBTQ, the opioid epidemic, and many others. The **A Closer Look** feature "A Day in the Life of Your Body" lets students consider how often their heart beats and their lungs inhale, how fast their hair and fingernails grow, and other fascinating events.

Relevancy Modules

New **Relevancy Modules** correspond with each unit in *Essentials of the Living World, 6e*. These modules demonstrate the connections between biological content and topics that are of interest to society as a whole. Each module consists of an overview of basic scientific concepts and then a closer look at the application of these concepts to the topic. Assessment questions, specific to the module, are also available.

These modules are available as a supplementary e-book to the existing text within Connect and may be assigned by the instructor for use in a variety of ways in the classroom. Examples of topics covered include cancer biology, fermentation science, weed evolution, antibiotic resistance, mega crops, the biology of weight gain, and climate change. New topics are planned for launch each year to keep this resource current.

Relevancy Videos: BioNow

Like the Inquiry & Analysis feature at the end of each chapter of *Essentials of the Living World*, **BioNow videos**, narrated and produced by educator Jason Carlson, provide a relevant, applied approach that allows your 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 students relate their daily lives to the biology you teach, and then connect what they learn back to their lives.

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 your students see the science as something they can do and understand.

Relevancy Readings

Answering Your Questions About...

A Closer Look

Today's Biology

Biology and Staying Healthy

New to This Edition

Editing Your Genes. The most exciting advances since this text's last edition have been applications of a new, easy-to-use tool called CRISPR that allows researchers to edit genes. As described in Section 11.4 on pages 198–200, the gene-editing tool CRISPR is being used to treat human disease on many fronts, including developing a potential cure for AIDS, facilitating organ transplants from pigs (!), correcting disease-causing mutations such as cystic fibrosis and sickle-cell disease, and genetically modifying a patient's own cells to fight leukemia.

Can CRISPR Eliminate Malaria? Researchers have begun to test the possibility of incorporating CRISPR in a so-called gene drive. As described in Section 11.5 on pages 201–202, the approach allows a CRISPR-modified gene to spread through entire populations of malaria-bearing mosquitos, carrying a gene alteration that makes the mosquitos sterile. This approach has the potential to eliminate malaria in one stroke!

Geoengineering to Combat Global Warming. With atmospheric CO_2 levels at a 2 million-year high and efforts to reduce emissions faltering, attempts to engineer the earth's climate offer what may be our best hope of combating global warming. A so-called geoengineering approach, described in the Chapter 6 opening essay on pages 104–105, removes CO_2 from the atmosphere by fertilizing earth's oceans to induce massive photosynthesis. Earth's oceans are rich in marine algae, their growth limited primarily by lack of iron (Fe is a key component of chlorophyll). In the lab, every pound of iron added to ocean water could remove as much as 100,000 pounds of carbon from the air! Very controversial small-scale tests indicate that algal blooms are indeed produced by Fe fertilization and that the blooms sink to the ocean bottom, the carbon effectively returned to where it came from. But there are potentially serious problems with this approach, so it needs much more work before its real promise can be evaluated.

Ebola Outbreak. In 2014–2015, an outbreak of Ebola virus in three densely populated countries of West Africa infected over 24,000 people, killing half of them. Described in Section 16.3 on page 302, never has an Ebola outbreak affected so many people in so many different places. New outbreaks in 2017 and 2018 have failed to spread as far, at least partially due to the development of an effective vaccine, but the potential for future epidemics remains a very real threat.

The Search for Life on Other Planets. For over 20 years, astronomers have been detecting planets orbiting distant stars. As described in Section 16.1 on pages 296–297, over 10,000 had been identified. Might any of them be enough like earth to harbor life? In 2016, astronomers found a candidate planet 1,400 light-years from Earth. Labeled Kepler 452b, it orbits a star very much like our sun. In the last two years, they have reported finding several other "Goldilocks" exoplanets much closer to earth. One is only 4 light-years away, practically a neighbor.

Role of Volcanoes in Mass Extinctions. A large asteroid slammed into earth 66 million years ago (recent, more accurate dating has revised the old "65 million years ago" date), the same time dinosaurs went extinct. Cause and effect? Perhaps not. Other mass extinctions are not correlated with similar impacts, while almost all ARE correlated with huge volcanic eruptions, as described in Section 18.7 on page 363. This was even true 66 million years ago. Perhaps in this instance, the asteroid impact triggered volcanic eruptions, like setting off a bear trap with a nudge.

Meet the Denisovans. When DNA was recovered from an ancient fingerbone found in Siberia, and its entire genome was sequenced, the sequence proved to be human, but was unlike either Neanderthals or modern humans. It was a new species of human. Now called the Denisovans (after the name of the cave where the fingerbone was found), this ancient species of human, described in the Chapter 18 opening essay on pages 336–337, has been shown in the last few years to have interbred with both Neanderthals and modern humans. Indeed, a recently discovered fossil from the cave has proven to be the offspring of a Neanderthal–Denisovan mating!

A Sense of Where You Are. How is LeBron James able to sink a jump shot without looking at the basket? Seeking an answer to this question, explored in Section 28.8 on pages 554–555, has led to two recent Nobel prizes and a lot of rat races through mazes. Researchers were able to show that your brain keeps a "map" of where you are in three dimensions and constantly updates it as you move through space.

Students—study more efficiently, retain more and achieve better outcomes. Instructors—focus on what you love—teaching.

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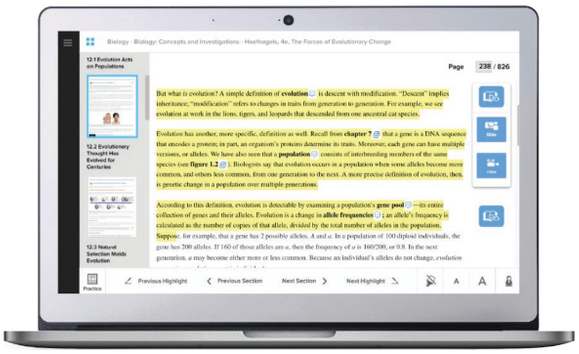

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For Students

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>
> - Jordan Cunningham,
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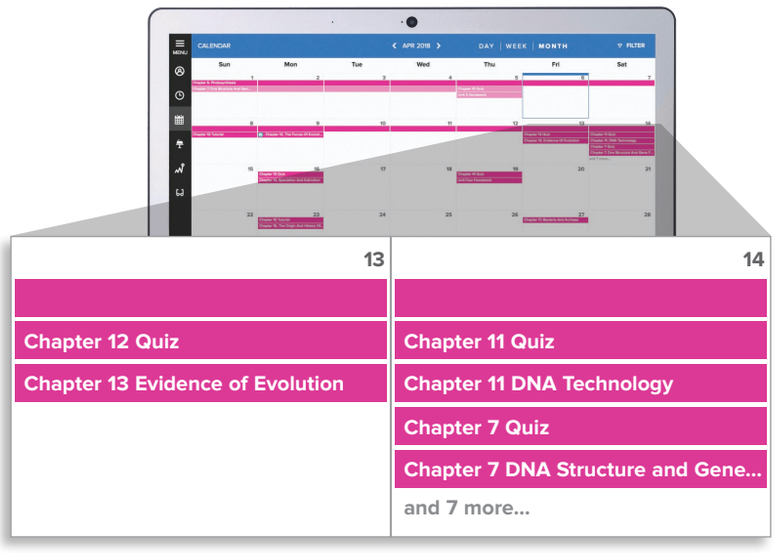

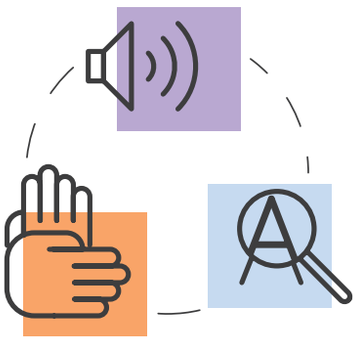

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Acknowledgments

This sixth edition of *Essentials of the Living World* has had a major do-over, breathing new life into what was always a sprightly text. An army of editorial, production, and marketing staff has been hard at work. While I cannot mention them all here, they all have my thanks.

Executive Brand Manager Michelle Vogler and Senior Product Developer Anne Winch were my editorial team, with whom I worked every day. They provided valuable advice and support to a sometimes querulous and always anxious author. Managing Director Thomas Timp aggressively backed my attempts to improve this text, overseeing all the problems an overeager author inadvertently creates, and he did so with humor and consistent support.

Senior Program Manager Angie Fitzpatrick and Senior Content Project Manager Vicki Krug spearheaded our production team, working miracles to better adapt this text to the world of Internet publishing. Every word I wrote was checked by word hawks Marilynn Taylor, Mike McGee, and Angie Sigwarth, catching many a miscue that my less-sharp eye had missed. The photo program was carried out by Content Licensing Specialist Lori Hancock and Photo Research Specialist Alicia Weddle; many a new photo in this edition bears their fingerprints. David Hash did a great job with the new, more open page design—he seems to know just how to tweak an author's "creative suggestion" into something better than I imagined possible. And then do it again.

The marketing of *Essentials of the Living World, 6e* has been planned and supervised by Senior Marketing Manager Britney Ross, who has been quick to address problems and eager to help the many able sales reps who present this book to instructors. Senior Market Development Manager Beth Bettcher has contributed her experience and enthusiasm. No author could wish for a better, more fiercely competitive marketing team.

The key to any successful revision is knowing what to revise. Fully 33 instructors provided me guidance for this edition. Many of them were selected for the reviewer panel precisely because they had chosen not to adopt this text in its previous edition. I wanted to know why. They told me. While I loved the reviews that praised my text, it is to these unhappy reviewers that I devote this edition. I have tried very hard to listen to them, and I believe *Essentials of the Living World* is a better book for their honest appraisal.

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Southwestern Oklahoma State University

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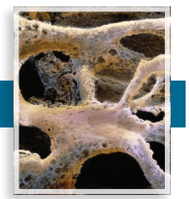
Animal Life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0 Studying Biology

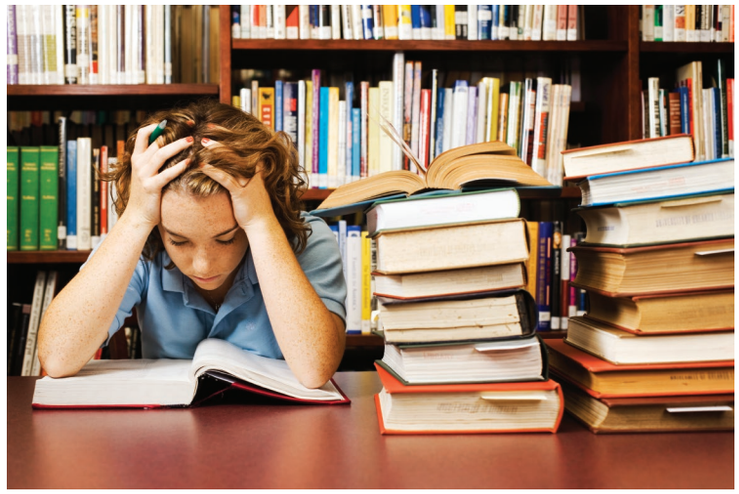
LEARNING PATH ▼

Learning

1. How to Study
2. Using Your Textbook
3. Using Your Textbook's Internet Resources

Putting What You Learn to Work

4. Science Is a Way of Thinking
5. How to Read a Graph



HER SUCCESS WILL depend not only on how much she studies, but also on when.

Pulling an All-Nighter

At some point in the next months, you will face that scary rite: the first exam in this course. Many students face the challenge of exams by cramming. They live and die by the all-nighter, black coffee becomes their closest friend during exam week, and sleep is a luxury they can't afford. Trying to cram enough in to meet any possible question, they feel they can't waste time sleeping.

Sleeping

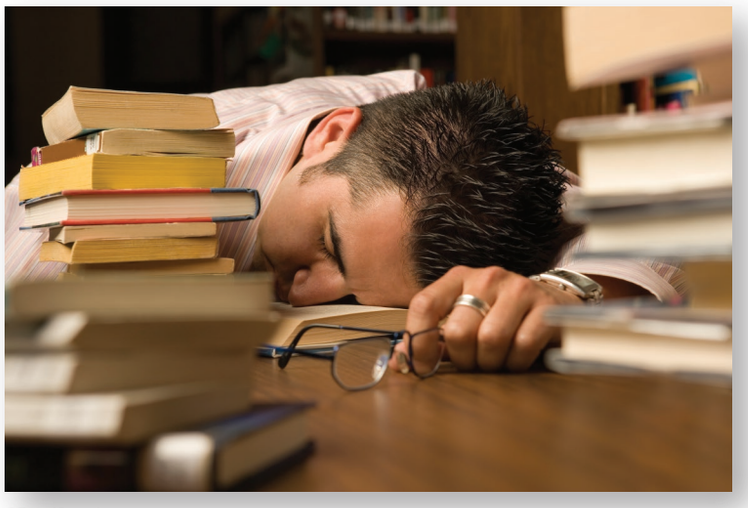
If you take this approach, you won't have much luck. Why doesn't the hard work of cramming give good grades? Because of how humans learn. Researchers have demonstrated that memory of newly learned information improves only after hours of sleeping. If you wanted to do well on an exam, you could not have chosen a poorer way to prepare than an all-nighter.

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

A Closer Look at Learning

To sort out the role of sleep in learning, Harvard Medical School researchers used 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 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 in performing the target identification.



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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.

Moving Your Short-Term Experiences to Long-Term Memory

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. 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.

The Next Hours. 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 manufacturing 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. 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, as 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 what it has learned, until practice makes perfect.

That's why getting by on three or four hours of sleep during exam week and crashing for 12 hours on weekends doesn't work. After a few days, all of the facts memorized during "all-nighters" fade away, never given a chance to integrate properly into memory circuits.

Learning

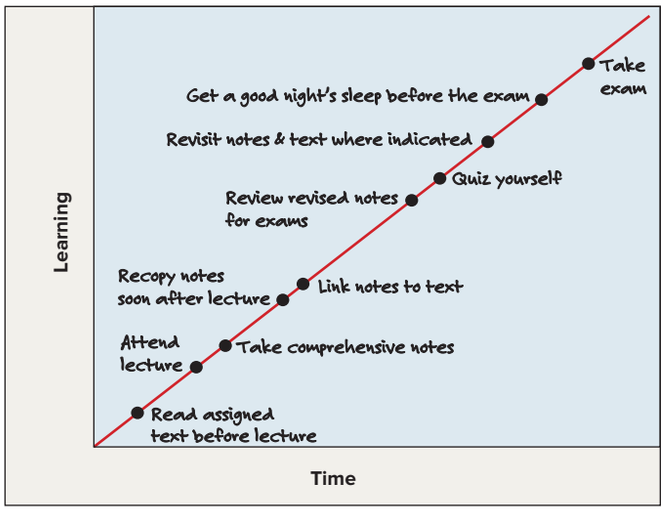


Figure 0.1 **A learning timeline.**

0.1 How to Study

Studying and learning are not the same thing. Just putting in time is not enough—it is not how long you study, but how effectively.

Taking Notes

LEARNING OBJECTIVE 0.1.1 **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 but 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. Also, simply rewriting your notes to make them legible, neat, and tidy can be a tremendous improvement that will further enhance your ease of learning (**figure 0.1**).

Remembering and Forgetting

LEARNING OBJECTIVE 0.1.2 **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. 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 that 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.

BIOLOGY & YOU

Improving Memory. There is an active market on the Internet for commercial products that claim to improve your memory. Many of these products involve repetitive games or other gimmicks; few have any lasting impact on memory. Psychologists have carried out considerable research on this subject and have found that the best way to improve memory seems to be to increase the supply of oxygen to the brain. How do you do this? These researchers recommend aerobic exercise. Walking for three hours each week significantly increases brain oxygen levels, as does swimming or cycling. One study found that chewing gum while studying will supply the brain with enough oxygen to improve memorizing items simply because of the muscle movement.

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. 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 hour. You should use your textbook as well when 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 and learn the entire contents of a chapter in one session; break it up into small pieces that are "easily digested."

Learning

LEARNING OBJECTIVE 0.1.3 **List 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. Learning strategists refer to this transfer as *rehearsal*. As its name implies, rehearsal always involves some form of repetition. There are four 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, as 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, such as the stages of mitosis, you will be able to recall the entire sequence if you can remember what gets the sequence started.

Linking. Biology has a natural hierarchy of information, with terms and concepts nested within other terms and concepts. You will learn facts and concepts more easily if you attempt to connect them with something you already know, linking them to some information that is already stored in your memory. Throughout this textbook, you will see arrows, like the one in figure 0.3, indicating such links. Use them to check back over concepts and processes you have already learned. You will be surprised how much doing this will help you learn the new material.

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 several Apps (Application dialogs) in the outer margins that allow you to briefly explore a "real-world" topic related to what you are learning. Read them. You may not be tested on these Apps, but reading them will provide you with another "hook" to help you learn the material on which you will be tested.

Figure 0.2 **Learning requires work.**

Learning is something you do, not something that happens to you.

IMPLICATION FOR YOU If you are honest with yourself, how many of the four rehearsal techniques (critical thinking skills) do you use when you take a science course like this one? Do you think they are as important in nonscience classes such as English or history? Why?

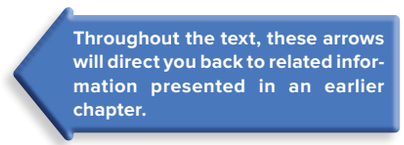


Figure 0.3 **Linking concepts.**

These linking arrows, found throughout the text, will help you to form connections between seemingly discrete topics covered earlier in the text.

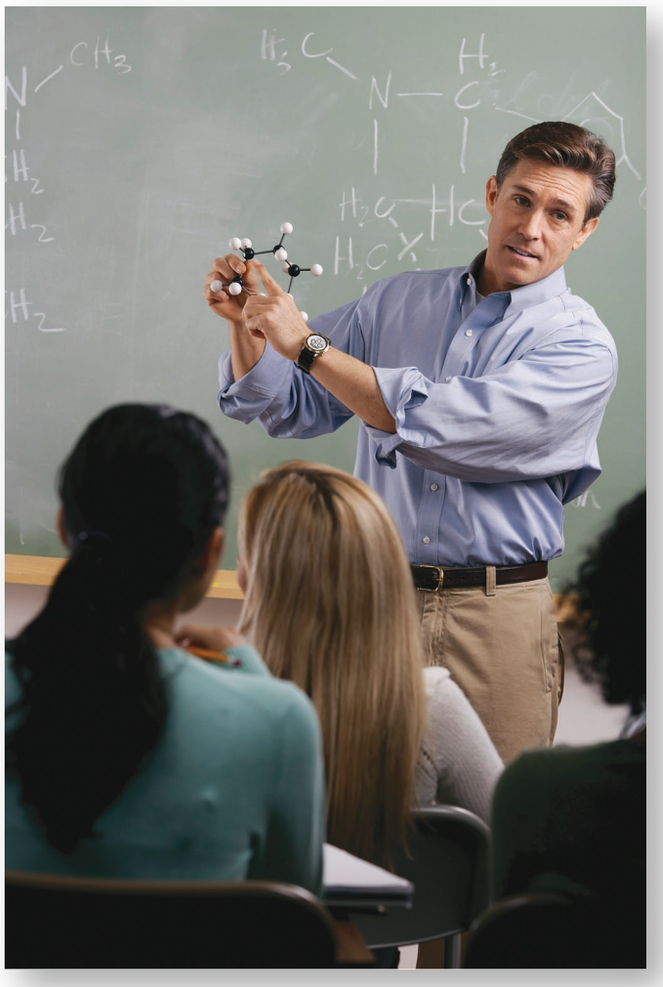


Figure 0.4 Critical learning occurs in the classroom.

Learning occurs in at least four distinct stages: doing assigned textbook readings before lecture; attending class; listening and taking notes during lecture; and recopying notes shortly after lecture.

Studying to Learn

LEARNING OBJECTIVE 0.1.4 **Describe three strategies to improve studying efficiency.**

How Long Should I Study? If I have heard it once, I have heard it a thousand times, "Gee, Professor Johnson, 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 ensure a favorable outcome. Many students treat studying for biology like penance: If you do it, you will be rewarded for having done so. Not always.

The length of time spent 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 to spend it all in one or two sessions. There are two good 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. For most of us, effective concentration also means a comfortable, quiet environment with no outside distractions such as loud music or conversations.

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.

Four Keys to Success 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 simple, obvious things (figure 0.4):

- *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.

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.

0.2 Using Your Textbook

Your text is more than a list of what you are supposed to know. It is a tool that helps you understand: This is the key to true learning.

A Textbook Is a Tool

LEARNING OBJECTIVE 0.2.1 **Describe how you can use your text to reinforce 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.

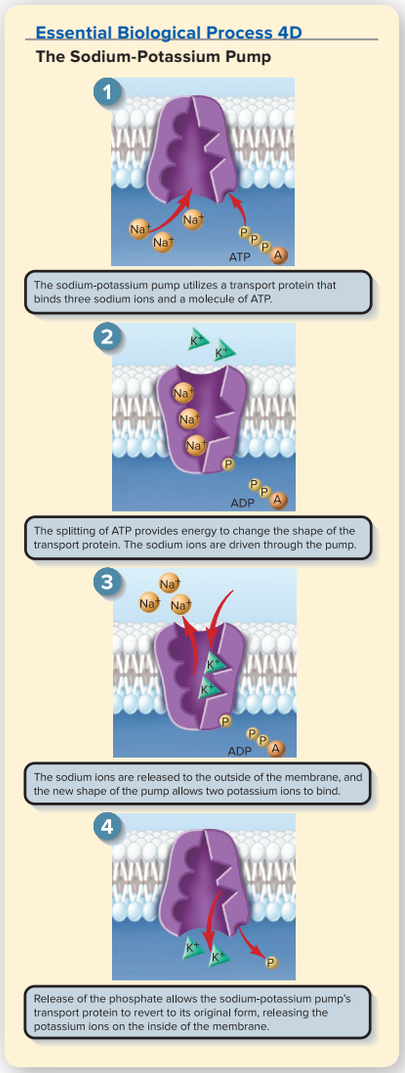
When to Use Your Text. While you can glance at your text at any time to refresh your memory or answer a question that pops into your mind, your use of your text as a learning tool should focus on providing support for the other two "legs" of course success: lectures and class notes.

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 much easier to follow the discussion and take better notes.

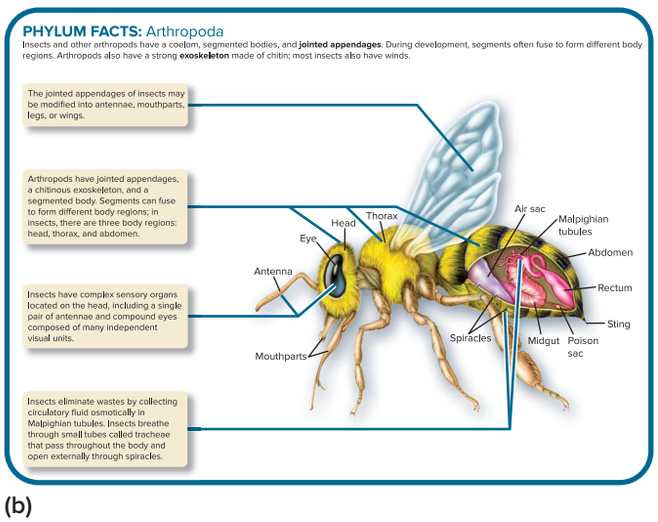
Link the Text to Your Lecture Notes. Your text provides you with a powerful tool to reinforce ideas and information you encounter in lecture. Text illustrations and detailed explanations can pound home an idea quickly grasped in lecture and answer any questions that might occur to you as you sort through 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 far better learning tools as you study for exams later.

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 a topic explodes at you off the page of 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 *learning objective* at a time, and focus on the concepts in each learning objective as you recopy your notes. Pay attention to the "linking" arrows in the text, as using them will reinforce what you are learning. 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 your taking it well.



(a)



(b)

Figure 0.5
Visual learning tools.

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

Learning Tools at Your Disposal

LEARNING OBJECTIVE 0.2.2 **Review the assessment tools that your text provides to help you master the material.**

A textbook is more than just words. What do you see when you flip through the pages of this text? Pictures, lots of them. And questions, scattered through each chapter and clustered at chapter's end. The pictures and quiz questions you will encounter within each chapter can be an important part of your learning experience.

Let the Illustrations Teach You. All introductory biology texts are rich with colorful photographs and diagrams. They are there not 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:

Essential Biological Process Illustrations. 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. There are several essential biological processes that 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 essential biological processes in the text, you will be provided with an illustration to help you better understand. These *Essential Biological Process* illustrations break the process down into easily understood stages, so that you can grasp how the overall process works without being lost in a forest of details (**figure 0.5a**).

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 will each be 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. In chapter 18, you will encounter a train of animal phyla (a phylum is a major category of organisms). In such a sea of information, what should you learn? Every time you encounter a phylum in chapter 18, 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 0.5b**). If you learned and understood only the items highlighted there, you would have mastered much of what you need to know.

Check What You Know. As you move through a chapter, addressing first one topic and then another, it will be important that you monitor your progress—not only what you have read, but how well you have understood it.

Putting Concepts to Work. At the end of each learning objective within a chapter, you will encounter a "putting the concept to work" question you can use to reinforce what you are learning. If you can't answer it, you should go back and have another look at that section.

LearnSmart Questions. When you complete a chapter, you can gauge how well you have learned the material by answering the *LearnSmart* questions provided by *Connect,* if your class utilizes this program (discussed in the next section).

0.3 Using Your Textbook's Internet Resources

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

Connect

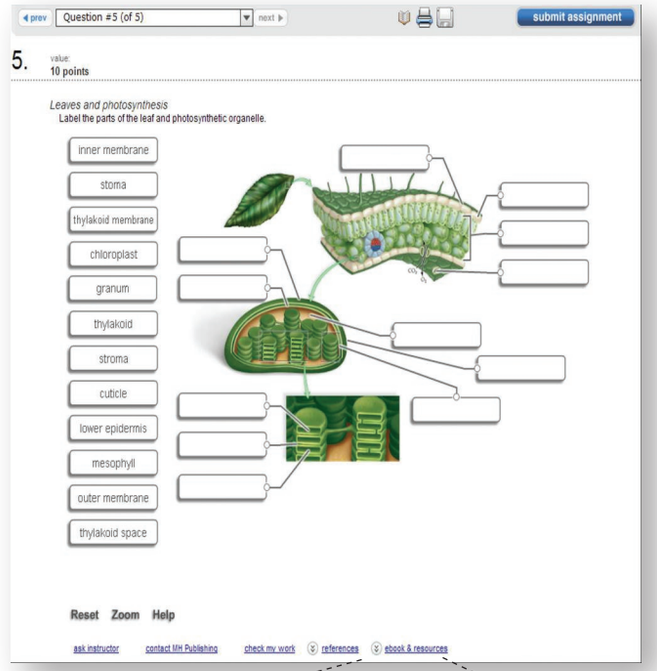
LEARNING OBJECTIVE 0.3.1 Describe the five kinds of interactive questions encountered in *Connect*.

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 visual learners.

A visual learner is best tested with visual and interactive questions. 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, such as the one you see in figure 0.6. *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 visual and 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. And should quizzes and exams be administered to you as unlinked *Connect* questions, it will be like meeting an old friend, a familiar face you have met many times before.

Kinds of *Connect* Questions. *Connect* presents you with five kinds of interactive questions: *Labeling questions,* such as figure 0.6, challenge you to drag terms to correctly label an illustration. *Composition questions* ask you to place words into a paragraph to correctly finish a sentence. *Sequence questions* have you arrange a series of images or process steps into the proper order. *Classification questions* require you to place a set of terms or characteristics into their appropriate categories. Lastly, *Inquiry and Analysis questions* ask you to select the graph that best portrays the results expected when an experiment is modified in a particular way.



(a)

(b)

Figure 0.6 Using *Connect*.

Using a text-integrated assessment program called *Connect,* your instructor is able to provide you with a series of interactive questions that test your understanding of key concepts and information. (a) In the question about leaves and photosynthesis above, for example, your job is to correctly label the parts of a leaf and its chloroplasts. (b) By clicking on the "*eBook* and resources" button below the question, you can at any point review the learning objective in the *eBook* where this material is discussed.