Science

Biology:
The Study of Life

Third Edition

High School Teacher Edition

Oak Meadow

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The Study of Life

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Teacher Edition

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Table of Contents

Unit 2: Ecology

Unit 3: Cells

Unit 4: Genetics

Unit 5: Evolution

Unit 6: Diversity of Life

Appendix

Teacher Edition Introduction

In this course, students are encouraged to consider science as a verb, not a noun, and as an active exploration rather than a static body of previously discovered knowledge. Science is questioning, wondering, examining, and imagining: What would happen if . . . ? Why does . . . ? How can . . . ? Science is observing and measuring, guessing what might happen, and then watching and recording what does happen. Science is always attempting to answer questions about our world.

Before the first lesson begins, students are directed to this video, which helps them consider the far-reaching implications of biology, the study of life:

"Introduction to Biology"

You can find a link to this video—and all the online resources in this course—at oakmeadow.com/curriculum-links.

This course puts into practice a major shift in science education. Communication and collaboration are becoming more and more important as scientific advancement has increasingly global implications. Science is no longer a bunch of facts to learn, and information is widely available. It is more important for students to understand broader concepts and how they are interconnected.

Supporting Your Students

The textbook for this course is *Miller & Levine Biology*, and the Oak Meadow Biology Lab Manual and Lab Kit are required. In addition to the items in the lab kit, other household materials will be needed. You will find a full materials list (sorted according to lesson) and the lab kit list in the appendix. This will help you and your student plan ahead so that all the necessary materials are on hand when needed.

Each semester has a special lab week (lessons 14 and 33) where students use the labs they've done so far to create an original experiment. They do a full lab report and then undergo a peer review with a partner (like the peer review a scientist would do with an article for publication). For example, in semester 1, students learn how to use quadrats to estimate populations, so they might decide to use this technique to compare clover populations on a lawn where pesticides are used and one where they aren't. They would design, conduct, and write up their experiment. Their peer review partner would be able to give them feedback because they have also learned how quadrats work. You might want to plan in advance for these peer review labs and argumentation so each student has the opportunity to review and be reviewed by a peer.

The questions in the coursebook are designed to be answered using information from the textbook readings. No additional research is needed unless otherwise stated. In fact, though students can be tempted to look up answers online, this is strongly discouraged, as it often takes the material out of context and does not contribute to a solid understanding of the material.

Students may choose to find online videos to help explain some of the topics. There are many great videos available, and several are included in the lessons. Watching these videos is encouraged if it helps a student visualize a concept.

This teacher edition can serve as your support as you guide and evaluate your student's work. In it, you will find the full text for all assignments, activities, and labs. Teacher edition answers are shown in **orange**. If more information is needed about any assignment, you can refer to the textbook.

Note that occasionally student answers may differ from what is in this teacher edition. This is especially true for critical thinking questions (which may have additional possible answers) as well as in labs where student responses need to match the data they actually collect.

When a student gets a factual answer wrong, you can share the correct answer and address any underlying misconceptions. The focus should always be on the learning process rather than on a sense of judgment. Several incorrect answers related to a particular topic point to an area the student will benefit from revisiting.

For obvious reasons, it is best not to share this teacher edition with your student. Each student is expected to produce original work, and any incidence of plagiarism should be taken very seriously. If you notice a student's answers matching those of the teacher edition word for word, a discussion about plagiarism and the importance of doing original work is necessary. While students in high school are expected to be well aware of academic honesty, some confusion may exist, so any discussion about it should be approached as a learning opportunity. Make sure your student is familiar with when and how to properly attribute sources.

We encourage you and your student to explore the topics introduced this year by exchanging ideas, going on relevant field trips, viewing and discussing videos related to course topics, and learning in other active, experiential ways. We hope this course leads your student to a better appreciation of science and how scientific inquiry can enhance our understanding of the wider world.

A Note About the Workload

Oak Meadow courses are designed to be flexible. Teachers can require all assignments to be completed or designate some assignments as required and others as optional. This lets teachers adapt the course for a wide range of student abilities, goals, and skills.

Students vary greatly in terms of their ability to absorb information and express themselves. Some may find the reading in this course takes longer than expected; others may find the writing assignments take a great deal of time. In general, students can expect to spend about five to seven hours on each weekly lesson. If your student needs more time to complete the work, you can modify lessons to

focus on fewer assignments or allow them to complete some of the written assignments orally. Modifications like these can allow students to produce work that is of a higher quality than if they have to rush to get everything done.

Each lesson in this course can be customized to suit your student's needs. Use your judgment in culling, substituting, and adjusting assignments as needed so that your student can meet the course's main objectives while devoting an appropriate amount of time to their studies. Keep an eye on the workload as your student progresses through the course and make adjustments so they have time for meaningful learning experiences.

Coursebook Introduction

> *"Science is much more a way of thinking than it is a body of knowledge."*
>
> **Carl Sagan**

Have you ever heard something described as "more an art than a science"? This common phrase makes it seem like science is a rigid set of rules and facts, with no room for wonder or imagination. This couldn't be further from the truth.

Consider science as a verb, not a noun, and as an active exploration rather than a static body of previously discovered knowledge. Science is questioning, wondering, examining, and imagining: What would happen if . . . ? Why does . . . ? How can . . . ? Science is observing and measuring, guessing what might happen, and then watching and recording what does happen. Science is always attempting to answer questions about our world.

Have you ever wondered what you have in common with the butterfly in your garden, the mold that's used to make your cheese, the bacteria that gave you strep throat, or the houseplant over in the corner of the room? You are more connected to all other life-forms in the world than you might realize. In fact, all life-forms are made of the same stuff, and the molecules that make up your body might have been part of a plant, fish, bug, or bacteria (or maybe even all of them) at some point in the past.

Welcome to *Biology: The Study of Life*! In this course, you will be immersed in the study of the living things that surround you. You'll be learning how *life* is defined and how you fit into the whole picture.

The word *biology* comes from the Greek words *bio*, which means "life," and *logos*, which means "knowledge" or "to study." Biology is the study of life—that's a big subject! In fact, every lesson opens the door to entire fields of study and possible careers.

To give you an idea of what to expect, take a few minutes to watch this quick video:

"Introduction to Biology"

You can find a link to this video—and all the online resources in this course—at oakmeadow.com/curriculum-links. This course uses many online resources, so bookmark this page for future reference.

Biology for the Next Generation

This course puts into practice a major shift in science education. Historically, scientists have often been isolated. The public was usually unaware of what scientists were doing, and scientists did not attempt to communicate their work. Times are changing! Communication and collaboration are becoming more and more important as scientific advancement has increasingly global implications. How does this affect you? Science is no longer a bunch of facts to learn, and information is widely available. You will not be tested on the names of the bones in the body or the orders of insects. Instead, we will focus on an understanding of broader concepts and how they are interconnected.

In this course, you will be *doing* science, writing about science, talking about science, asking questions about science, and thinking about science.

Integral to the study of biology (or any other scientific discipline) is the concept of **scientific inquiry**. In scientific inquiry, you are not only observing, inferring, and experimenting, but you are also encouraged to ask questions, form explanations, compare your explanations with current scientific knowledge, and communicate your ideas. We will be focusing on developing critical thinking and scientific reasoning skills and using these skills to advance your understanding of science. Throughout the course, you will be encouraged to dig more deeply into the material. Every question or wild idea is welcomed because it is by thinking "outside the box" that true scientific discoveries are made.

Now that you have an idea of what's ahead, here are some details that will help you get the most out of this course. Please take the time to read this entire introduction before you begin lesson 1.

Course Materials

This coursebook contains complete instructions for the wide variety of assignments, activities, and labs you'll be doing in this course. This course was designed to incorporate the Next Generation Science Standards (NGSS), a new framework for science education created by science teachers and organizations to prepare students for the new directions toward which science is heading. In addition to this coursebook, the following materials are used in this course:

- *Miller & Levine Biology, Student Edition* (Prentice Hall, 2019)
- Oak Meadow Biology Lab Manual
- Oak Meadow Biology Lab Kit

You will find a full materials list (sorted according to lesson) and lab kit list in the appendix of this coursebook. It's important to plan ahead so that you have the necessary materials on hand when you are ready to do your labs and activities.

About Your Textbook

The textbook we are using for this course, *Miller & Levine Biology*, is a comprehensive volume with a lot of useful resources and fascinating connections to current events and recent research. Please use it fully! Consult your textbook to answer questions rather than looking up information on the internet. You will be referred to great online resources throughout the course, and looking up information online can be helpful if you need further explanation on a topic. However, constantly looking for answers online as your primary source does you a great disservice for a variety of reasons. For one thing, an online search for a specific question gives you a tiny window into a larger topic that the book discusses in detail. If that is your only view on the material, you will miss important content and connections and will start to be more and more confused as the course goes on. Additionally, there are many cases where terminology or word usage can vary, so what you find online may not be relevant or accurate to this course. If you are struggling with the textbook readings, let your teacher know so you can get some support with this essential skill.

Take some time to get familiar with the layout of your textbook before you start the first lesson. There is a great student resource section in the back with lots of useful information that can help you throughout the year. Look it over, bookmark parts, and keep in mind that this resource exists.

How to Read Your Textbook

A science textbook is not a novel, and it takes a different kind of reading. Here are some tips:

- Pay attention to the key concepts, section headings, and main ideas.
- The highlighted words in the text are important, but the most important words to focus on are the ones you don't understand. You might already know the meaning of some highlighted words. Highlight any additional words you are unfamiliar with.
- Pay special attention to the images! This cannot be emphasized enough. The diagrams and illustrations are often easier to understand than the text and often provide information in a way that your brain can make sense of more easily. Use the text for additional information to augment the diagrams.
- Learn how to take good notes. There is a whole section on note-taking in the student resources section at the back of the book. Find a way that works for you.
- Use your notes! Taking notes is helpful in its own right, but referring to them for study is much more helpful.
- Mark up the textbook. Add notes in the margins, use sticky notes, highlight sections, and make it work for you.
- Reading a chapter straight through once is not always the best approach. You might need to skip around, going back and forth between sections, reading some parts two or three times. You can skim some parts and read other parts in depth.

How the Course Is Set Up

This course is designed for independent learning, so hopefully you will find it easy to navigate. However, it is assumed you will have an adult (such as a parent, tutor, or school-based teacher) supervising your work and providing support and feedback. We will refer to this person as "your teacher." If you have a question about your work, ask them for help.

In this course, there are 36 lessons. Most of the assignments in these lessons are short-answer questions. Try to be concise while answering the question completely using full sentences. If you are expected to write more than one or two sentences, it will be specified in the assignment. Sometimes, if you are simply naming something, full sentences are not required. When in doubt, write in full sentences.

You are required to complete all activities and labs unless it is specifically mentioned that there is a choice. All parts of each activity and lab are also required, unless otherwise specified.

You may wonder why there are no dissections in this course. At Oak Meadow, we have chosen not to use dissections for a few reasons. We feel that, although taking apart an animal in a hands-on way is a great learning experience, it is not necessary to destroy a living animal to understand its basic anatomy. Even in medical schools, models are used more and more often these days. When working with living things, we would like to do so with the utmost respect, recognizing that we don't own nature; we are a part of it. Oak Meadow's philosophy is to approach education in environmentally conscious and sustainable ways. However, if you feel that a dissection is in line with your interests and want to pursue it on your own, there are many dissection kits available online, and your work can be incorporated into the course.

In each lesson, you will find sections to guide your studies and deepen your understanding of the material.

Learning Objectives outline the main goals of the lesson and give you an idea of what to expect.

An **Assignment Checklist** is included at the beginning of each lesson so you can see at a glance what is required. You can check off assignments as you complete each one. Assignments are fully explained in the lesson.

The **Lesson Introduction** provides an overview of the lesson and important background information.

Think About It gives you prompts that can be used for reflection or for discussion with someone in your family or community. Pondering these topics will enrich your experience in the course. You are not required to submit anything for these sections, but do let your teacher know if you are discussing these prompts with others.

Reading assignments are given for each lesson. It is very important that you focus on the reading suggestions that are specified for each lesson, as they highlight the especially useful parts of the reading, and let you know which parts you can skim.

Comprehension Assignments are designed to help you solidify key concepts and knowledge. The answers to these assignments can be found in the textbook.

Critical Thinking Assignments encourage you to think deeper about the material and make important connections by applying your knowledge and your best scientific reasoning skills. The answers to these assignments are not directly in the textbook—they require you to think and problem-solve on your own, using what you've learned. Often, there are multiple correct answers, so make sure you explain your thinking.

Activities provide additional hands-on ways to explore the topics you are studying.

Labs give you a way to explore, experiment, and discover how the concepts you are learning play out in real life. You will have some pre-lab work to complete before you do the lab. Once you have done the lab, you will do the post-lab assignments, which will detail everything that needs to be submitted. This course also includes lab weeks where there is just lab work without any textbook reading or questions. Each lab week culminates with a lab report or lab poster to share your work. You will use an experiment design organizer (found in the appendix) to help you organize all the parts that belong in a proper scientific investigation.

Share Your Work provides reminders and information for students who are enrolled in school and submitting work to a teacher.

The **appendix** contains important material that you will be expected to read and incorporate into your work throughout the year. Take some time to familiarize yourself with the information in the appendix. You will find academic expectations, original work guidelines, tips on how to avoid accidental plagiarism, and details on citing sources and images. You will also find a list of citizen science opportunities, a comprehensive works cited section that lists the dozens of excellent resources mentioned in this course, a materials list, and more.

Online Resources

This course makes good use of technology and the vast resources found online. Links to all the online resources in this course are easily accessed at oakmeadow.com/curriculum-links. Bookmark this page because you will be returning to it frequently.

It's fun to see videos and films that show biology in action, like the following one:

"Lord of the Ants"

Here are some other excellent resources for you to use throughout the course:

Encyclopedia of Life

Understanding Science

One of the best ways to learn is to get involved. If you are interested in taking an active role in an ongoing research project, you can find an astounding array of citizen science opportunities at this website:

Zooniverse

For more great citizen science ideas, check out the detailed list in the appendix.

If you don't have internet service at home, you are encouraged to do the online activities at your local library. If you are unable to use the internet, talk to your teacher about alternative assignments.

Academic Expectations

The appendix contains important material that you will need to read and incorporate into your work throughout the year. You will find information about original work guidelines, tips on how to avoid accidental plagiarism, and details on citing sources and images. Take some time to familiarize yourself with these resources.

A Note About the Workload

Students vary greatly in terms of reading speed, reading comprehension, and writing ability. Some might find the reading in this course takes longer than expected; others might find the writing assignments take a great deal of time. In general, you can expect to spend about five to seven hours on each weekly lesson.

Keep an eye on the workload as you progress through the course. If you find you are struggling to complete the work in a reasonable time frame, discuss your options with your teacher, who might modify certain lessons depending on particular learning goals or challenges you are facing.

The Journey Ahead

Biology is a constantly changing field of study with new discoveries being made in every area. Scientists are constantly finding that the more we learn about nature, the more we learn about ourselves and the consequences and effects of our actions on the rest of the world. This makes the study of biology a deeply personal journey.

As you go through the course, be aware of this. Pay attention to the media, and learn about new discoveries as well as the controversies that often surround them. The more you learn about biology, the more you will be able to understand and relate to what you see and hear all around you. Enjoy!

Lesson

1

What Is Biology?

Learning Objectives

In this lesson, you will:

- Become familiar with the themes of biology and the properties of life.
- Analyze the nature of scientific thinking and inquiry.
- Practice scientific inquiry by designing and conducting scientific investigations.

ASSIGNMENT CHECKLIST

- ☐ Read chapter 1 in your textbook.
- ☐ Read the Review of Laboratory Safety in the lab manual.
- ☐ Complete the comprehension assignments.
- ☐ Complete the critical thinking assignments.
- ☐ Activity: Experiment Design
- ☐ Lesson 1 Lab: Walking Crooked

Lesson Introduction

Integral to the study of biology or any other scientific discipline is the concept of **scientific inquiry**. In scientific inquiry, you not only will observe, infer, and experiment, but you also are encouraged to ask questions, form explanations, compare your explanations with current scientific knowledge, and communicate your ideas. We will be focusing on developing critical thinking and scientific reasoning and using these skills to advance your understanding of science. Throughout the course, you will be encouraged to ask questions. In science, there is no such thing as a stupid question!

Note: When you see a word or term highlighted like s*cientific inquiry* above, that's a key term you should know.

Reading

1. In your textbook, read chapter 1, "The Science of Biology" (2–33).

   Note: The chapter refers to a "Lab Skills Handbook"—this is not required reading. It is found at the end of your textbook (page A-1), if you are interested.

Additional Reading Assignment for the Course

For this biology course, you will be reading one additional book. Below you will see a list of four books to choose from. They are all fascinating books, so you may have a hard time choosing. Feel free to read them all! Any one of these books will help you see science in a different light.

You have the entire year to complete this additional reading assignment (or the entire semester if you are only taking one semester of biology). You may submit your review of the book (details on this are below) at any point during either semester, and it will be graded with the semester grade. You will see reminders throughout the course about this; try not to leave it until the end. If you are going on a family trip or taking a vacation, that would be a good time to pick up one of these books.

• *A Planet of Viruses* by Carl Zimmer

Viruses are involved in almost every important function on Earth. With the increase in bacterial resistance to antibiotics, viruses might be the future in treating infectious disease. Every liter of seawater is estimated to contain up to one hundred *billion* viruses! Carl Zimmer states, "Viruses are the smallest living things known to science, and yet they hold the entire planet in their sway." Viruses even blur the line between life and nonlife. In describing the intriguing life history of several viruses in short chapters, Zimmer makes science truly fascinating and accessible to anyone.

Writing assignment: As you read through this book, keep notes for each chapter. Write down at least three facts from each chapter that you find especially interesting or surprising. After you complete the book, write an essay about the effect the book had on you. Was it worth your time, and do you feel it fits well with the biology course? In the textbook, we learn that viruses aren't officially living things since they are not made of cells. What are your thoughts on that after reading this book? Submit your essay and the three interesting facts from each chapter to your teacher when you complete the book.

• *Flight Behavior* by Barbara Kingsolver

In this excellent work of fiction, Kingsolver weaves together real life and science as climate change, environmental sustainability, and discoveries made in the natural world reflect and influence what is going on in the life of a young woman. Monarch butterflies migrating through the Appalachian Mountains provide a rich backdrop for the story.

Writing assignment: After you read the book, write an essay addressing some of the following questions.

a. How can many people look at one event and see it so very differently? Some felt that the butterflies were a miracle, and others felt their presence was a disastrous result of climate change. What does this say about human behavior and how people decide what to believe?

b. What do you think about Kingsolver using fiction to spark the conversation about climate change? Is this effective?

c. Comment on the process of science as it is introduced in this book. What did you learn about how science is done? Consider the sampling methods, data collection, and the concept of causation versus correlation that is addressed in the book. Did you end up with the feeling that science is accessible even to those who don't think they have a scientific mind?

d. Scientists express things with caution. Rarely are data expressed with certainty, as that would imply 100 percent certainty from a scientific perspective. We are accustomed to certainty, and may prefer not to believe an issue if it is only 98 percent certain. Comment on the idea of certainty and how it relates to the climate change issue.

• *The Immortal Life of Henrietta Lacks* by Rebecca Skloot

Henrietta Lacks was a poor black tobacco farmer who, in 1951, was diagnosed with cervical cancer. Her cells were taken from her tumor without her knowledge or consent, and became one of the most important tools in medicine. The HeLa cell line was essential in the development of the polio vaccine, cloning, gene mapping, cancer research, and more. HeLa cells have been, and continue to be, reproduced in labs throughout the world. Henrietta died as a result of her cancer. Meanwhile, her cell line lived on, and all of this happened without her family having any idea of what was going on. This book is like a detective story combined with a heart-wrenching novel. At times it is hard to believe it is all true. *The Immortal Life of Henrietta Lacks* brings the subject of bioethics to the forefront.

Content warning: This book accurately portrays difficult circumstances and contains violence, abuse, and other mature topics. As with all material in this course, please approach the topic with sensitivity and kindness, both to the people you are studying and to yourself. If you are struggling emotionally with topics in the book, please contact your teacher or another trusted adult.

Writing assignment: After you read the book, choose **three** of the following topics to discuss in an essay.

a. Review pages 524–527 of your textbook, on the topic of biotechnology ethics. How does this book fit into the discussion of bioethics as it is seen today? Do you feel that the discussion should have started many years ago, when Henrietta Lacks's cells were taken?

b. Deborah shares her mother's medical records with the author, Rebecca Skloot, but was adamant that she not copy everything. Deborah says, "Everybody in the world got her cells, only thing we got of our mother is just them records and her Bible." If you were in Deborah's situation, how would you react to someone wanting to look into your mother's medical records?

c. Rebecca Skloot was very careful not to take sides when she reported this story. Since we always bring our own perspectives and experiences into whatever we read, do you feel that Skloot was unbiased, or do you think that she took a side (scientist or family)? Did you take any particular side while reading the book, or are you in the middle? Explain.

d. Review the consent form that Henrietta signed (31). Based on this statement, do you believe TeLinde and Gey had the right to obtain a sample of her cervix to use in research? What information would they have had to give Henrietta for her to give *informed* consent? Do you think she would have agreed for her tissue to be used in research if she'd had all the information?

e. Do you feel the Lacks family should be financially compensated for the HeLa cells, all these years later? If so, where do you think the money should come from?

f. Review the case of John Moore (199–201). How does that make you feel? How do you feel about the Supreme Court of California's ruling that states when tissues are removed from your body, with or without consent, any claim you might have had to owning them vanishes?

g. Review chapter 32 (259–267), when Deborah and Zakariyya got to see the HeLa cells for the first time. How do you feel about the way Christoph Lengauer handled the situation? Relate this experience to the importance of informed consent. How could simple knowledge about the situation have prevented so much anger and misunderstanding?

- ***Stiff: The Curious Lives of Human Cadavers* by Mary Roach**

Medical students often practice surgery on cadavers. Before anatomy was understood, "body snatching" (the stealing of bodies from graves) for medical schools was a big business and the money earned from this practice fed many families. Today, criminal forensics is a very important and cutting-edge field, and understanding the process of human decay is necessary. And although it sounds horrible, the use of cadavers is far superior to the use of crash test dummies for auto safety research. While such a book may seem gruesome, Mary Roach is a master at making science, even *this* science, funny. If you are at all interested in medicine or forensics, this is a great read. No matter your interests, this book will open your eyes to fields of study you never knew existed.

Writing assignment: For this course, you are asked to read only the first six chapters (about 150 pages, half the book). As you read through each chapter, keep notes. Write down at least three facts from each chapter that you find especially interesting or surprising, and any other notes you want to jot down. After you complete the reading, write a report and critique of the book. Did it have any particular effect on you? How do you think it relates to the biology course? Do you find forensics to be an interesting biology topic? Submit your essay and the three interesting facts from each chapter when you complete the first six chapters.

2. In your lab manual, read the Review of Laboratory Safety, found in the introduction.

Think About It

Can all questions be answered by using scientific methods? If you are testing a hypothesis and your results don't support your hypothesis, is your investigation a failure? Take some time to consider these two questions and then discuss your thoughts with a friend, sibling, or parent. Express yourself clearly and check that your discussion partner understands the points you are making. You might have to explain some of the scientific concepts or methods on which your answers are based. Being able to "talk science" is an important skill, and you'll be practicing this throughout the course.

For this section, your student may want to discuss the topics presented with you, other adults, or peers. If you have the opportunity to have a discussion with your student, you might encourage alternative points of view by playing devil's advocate, or you might question your student's ideas, asking them to express these ideas with logic and evidence to support them. Be prepared to model giving support to your own argument as well.

Think About It boxes are found throughout the course. Make sure to read them and ponder the questions they raise. You are encouraged (but not required) to discuss these ideas with friends and family because this will enrich your experience in the course. (Let your teacher know if you would like to be paired with a peer to discuss any of these topics.) There is nothing you have to submit for this section, but if you do discuss Think About It topics with others, please let your teacher know and share a bit of what you discussed.

Comprehension Assignments

Refer to your textbook as necessary to respond to the following assignments.

1. Imagine you are going for a walk outside and come across a mystery object (previously unknown to science) that you suspect could be a new species. What characteristics would you look for to determine that it is, in fact, a living thing?

   Students should identify more than one of the following characteristics: made of cells, reproduces, grows and develops, has a metabolism, responds to stimuli, maintains homeostasis, and evolves.

2. Homeostasis is an important biological theme. Explain what homeostasis is, and give an example.

   Homeostasis is the maintenance of constant internal conditions in an organism. Examples will vary and may include body temperature, blood sugar, acidity, etc., or a home thermostat or cruise control in a car.

3. The textbook describes how systems are made of many parts that work together and interact to perform a particular function. Describe a system that is part of your everyday life. (It does not need to be related to biology.)

   Answers will vary. Students may describe their family, household, kitchen, computer, body, etc. Note: Some students might confuse a system with a routine. Be sure this distinction is made.

4. Chapter 1 discusses structure and function as an important theme in biology. Read the information below, and look for an example of structure and function:

   > Polar bears appear white, but their fur is actually made of clear hairs that allow sunlight through to the black skin underneath. This black skin is able to absorb heat well from the light. Polar bear hairs are also hollow, which means they trap air as insulation.

   Write down the example of structure and function you found, and explain why you think this example shows the theme.

   For each example of structure, the function is the same: keeping the bear warm! Structure examples include clear hairs, black skin, and hollow hairs. Students should explain that each structure example allows the function of staying warm to occur.

5. What is the importance of peer review in science?

   Peer review ensures that the methods and data collection have been carried out using unbiased science practices, and that the conclusions reached are valid and unbiased. Peer review is an important part of the scientific process.

Critical Thinking Assignments

1. Some things cannot be explored through scientific inquiry. To be considered for scientific inquiry, an observation or hypothesis must be *testable and verifiable*. This means that **empirical evidence** (evidence collected in observation or experimentation) can be gathered to verify or falsify the statement.

   Here are two examples of testable statements:

   - "The North Atlantic Right Whales are moving north because of warming oceans."
   - "Unicorns come into my room at night."

   These are both testable because empirical evidence can be collected to support or refute each statement.

   In contrast, here are two examples of nonscientific hypotheses or observations:

   - "War is wrong." (You can't test opinions.)
   - "Aliens built Stonehenge." (We can't verify that aliens were here when Stonehenge was built.)

Use these examples to answer the questions below.

a. Give an example of an observation or hypothesis that would be considered for scientific inquiry, and explain why it is testable and verifiable.

Examples will vary, but it's easy to come up with observations that would be considered scientific. To be considered scientific, an observation/phenomenon needs to be testable and verifiable: weather, animal behavior, plant growth, etc. Even things like "My little brother eats more cookies than vegetables" are testable.

b. Give an example of an observation or hypothesis that would not be considered for scientific inquiry, and explain why it is not.

Nonscientific examples:

- **"Ghosts are real."**
- **"Plants like sunlight."**
- **"Four leaf clovers are lucky."**

Students should explain that empirical evidence cannot be gathered to verify or falsify their statement.

2. Below is a description of a **controlled experiment**. You may want to review the section on page 12 of your textbook to see the features of this type of experiment.

> Students wanted to test how plant growth is impacted by light color. Students took nine pea plants of the same age and species and planted them in separate pots. The same amounts and types of water and potting soil were used. The plants were kept in the same room at the same temperature. There were three pea plants placed under a red light, three placed under a green light, and three placed in natural sunlight.

Based on this description of a controlled experiment, respond to the following prompts.

a. Identify the following:

the independent variable

light color

three constants

Examples include plant age, plant species, amount of water, amount of soil, type of soil, temperature, and same elevation (altitude).

the control group

the pea plants in natural sunlight

b. Why are constants and control groups important?

The control group provides a baseline to compare the experimental groups to. In this experiment, if you only had plants under red and green lights and they all died, you wouldn't know if this was because of the light color or if something about the other conditions (like water amounts) was responsible.

The constants are important because they let you compare the impact of the independent variable across all your tests. If we had plants under different light colors, but didn't control the amount of soil each plant had, then if some plants grew taller, we wouldn't know if this was due to the light color or the soil amount.

c. The dependent variable for the experiment is not specified but has to do with plant growth. Identify one type of **quantitative** data that could be collected and one type of **qualitative** data.

Quantitative examples include plant height, plant mass, plant growth rate, etc.

Qualitative examples include leaf color, wilting, texture, growth direction, etc.

d. Consider your qualitative data example as an observation that needs further investigation. How could you investigate it in a quantitative way?

Answers will vary. For example, if you wanted to investigate the qualitative observation of leaf color, you could create a chart where each color is assigned a number so that the color data can be analyzed numerically.

e. At the end of the experiment, Student A and Student B analyze their findings in writing below. Identify as many features as you can that make Student B's analysis stronger than Student A's.

Analysis by Student A	Analysis by Student B
I think my results prove that light color impacts plant growth. Since my peas grew better with red light than green, in my opinion it's best to grow plants under red lights.	These data support the hypothesis that light color impacts pea plant growth rates. The pea plants under red light grew an average of 1 cm per day, which was similar to the 0.9 cm per day growth rate of the pea plants under natural light. In contrast, the pea plants under green light only grew 0.5 cm per day. These differences indicate that pea plants may have a faster growth rate with some light colors than others.

Answers will vary but could include the following:

- **Student B avoids the personal language that Student A uses, such as "I think."**
- **Student B references specific data ("1 cm per day") while Student A uses generalizations ("grew better").**
- **Student B includes specific information about the experiment, such as the plant species, measurements, and which conditions were tested.**
- **Student A states that their data "proves" something, but this is not true because of the limited nature of this experiment. Student B says the data "support the hypothesis," which is much more accurate.**

3. Based on the definitions of theory discussed on page 14 of your textbook, give an example of a theory that you have come up with in your life that would not be considered a scientific theory. Explain why it is not a scientific theory.

   A scientific theory is supported by a wide range of evidence acquired through experimentation. In the everyday sense, a theory is just a guess. Students' examples will vary but should reflect that understanding.

Activities

Complete the following activity.

Activity: Experiment Design

In this activity, you will design a controlled experiment. As you work on this activity, keep the following things in mind:

- You will not be carrying out this experiment. Pretend you have the resources, space, time, etc., to carry out your experiment in whatever way you plan it. Don't worry about practicality.
- For help, pages 10–13 in the textbook explain the main features of scientific methodology and pages A-8–14 (in the back of the textbook) discuss this in detail. (Keep in mind that there are variations in how scientific inquiry is carried out; the book is just laying out a general format.)
- The controlled experiment described in the Critical Thinking assignments included a control group but not all controlled experiments require this. It will depend on the investigation you choose.

Step 1

Choose one of the experiment topics below. (Note: Since we are providing a list of topics, we have skipped over the process of observing, which is often part of designing an investigation.)

- You designed a new pill that has potential for being a cure for diabetes, but you want to know if this new drug will work.
- You are curious to know if hot water freezes faster than cold water. (Feel free to actually carry out this experiment!)
- A forest has started getting acid rain, and at the same time, the frog population has dropped. You want to know if the acid rain is causing the population to decrease.

Step 2

In the appendix of this coursebook, you will find an experiment design organizer. This is to help you remember to include all the parts that go into an investigation.

Create a copy of this organizer to use in step 3.

Step 3

Think through the prompts below and fill out the experiment design organizer as you go.

1. Write one testable question related to your scenario; this will be your **guiding question**.
2. Consider an explanation for this question, and write this in the form of a testable **hypothesis**.
3. Describe what you would observe happening if your hypothesis is correct, and write this as your **prediction**.
4. Identify the **independent variable** (the variable that is intentionally changed in order to test it) and the **dependent variable(s)** (the variable that is measured in response to the independent variable).
5. Identify the **constants** (or controlled variables) that you will keep the same.
6. List the **materials** you will need.
7. Describe the **procedure** you will use to test your hypothesis. You may or may not include a control group. If you do, identify what it is. Explain each step clearly.

Submit your finished experiment design. If you chose to carry out the experiment on freezing hot versus cold water, then share that information with your teacher as well.

Answers will vary depending on the experiment the student chooses. All boxes of the design organizer should have information in them. Make sure the hypothesis is testable and the prediction relates directly to the hypothesis. Check that the variables are categorized correctly: independent, dependent, and controlled/constant. The procedure should show reasonable detail and a logical sequence.

Lab

In this lab, you will use your own body to practice scientific inquiry.

Complete the following:

- Lesson 1 Lab: Walking Crooked

All labs are found in the Biology Lab Manual.

See the lab manual for the complete lab instructions. Answers for the lesson 1 lab are below.

Pre-Lab Work

1. a. What is the independent variable?

   blindfolded or not blindfolded

   b. What is the dependent variable(s)?

   Students could list one or more of these: distance strayed, variation to the left or right, and qualitative observations in the Notes section.

c. What is one constant in the lab?

Students should name at least one of the following: all people are tested on the same course with the same sound cues, distance, and blindfold.

2. Write a hypothesis.

Student hypotheses can vary. One example: Blindfolded people will not be able to walk in a straight line.

3. Look at the data table in the Results section. Where will you record quantitative data? Where could you record qualitative data?

Quantitative data is in the Distance Strayed section. Qualitative data is in the Left or Right and Notes sections.

Analysis and Conclusion: Post-Lab Questions

1. Keeping in mind the difference between testable and nontestable hypotheses, write a short paragraph that uses evidence from your data table to discuss whether or not the data supports your hypothesis.

   Note: In formal science writing, it is best to avoid "I" statements, such as "I believe" or "I think" or even "my data," because this can introduce bias and opinion into what should be objective writing. To avoid this, here are some sentence starters that you can use to help you (but you are not required to use these words):

   - "The data from the lab does/does not support the hypothesis that _____"
   - "In this lab, it was observed that _____, which does/does not support the hypothesis that _____"
   - "The data includes _____, which indicates that _____"

   Students should state whether or not their results support their hypothesis by referencing specific results from their data table. Since this is the beginning of the course, students might do things like use "I" statements, talk about "proving" their hypothesis, or struggle to reference specific results from the table. That's understandable at this point, and you can use the opportunity to point out these issues to the student and provide suggestions on how to improve their work.

2. A test like this often results in more questions than you started with. Here are a few questions that might come up:

   - Why don't people walk straight?
   - Will one person always go the same direction?
   - Is there a predictable pattern if you are left- or right-handed?
   - Would this translate to different activities, such as paddling a kayak?

What else do you wonder? Come up with at least three questions about this experiment that could be tested. There are many possible questions!

Any questions are allowed, as long as they are testable. Students should not be penalized for questions that seem silly. The questions provided are meant to get students thinking, but it is not an exhaustive list by any means.

3. Submit the following to your teacher:
    - Responses to the pre-lab work
    - Photo of your setup
    - Your completed data table
    - Analysis and conclusion (post-lab questions)

SHARE YOUR WORK

At the end of each lesson, you will share your work with your teacher for feedback. (If your teacher prefers a different submission schedule, they will let you know.) You are not necessarily required to complete all the assignments, so check with your teacher at the beginning of each lesson to make sure you understand what you are required to do.

You can use the checklist below to organize your work submission.

- Responses to comprehension assignments
- Responses to critical thinking assignments
- Activity: Experiment Design
- Lesson 1 Lab: Walking Crooked

Your teacher will let you know the best way to submit your work. If you have any questions about the lesson content, assignments, or how to share your work, contact your teacher.

In the coursebook, students are prompted to share their work at the end of each lesson so they can receive timely feedback. If you (or the supervising teacher) prefer a different submission schedule, make sure your student understands when and how to submit work and when to expect feedback.

Lesson

2

The Chemistry of Life

Learning Objectives

In this lesson, you will:

- Become familiar with atoms, elements, and molecules, and how they join in ionic and covalent bonds.
- Explore the properties of water and how water supports life.
- Learn about the four types of carbon-based molecules in living things.
- Become familiar with the basics of the chemical reactions that take place in living things, and the importance of enzymes.

ASSIGNMENT CHECKLIST

- ☐ Read chapter 2 in your textbook.
- ☐ Complete the comprehension assignments.
- ☐ Complete the critical thinking assignments.
- ☐ Activity: Graphing Practice
- ☐ Lesson 2 Lab: Determining the pH of Common Substances

Lesson Introduction

Look at the picture on page 40 in your textbook of the basilisk lizard "running" on water. It is truly astounding that life exists in so many unique forms!

Throughout this course, you will be studying the innumerable types of life on our planet, including our own amazing bodies. Despite the variety, all life on Earth consists of the same basic ingredients. Take cellulose, for example, which makes up the cell walls of plants. Did you know that plants produce 100 billion tons of cellulose a year? It is the most abundant organic molecule on Earth, and yet we can't even digest it. The only animals that can are those that are able to enlist the help of microorganisms that contain the right enzymes.

In this lesson, you will learn about the building blocks of life—the special properties of the atoms, elements, and molecules that make up every living cell, and the chemical reactions that keep us going.

Think About It

The names of most enzymes end in the suffix *-ase*. Whenever you see a word with this suffix, you know you are reading about an enzyme. Read the list below of common enzymes in living things. Can you identify what substrate each enzyme acts on? If you can, discuss this list with a family member or friend. Make your best guess, and then check the end of this lesson for answers. How did you do?

- protease **proteins**
- lipase **lipids**
- lactase **lactose**
- amylase (tricky one!) **amylose**
- cellulase **cellulose**
- polymerase **polymers**

Extra challenge! Which of the enzymes in the above list is *not* found in our bodies? (If you need a hint, read the introduction to this lesson again.)

Cellulase is not found in our bodies. We don't have the capacity (or the microorganisms with the capacity) to digest cellulose.

Reading

1. In your textbook, read chapter 2, "The Chemistry of Life" (40–65).

   You can skim section 2.1, taking note of the headings, diagrams, and highlighted terms. Read the other sections in more depth.

Comprehension Assignments

1. **Mnemonic devices** are often used in biology as a memory tool. "ROY G BIV" is a well-known mnemonic device for remembering the colors of the rainbow (red, orange, yellow, green, blue, indigo, violet). Often a catchy phrase is created where the first letter of each word corresponds to the first letter of each term you are trying to remember.

   Come up with a mnemonic device to remember the four elements that make up 99 percent of the mass of living things. (We will be discussing these elements a lot in the next few chapters.)

   The elements are carbon, hydrogen, nitrogen, and oxygen. The mnemonic device can include these in any order.

2. Why doesn't oil dissolve in water?

   Oil is made of nonpolar molecules, which means they have no charged regions. There is no attraction between the oil and the water. The water molecules are attracted to one another by hydrogen bonds, and they effectively push the oil away.

3. Carbon is often referred to as the building block of life. What are some special bonding properties that make carbon so important?

   Carbon atoms have four valence electrons, so they can each bond with up to four other atoms. Carbon forms these bonds with a wide variety of other elements but can also bond to other carbon atoms. These bonds can be single, double, or triple bonds. Chains of carbon atoms can even form rings. The bonding versatility of carbon is unique.

4. Use the information in section 2.3 ("Carbon Compounds") of your textbook to fill in the missing information in the following table.

Properties of the Four Categories of Organic Macromolecules

Macromolecule (polymers)	Monomer	Function(s)	Example of a molecule of this type
Carbohydrates	monosaccharides	**store and release energy, structural support and protection**	**glucose, glycogen, starch, cellulose**
Lipids	fatty acids and glycerol	**store energy, found in cell membrane**	**steroids, triglycerides**
Nucleic acids	**nucleotides**	**communicate and store genetic information**	**RNA, DNA**
Proteins	**amino acids**	**variety of work in an organism, including regulating, building, transporting, etc.**	**thyroxine, keratin, hemoglobin**

5. Why is the shape of an enzyme so critical? (You may want to review the sections on activation energy and protein structure.)

   As a protein, each type of enzyme has a unique folded structure. This structure allows the enzyme to bond with a unique substrate to catalyze a reaction. If the shape of an enzyme changes, it can no longer bond with the substrate. As a result, there is no way to lower the activation energy of the reaction, so it might happen too slowly for a living thing to survive.

Critical Thinking Assignments

1. The pH scale is a negative logarithm. That means that there is a tenfold difference in H+ ion concentration between one pH value and the next. Given this information, respond to the following.

   a. What is the difference in H+ ion concentration between a substance with a pH of 2 and a substance with a pH of 4?

   The substance with a pH of 2 has 100 times more H+ ions than the substance with a pH of 4. It could be said that it is 100 times more acidic. The key word in the explanation is "tenfold." Each pH unit has 10 times more or fewer H+ ions than the pH unit above or below it, respectively.

   b. Why is it so important that the pH of human blood remain in a very narrow range?

   Reactions in cells require a specific pH range (this is mainly for enzymes to function appropriately). Because pH is a logarithmic scale, a small difference in the number results in a huge difference in acidity. This can limit cellular processes and upset homeostasis.

   c. Compare the impact of acids versus bases on the H+ concentration in a water-based solution.

   When acids or bases are mixed with water, these substances either add H+ ions or remove them (respectively) from the solution.

2. How are the properties of water essential for life on Earth? Answer this question either in one or two written paragraphs or as a creative piece (song, cartoon, etc.).

   Use the concepts from pages 47–49 in the textbook, such as polarity, hydrogen bonding, cohesion, adhesion, heat capacity, etc.

   Students should submit a written or creative expression of the following ideas.

   Water is polar. This means:

   - **many substances dissolve in water, including substances that are critical for living things, such as oxygen, salts, and nutrients.**
   - **hydrogen bonds form between water molecules.**

   The presence of hydrogen bonds in water causes:

   - **cohesion (water "sticking" to itself) and adhesions (water "sticking" to other substances), which is critical for water to be able to move through plants.**
   - **water to have a high heat capacity, which means that a lot of energy must be added or removed to change the temperature of water (because energy must first be used to make/break hydrogen bonds before impacting the temperature). This helps moderate temperatures within living things but also anywhere organisms live in or near water.**

Activities

Complete the following activity.

Activity: Graphing Practice

In this course, you will be graphing data. Graphing and graph interpretation are very important skills to develop. If you are already familiar with graphing, consider this extra practice.

1. First, review the Salt Marsh Experiment from chapter 1 in your textbook (figure 1-2, page 10) to make sure you understand independent and dependent variables. Why is nitrogen considered the independent variable and height the dependent variable?

   The independent variable is what the researchers change in their different test groups. This is the nitrogen level. The dependent variable is what the researchers measure in response, which is the height of the plants. You could say the height "depends" on the nitrogen levels.

2. Now let's look at how independent and dependent variables are shown on graphs. The independent variable is on the *x*-axis of the graph while the dependent variable is on the *y*-axis. This is the standard way that graphs are created. It works that way because this is the natural way our eyes and brain can make sense of the data.

   Now, turn to page A-18 in the back of your textbook. What are the independent and dependent variables for the "Effect of Alcohol on Reaction Rate" graph?

   Independent: blood alcohol concentration

   Dependent: reaction time

3. The "Effect of Alcohol on Reaction Rate" graph is pretty straightforward, but what if you wanted to also compare the reaction time of males versus females at different blood alcohol levels? Doing this adds a second independent variable (gender). You could still graph this to show both independent variables by separating each blood alcohol concentration bar into two: one for female levels and one for male.

   Check out the following graphs with multiple independent variables and identify the independent and dependent variables of each.

   a. Graph 1: "Comparing Sources of Fat" on page A-18

      Independent variables: food (butter, margarine, and olive oil) and type of fat

      Dependent variable: fat content

   b. Graph 2: "Growth of Tortoise Shell" on page A-17

      Independent variables: wild versus zoo tortoises, and tortoise age

      Dependent variable: length of shell

4. Compare all three graphs you looked at and come up with a list of characteristics that all graphs should have.

   Students should at least state the following:

   - **Descriptive title (the title usually includes both variables)**
   - **Numbered scales on the *x*-axis and *y*-axis with units specified**
   - **Labels for both the *x*-axis and *y*-axis**
   - **Plotted data**

   Students might also mention a key or color-coding, which is needed on some graphs but not others.

5. Use your list to assess the Salt Marsh Experiment graph on page 10. What features are missing?

   This graph does not have a title or numbered scales on the axes.

Lab

In this lab, you will investigate the pH of common household substances using pH indicator paper, which changes color depending on the pH of the solution being tested.

Complete the following:

- Lesson 2 Lab: Determining the pH of Common Substances

All labs are found in the Biology Lab Manual.

See the lab manual for the complete lab instructions. Answers for the lesson 2 lab are below.

Results

1. Use the following data table (or one like it) to record your results.

   Check that the data table has appropriate headings for each column.

Analysis and Conclusion: Post-Lab Questions

1. Draw a pH scale similar to the one on page 50 of your textbook, with a range of 0 to 14 (acidic to basic). Label the pH scale with your solutions.

   The drawing should look like figure 2-10 on page 50 but with the student's test solutions.

2. Summarize your findings, including the pH range you observed, how your results compare to your predictions, and what this indicates about how acidic or basic most household substances are.

   Answers will vary, but students should provide a clear explanation of their findings. Most household materials range from a pH of 3 to 12, so they are not extremely acidic or basic. Substances that are consumed (vinegar, lemon juice, coffee, etc.) tend to be acidic. Many cleaning substances are more basic.

3. Apply your pH knowledge: Why can't you measure the pH of cooking oil?

   The pH scale is used for aqueous (water-based) solutions only. Oil has no pH because it is not an aqueous solution with a hydrogen ion concentration.

4. Submit the following to your teacher:
   - Photo of your setup
   - Your completed data table
   - Analysis and conclusion (post-lab questions)

Further Study

If you are interested in learning more about the lesson topics, you can complete the following activity. All Further Study activities are optional.

Learn About Enzyme Deficiencies

You have learned about the importance of enzymes. (The case study in chapter 2 is a fascinating example of how enzymes are impacted by elements in our diets.) Use research to learn more about an enzyme deficiency (some examples are below), and write a one-page report. Be sure to include your sources.

- phenylketonuria (enzyme phenylalanine hydroxylase)
- galactosemia (affects enzymes that break down galactose)
- lactose intolerance (deficiency of lactase)

SHARE YOUR WORK

When you have completed your work, share it with your teacher. You can use the checklist below to organize your work submission.

- Responses to comprehension assignments
- Responses to critical thinking assignments
- Activity: Graphing Practice
- Lesson 2 Lab: Determining the pH of Common Substances

If you have any questions about the lesson content, assignments, or how to share your work, contact your teacher.

Think About It: Discussion Points

How did you do?

- protease: proteins
- lipase: lipids
- lactase: lactose
- amylase: amylose (a component of starches)
- cellulase: cellulose
- polymerase: polymers (DNA or RNA polymerase catalyzes the synthesis of DNA or RNA—we'll be covering that later)

Extra challenge: Cellulase is not found in the human body. We don't have the capacity (or the microorganisms with the capacity) to digest cellulose.