Biology:
The Study of Life
Second Edition

Teacher Edition

Oak Meadow

Oak Meadow, Inc.
Post Office Box 615
Putney, Vermont 05346
oakmeadow.com

Table of Contents

Unit 2: Cells

Unit 3: Genetics

Unit 4: Evolution

Unit 5: Ecology

Unit 6: Classification and Diversity

Unit 7: Plants

Unit 8: Animals

Teacher Edition Introduction

In Oak Meadow Biology, students are encouraged to consider science as a verb, not a noun, 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" (*YouTube*)
>
> www.youtube.com/watch?v=7L7x0BAqWis

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

The textbook for this course is *Holt McDougal Biology: Student Edition 2017* (Houghton Mifflin Harcourt) and the Oak Meadow Biology lab kit is required. In addition, 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.

In this teacher edition, 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.

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 these lessons. Watching these is encouraged if it helps a student to visualize a concept. Students should cite anything they access online if used to answer the questions.

Note that occasionally student answers may differ from what is in this edition. An example is the modeling labs in lessons 5 and 6. If the student models a different number of chromosomes, the analysis answers may differ slightly. These answers are assuming the student follows the instructions exactly.

If you are homeschooling independently, this teacher edition can serve as your support as you guide and evaluate your student's work. 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 through dynamic exchanges of ideas, relevant field trips, viewing and discussing films and videos related to course topics, and in other active, experiential ways. We hope this course leads your student into a better appreciation and understanding of science and how scientific inquiry can enhance our understanding of the wider world.

Coursebook Introduction

> *Science is a way of thinking much more 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, as an active exploration rather than a static body of previously discovered knowledge. Science is a process. 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. And science is always changing. As new information comes along, our body of knowledge grows, and former conclusions might evolve or be replaced by new tested and verified principles. Science is a living, breathing process!

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 Oak Meadow Biology! 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. Biology is the study of life. That's a big subject, and part of the reason you have such a large textbook. In fact, every lesson opens the door to entire fields of study and possible careers!

The word *biology* comes from the Greek words *bio*, which means "life," and *logos*, which means "knowledge" or "to study."

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

"Introduction to Biology" (*YouTube*)

www.youtube.com/watch?v=7L7x0BAqWis

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 the 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? Well, science is no longer a bunch of facts to learn. Information is widely available. You will not be tested on the names of the bones in the body or the orders of insects. Instead, you 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. You 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 crazy 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 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:

- *Holt McDougal Biology: Student Edition 2017* by Stephen Nowicki (Houghton Mifflin Harcourt)
- 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 you are using for this course, *Holt McDougal Biology: Student Edition 2017*, is a comprehensive volume that is extremely well organized. Please use it fully! Consult your textbook to answer

questions rather than looking up information on the internet. This is extremely important. 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 because it takes the information out of context. Essential connections to the big picture are lost when you do this.

Take some time to get familiar with the layout of your textbook before you start the course. There is a great student resource section in the back with lots of useful information that can help you out as you go through the course. Look it over, bookmark parts, and don't forget 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 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, highlight sections, and make it work for you.
- Reading a chapter straight through once is not the best approach. You will need to skip around, going back and forth between sections, reading some parts two or three times. Skim some parts, and read other parts in depth.

How the Course Is Set Up

In this course, there are 28 lessons. On page xvii, you will find a suggested timetable to help you plan how much time will be needed for each lesson. Most of the questions in these lessons are short answer questions. Try to be concise, yet answer 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. Usually the way the question is worded will give you a clue about how to answer. When in doubt, write in full sentences.

In some of the lessons, you will be offered a choice of activities, some of which will be creative projects. Even if you don't think you're very creative, you will be expected to try these occasionally. You will not be marked down for "bad" artwork or poetry. Practice expressing yourself while at the same time demonstrating your scientific awareness.

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.
- **Think About It** gives you an opportunity to discuss with someone in your family or community your thoughts and opinions about what you are learning. This section will help you consider alternate viewpoints, clarify your views, and practice logical argumentation. Please pay attention to the "Think About It" sections! They enrich the course greatly and will help you get much more out of the course. Be sure to let your teacher know if you've read and discussed these sections, and feel free to share a summary.
- **Reading** and/or **Viewing** tells you the reading assignment for the lesson as well as some relevant online videos. 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** questions are designed to help you solidify key concepts and knowledge.
- **Critical Thinking** questions encourage you to think deeper about the material and make important connections by applying your knowledge and your best scientific reasoning skills.
- **Activities** provide a wide range of 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. Some labs include labeled data tables, some include blank data tables, and some include no data tables (you'll be creating your own). Some have lines for answers; others don't. This allows you to gain practice in multiple ways of recording your data and formulating your response. You will also be provided with a lab design organizer. This is a template to help you

organize all the parts that belong in a proper scientific investigation and lab report. Copy the template in the appendix or create your own version.

- An **Assignment Checklist** is included at the beginning of each lesson so you can see at a glance what is required. It will make it easy for you to check off assignments as you complete each one. Assignments are fully explained in the lesson.
- **Share Your Work** is found at the end of most lessons. This section provides reminders and information for students who are submitting work to a supervising 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. In this appendix, you will find academic expectations, original work guidelines, information about 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 page that lists the dozens of excellent resources mentioned in this course, a materials list, and enough graph paper to complete the labs and assignments that require graphs or diagrams.

In this coursebook, you will occasionally find references to "your teacher." It is assumed that you will be working with an adult who assesses and supports your learning. This teacher—who may be a parent, tutor, or supervising teacher—is the one to whom these notes refer.

Online Resources

This course makes good use of technology and the vast resources found online. You'll have plenty of opportunities to do online activities and labs. For instance, one of the best ways to learn is to get involved. It's fun to see videos and films that show biology in action, like this one:

- "Lord of the Ants" (www.youtube.com/watch?v=YBafE_i_TGo)

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

- *Encyclopedia of Life* (eol.org)
- *Understanding Science* (undsci.berkeley.edu)

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* (www.zooniverse.org)

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, please talk to your teacher about alternative assignments.

Academic Expectations

If you are working with a supervising teacher, you'll find a reminder at the end of every lesson that instructs you to submit your work to your teacher. Continue working on your next lesson while you are waiting for your teacher to provide feedback.

Please follow the assignments in order and submit them according to the instructions provided by your teacher.

You are expected to meet your work with integrity and engagement. Your work should be original and give an authentic sense of your thoughts and understanding, rather than what you think the teacher reviewing your work wants to hear. When you use other sources, you are required to cite them accurately. Plagiarism, whether accidental or intentional, is a serious matter.

The appendix of this coursebook includes information on academic expectations and original work guidelines. It is your responsibility to make sure you understand these academic expectations and abide by them.

Please remember to stay in touch with your teacher and share your comments, ideas, questions, and challenges. Your teacher is eager to help you!

The Journey Ahead

Biology is a constantly changing field of study, as new discoveries are 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!

Suggested Lesson Timetable (based on 36 weeks of study)

Unit 1: Introducing Biology (2 weeks total)

- Lesson 1: 1 week
- Lesson 2: 1 week

Unit 2: Cells (4 weeks total)

- Lesson 3: 1.5 weeks
- Lesson 4: 1.5 weeks
- Lesson 5: 1 week

Unit 3: Genetics (5.5 weeks total)

- Lesson 6: 1.5 weeks
- Lesson 7: 1.5 weeks
- Lesson 8: 1.5 weeks
- Lesson 9: 1 week

Unit 4: Evolution (4 weeks total)

- Lesson 10: 1 week
- Lesson 11: 1.5 weeks
- Lesson 12: 1.5 weeks

Unit 5: Ecology (5 weeks)

- Lesson 13: 1 week
- Lesson 14: 1.5 weeks

[end of semester 1]

- Lesson 15: 1 week
- Lesson 16: 1.5 weeks

Unit 6: Classification and Diversity (3.5 weeks total)

- Lesson 17: 1 week
- Lesson 18: 1 week
- Lesson 19: 1.5 weeks

Unit 7: Plants (4 weeks total)

- Lesson 20: 1.5 weeks
- Lesson 21: 1.5 weeks
- Lesson 22: 1 week

Unit 8: Animals (7 weeks total)

- Lesson 23: 2 weeks
- Lesson 24: 2 weeks
- Lesson 25: 1 week
- Lesson 26: 1 week
- Lesson 27: 1 week

Final Wrap-Up

- Lesson 28: 1 week

Lesson

1

What Is Biology?

Integral to the study of biology or any other scientific discipline is the concept of ***scientific inquiry***. In scientific inquiry, you not only will be observing, inferring, and experimenting, but you will be encouraged to ask questions, form explanations, compare your explanations with current scientific knowledge, and communicate your ideas. You 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 question. Remember: in science, there is no such thing as a stupid question!

When you see a word or term highlighted, such as *scientific inquiry* above, that's a key term you should know. You'll find the word defined in your textbook.

Plan to spend one week on this lesson.

ASSIGNMENT CHECKLIST

- ☐ Read chapter 1, "Biology in the 21st Century" (2–31).
- ☐ Answer seven Comprehension questions.
- ☐ Complete three Critical Thinking questions.
- ☐ Activity A: Data Analysis Lab
- ☐ Activity B: Experiment Design
- ☐ Lesson 1 Lab: Walking Crooked!

Learning Objectives

- Define *biology* and become familiar with the themes of biology and the properties of life
- Review and practice the scientific process and the concept of scientific inquiry
- Explore examples of modern technology and its uses in biology

Assignments

Reading

Read chapter 1, "Biology in the 21st Century" (2–31), in your textbook.

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. If you choose this book, be sure to acquire the most recent edition, which includes COVID-19.

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, as 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 different 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.

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

a. Review pages 60–62 of your textbook, on the topic of bioethics. 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 book, 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.

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, with other adults, or with 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.

Comprehension

1. Given the definition of biodiversity found on page 5 of your textbook, how would you define ***species diversity***? How about ***genetic diversity*** and ***ecosystem diversity***? Based on your understanding of the meaning of diversity, explain what you think these terms mean. (You will be exploring each of these concepts later in the course.)

   Species diversity is the variety and number of species in a given area. Genetic diversity refers to the variety of genes present in a population of a species; the higher the genetic diversity, the more stable (less vulnerable to disruption) the population is. Ecosystem diversity is the variety of ecosystems in an area. (Information on this topic is found on page 5 of the textbook. You'll see page numbers after most of the answers that will give you a textbook reference.)

2. If you were to determine if an organism is alive, what characteristics would you look for?

   Students may describe any of the characteristics of life found on pages 8–9: cells, use of energy, responsiveness, and reproduction and development.

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

   Examples will vary, and may include body temperature, blood sugar, acidity, etc., or a home thermostat or cruise control in a car. Homeostasis is "the maintenance of constant internal conditions in an organism." Note that "stasis" means stable, equilibrium, etc. Homeostasis is not a process. Example: sweating or shivering help to restore homeostasis (constant body temperature). They are not examples of homeostasis. (11)

4. How does natural selection lead to adaptation?

   In natural selection, individuals with favorable traits survive better and are more likely to reproduce, which passes on the favorable genes to the next generation. Gradually, the makeup of the population changes and adaptation has occurred. Adaptation and evolution are constantly occurring. (12)

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

   Peer review ensures that the methods and data collection have been carried out using good, unbiased science practices; and that the conclusions reached are valid and supported by the data. It is an important part of the scientific process. (17, 20)

6. For each of the following scenarios, describe what type of imaging would be used.

   a. You fell while skateboarding, and your arm appears to be broken.

      x-ray

   b. Your friend has a bad sore throat, and the nurse at the health center took a throat swab to be analyzed for strep throat.

      light microscope

   c. Your dentist takes images of your teeth.

      x-ray

   d. Your older sister had a skiing injury, and the doctor suspects that she has a torn ligament (ligaments are cartilage that connect your bones to each other).

      MRI

   e. Bonus question: Can you list any other imaging techniques that anyone in your family has experienced?

      Answers will vary, but students might suggest ultrasound, CT scan, PET scan, etc. While an electrocardiogram (EKG or ECG) does not take a picture, the data collected are mapped and graphed, and could be considered medical imaging. This is also true for EEG. The purpose of this is for the student to become aware of the amazing array of imaging technology that is available.

7. Describe two potential benefits and two potential risks of biotechnology.

   Benefits: prevention and treatment of disease and illness, solving crimes, solving modern problems, improving crop growth and insect resistance. Risks: ethical concerns, potential safety issues or negative environmental effects of genetically modified crops. (30-31)

Critical Thinking

1. Answer either a or b, or both for extra credit.

   a. You will hear a lot about the important concept of systems in your science courses. Review the section on systems in the textbook, and describe a system that is part of your everyday life. It does not have to be related to biology.

Answers will vary. Students may describe their family, household, kitchen, computer, body, etc. A system is an organized group of related parts that interact to form a whole. Note: some students might confuse a system with a routine. Be sure this distinction is made.

b. Based on the definitions of theory discussed on page 19 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. (19)

2. Look at the picture of the polar bear hair on page 11 of your textbook, think about its structure, and consider the following additional information: polar bears have black skin. Their hair is transparent, and only appears white because it reflects visible light in the same way snow does. How do the characteristics of the hair and skin contribute to homeostasis in the polar bear?

The hairs of the polar bear are hollow, which traps air and aids insulation. The transparency allows the heat from the sun to get through to the black skin, which absorbs the heat well. This is a perfect example of structure and function working together to keep the bear warm.

3. Review the discussion of scientific inquiry on pages 15 and 19 of your textbook. Note that to be considered for scientific inquiry, an explanation or observation needs to be *testable and verifiable*. Here are two examples of testable observations: "The North Atlantic Right Whales are moving north because of warming oceans." "Unicorns come into my room at night." The reason these are testable is that empirical evidence could be collected to verify or falsify each one. Two examples of nonscientific observations are "War is wrong" (you can't test opinions) and "Aliens built Stonehenge" (we can't verify that aliens were here when Stonehenge was built).

   Now answer the following:

   a. What is empirical evidence?

   Empirical evidence is "evidence that is observed directly through research and investigation." (15)

   b. Why is logical thinking so important in science?

   Logical thinking is a disciplined manner of thinking that is very important in the scientific process. It ensures that conclusions are based on known facts and evidence, and that scientists present findings that are supported by solid evidence.

   c. Give at least one example of an observation 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. (19)

d. Come up with at least one example of something that would not be considered for scientific inquiry. 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 each of those.

Activities

Complete both of the following activities.

A. Data Analysis Lab

Complete the Data Analysis Lab on page 14 of your textbook. In addition to the two questions in the lab, answer the following, and label it #3: Consider the qualitative data examples about the dolphins as observations that need further investigation. Choose one of these observations and describe how it might be investigated in a quantitative way.

1. **The jackals appear to be playing; they look young; they appear healthy.**
2. **There are five jackals in the group; two jackals are lying down; one jackal is on its back.**
3. **Answers will vary. Observation of many dolphins (or dolphins captured in photos), recording the number of each color or creating a scale to rank the colors from white to gray; recording play behavior and how often each behavior is exhibited; skin can be examined more closely, and the skin of many dolphins can be compared.**

B. Experiment Design

Design a controlled experiment about one of the topics listed below (you will not be carrying out this experiment). As mentioned in lab 1 below, there are variations in the way scientific investigations are carried out. However, section 1.3 in the textbook explains the general format. An *observation* of something usually leads to *questions*, from which a *hypothesis* is generated and tested.

In the appendix of this coursebook, you will find a lab design organizer for your experimental design process. This is to help you remember to include all the parts that go into an investigation.

For this exercise, pretend you have the resources, space, time, etc., to carry out your experiment in whatever way you plan it. Don't worry about practicality.

Note: You are asked to create a *controlled experiment*. This doesn't necessarily mean you will have a "control group" (that depends on your subject of study). What that means is that there will be variables that you are controlling; these are known as your constants. You keep those variables the same for all your experimental groups.

Experiment topics:

- You have a new drug that has potential for being a cure for the common cold. Design an experiment to test the drug's effectiveness.

- Does hot water freeze faster than cold water? (Feel free to actually carry out this experiment!)
- Is acid rain causing a decline in the population of amphibians (frogs and salamanders)?

Explain the following steps of your experiment. Practice filling in the lab design organizer for this.

1. Identify the situation or problem based on your observation.
2. What are the questions that come up about the problem?
3. Consider an explanation for the situation, and put it in the form of a testable hypothesis.
4. Predict what will happen in your experiment if your hypothesis is correct.
5. Identify the independent and dependent variables. What variables will be kept constant?
6. What materials do you need?
7. Describe the procedure you will use to test your hypothesis. You may or may not be including a control group. If you do, explain what it is. Explain each step clearly.

Share your lab design organizer with your teacher. If the procedure doesn't fit on it, write the procedure on a separate page.

Answers will vary depending on the experiment the student chooses. All the steps of a scientific investigation should be followed. Variables should be identified.

Lab

Perform Lesson 1 Lab: Walking Crooked! Turn to the lab for detailed instructions (each lab is found directly following the lesson assignments).

SHARE YOUR WORK

For the discussion assignment in "Think About It," you can connect with a classmate, or talk to a friend or parent.

Share your work from this lesson with your teacher according to their instructions. All handwritten work needs to be very legible and photos and scans of good quality and taken with good lighting. Take photos holding the camera directly above the page as it sits on a desk, not at an angle. The photo should fill the frame. If you have any questions about the lesson or how to submit your work, contact your teacher.

Name _____

LAB

1

Walking Crooked!

This lab uses your own body to practice scientific inquiry. The step-by-step scientific method that you learned in this chapter is one example of how scientific investigations take place. There are variations. For example, you may simply have a question and you develop a way to test it, or your hypothesis is just something you've heard. Is this still scientific inquiry? Yes! You are controlling the variables, setting up an investigation, and looking for an answer.

The Guiding Question

Can a blindfolded person walk in a straight line?

Materials

- measuring tape or string, 10 meters long (Note that in science we use the metric system, so if you aren't using it yet, it's time to start!)
- 5–10 markers to imitate "bread crumbs" to mark your path, such as popcorn, small plastic toys, dry beans (if they are easy to see), etc.
- blindfold

You will also need a large or outdoor space that is flat, with even terrain, and a partner.

Hypothesis

Develop a hypothesis to answer the guiding question. Write it down.

Procedure

1. Using the tape measure or string, mark a straight line 10 meters long. Leave it on the ground.
2. Stand at one end of the string facing in the direction the string goes, and have your partner blindfold you. If there is noise coming from a certain direction, you may need to control for this.
3. When your partner says, "Go," start walking slowly toward what you think is the other end of the marked area. Your partner will quietly walk behind you, dropping the "bread crumbs" to mark your path of travel. When you get toward the end of the 10 meters (or if it becomes unsafe), your partner will say, "Stop." Take off the blindfold and observe the results.

4. Measure how far you've strayed from the far end of the 10-meter path. Record your results in the data table below. Be sure to note whether you have strayed to the right or left. You might also want to note if there was a continuous curve to the path you took.

Data Table: Measuring Deviations from a Straight Line When Blindfolded

Person	Distance strayed	Right or left	Notes

5. Pick up the markers, switch places with your partner, and repeat the test. If you have more people available, it is fun to do this with as many people as you can. Record all data.

Analyze and Conclude

Describe your results. Answer the guiding question, using your results as evidence to support your conclusion. Was your hypothesis supported by your data?

Name _____

Biology—Lesson 1 Lab: Walking Crooked!

Making Connections

A test like this often results in more questions than you started with. Here are a few samples:

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

Now it's your turn to come up with more questions about this experiment that could be tested. Think broadly—you might consider anatomy, gender, terrain, etc. You might have questions about why this happens, or you may want to look for patterns. Write down at least three questions. There are no wrong answers!

Students are asked to record their data on the data table titled "Measuring Deviations from the Straight Line When Blindfolded." Students will likely notice that nobody walks straight, even if they try. The goal of this activity is for the students to have fun while observing an unexplained phenomenon of the human body, and to come up with questions. Any questions are welcomed, and students will not be penalized for questions that seem silly. Additional questions are listed as a guide to get students thinking. It is not an exhaustive list, by any means.

Lesson

2

The Chemistry of Life

Take a look at the picture in your textbook of the Venus flytrap consuming a frog (33). 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, that 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.

Plan to spend one week on this lesson.

ASSIGNMENT CHECKLIST

- ☐ Read chapter 2, "Chemistry of Life" (36–60).
- ☐ Complete five Comprehension questions.
- ☐ Answer four Critical Thinking questions.
- ☐ Activity: Graph Practice!
- ☐ Lesson 2 Lab: Determining the pH of Common Substances

Learning Objectives

- 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

Assignments

Reading

Read chapter 2, "Chemistry of Life" (36–60), in your textbook.

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

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 **breaks down protein**
- lipase **lipids**
- lactase **lactose**
- amylase (tricky one!) **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! 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.

Comprehension

Refer to your textbook as necessary to answer the following comprehension questions.

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 to remember the four elements that make up 96 percent of the human body. (We will be discussing these elements a lot in the next few chapters.)

   The elements are carbon, hydrogen, nitrogen, and oxygen. The mnemonic can include these in any order. (35)

2. What special bonding properties of carbon make it the "building block of life"?

   Carbon atoms have four unpaired electrons, so they can each bond with up to four other atoms. (46)

3. Answer the following questions.

   a. What monomer building blocks make up proteins? Nucleic acids?

   Amino acids make up proteins. Nucleotides make up nucleic acids. (49–50)

   b. Is starch a monomer or a polymer?

   Starch is a polymer. (47)

4. Describe the functions of carbohydrates and lipids in living things.

   Carbohydrates provide energy for cells and are a major part of plant cell structure. Lipids also provide energy, are an important part of cell membranes, and are a component of hormones. (47–49)

5. What is activation energy? How do enzymes increase the speed of chemical reactions?

   Activation energy is the amount of energy that needs to be absorbed for a chemical reaction to start. Enzymes increase the speed of reactions by lowering the activation energy. Students may go on to describe the mechanism by which they do this. (55, 57–58)

Critical Thinking

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, answer the following two questions.

   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 10x more or less H+ ions than the pH unit above or below it, respectively.

   b. Why is it so very important that the pH of human blood remain in a very narrow range? (Hint: there is more information about internal pH in section 2.5 of your textbook.)

   Because pH is a logarithmic scale, small differences in the number results in a huge difference in acidity. This could easily upset homeostasis. Cellular functions depend on enzymes, and enzymes could be destroyed by high or low pH.

2. For this assignment, show what you know about the amazing properties of water.

   - What are the ways in which the polarity and hydrogen bonding properties of water molecules are essential for life to exist?
   - Because of the polar nature of water molecules, water is known as the "universal solvent," meaning more substances dissolve in water than any other liquid. How does that help support life?

- Why doesn't oil dissolve in water?
- How do water solutions form acids and bases, and why does this matter for cell processes?

You have two options for sharing these properties that make water so unique, and so important to life on Earth. Choose a or b.

a. Write one or two paragraphs, addressing these questions and topics.

b. Get creative! Either write a poem or a song to a familiar tune (humorous or serious), or create an illustration that includes the concepts.

Students will choose either a or b.

Water's hydrogen bonds give it a high specific heat, which means it takes a lot of energy for water to change temperature. This regulates cell temperatures, and without this property, water would not be a liquid at temperatures that support life. The polar nature of water allows many compounds to dissolve. These include compounds necessary for life, such as oxygen, nutrients, salts, etc. Adhesion and cohesion allow water to move through plants. Oils cannot dissolve in water because they are nonpolar. They have no charged regions, so 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. Acids and bases form in water solutions when hydrogen ions (H+) are released into the water or removed from the water, respectively. A constant pH within a narrow range is important for cellular processes. (42–45)

3. Explain how proteins and nucleic acids are related.

The nucleic acid DNA contain the genetic information that codes for a protein, and the nucleic acid RNA assembles the protein based on the code in the DNA. (50)

4. What does it mean when a chemical reaction has arrows going in both directions? How does this make it hard to determine which are the reactants and which are the products?

It means that the reaction is reversible; it can move in one direction or the other, and which way it goes depends on the concentrations of the reactants and products. When the reaction takes place at an equal rate in both directions, it is in *equilibrium*. Since the reaction is going both ways, both sides of the equation could be considered reactants and products. (Students will need to understand reactants, products, and chemical equations to answer this.) (53)

Activity

Graph Practice!

In this course, you will be doing some graphing. Graphing and graph interpretation are very important skills to develop. Let's start now. If you are already familiar with graphing, consider this some extra practice.

A. Before you continue, be sure you understand what independent and dependent variables are in scientific investigation. You learned this in lesson 1, and will be revisiting it often!

Once you are clear on that, look at figure 3.4 on page 18 of your textbook. Notice that the independent variable is on the *x*-axis of the graph, and the dependent variable is on the *y*-axis. This is the standard way that graphs are created. It works that way because that is the natural way our eyes and brain can make sense of the data.

When you submit your work for this lesson, let your teacher know that you have completed this and understand it.

Students should note this.

B. Got that? Now, turn to page R15 at the back of your textbook. (Don't forget that these resource pages are here; they are very helpful!).

1. Look at Graph 2 on page R15. What is the independent variable? What is the dependent variable, and why is it the dependent variable?

   The independent variable is "time" or "time spent exercising." The dependent variable is "blood insulin levels." Blood insulin level is the dependent variable because that is the one that is measured. You can say it "depends on" the time spent exercising.

2. Now look at Graph 5 on page R16. Again, identify the independent and dependent variables.

   The independent variable is the syndrome (types of genetic disorders). The dependent variable is the incidence per 100,000 births.

C. Turn back to the "Identifying Variables" activity on page 51 in your textbook. Read the "Model" example, noting the consistency here—the independent variable is on the *x*-axis, and the dependent variable is on the *y*-axis.

Read the practice section, and answer questions 1 and 2. Note: Digestive enzymes (which are proteins) help break down proteins into amino acids and make them available to the body.

1. **The independent variable is pH because pH is manipulated. The dependent variable is the protein concentration, because that is what is measured. (Be sure the student answers the "explain your answers" part.)**
2. **If the amount of time needed to break down the protein in each test tube was measured, time could be a dependent variable. In B above, students will note that time is an independent variable, and that is frequently the case, as often we are measuring something as a result of the passage of time. This question might be challenging—a teachable moment!**

Optional Extra Credit Activity

Enzyme Deficiencies Research

You have learned about the importance of enzymes. Research one of the following enzyme deficiencies and write a brief (one page) report. Note that many enzyme disorders are a result of a mutation in a gene that gives instructions for the making of certain enzymes. (Remember, enzymes are proteins, and genes code for the building of proteins.) In your report, describe the enzyme and its function, the

effects a deficiency of the particular enzyme has on a person's health, how the deficiency is diagnosed, and what the most likely treatments would be. Be sure to include your sources.

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

Lab

Complete Lesson 2 Lab: Determining the pH of Common Substances. 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.

SHARE YOUR WORK

When you have completed this lesson, share your work with your teacher according to their submission instructions. Contact your teacher if you have any questions.

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.

Name _____

LAB

2

Determining the pH of Common Substances

The Guiding Question

What is the pH of common household substances?

Materials

- pH indicator paper
- 6 common household substances (you may choose from this list):
  - lemon juice
  - window cleaner
  - coffee
  - vinegar
  - bleach (wear gloves to avoid contact with bleach)
  - mouthwash
  - cola or other type of soda
  - milk
  - baking soda dissolved in water
  - orange juice or other fruit juice
  - tea
  - dish detergent
- water (this will be your control—label it #7)

Biology—Lesson 2 Lab:
Determining the pH of Common Substances

Procedure

1. Label the data table below with columns for solution, predicted pH, and measured pH.

Data Table: pH of Common Substances

1.		
2.		
3.		
4.		
5.		
6.		
7.		

2. Predict the pH of each solution you will be testing, as well as the water. Record your predictions on the data table.
3. Test each solution with the pH paper and record your results in your data table. To test a solution, dip one end of the paper *very briefly* into the solution. If you hold it in there too long, it will wash out the indicator. Give it just a quick dip, and then pull it out and compare that end to the color chart to read the pH.
4. Draw a pH scale similar to the one on page 41 of your textbook, with a range of 0 to 14 (acidic to basic). Label the pH scale with your solutions.

Name _____

Biology—Lesson 2 Lab:
Determining the pH of Common Substances

Analyze and Conclude

1. Summarize your findings. Were your results very different from your predictions?

   Answers will vary, but students should provide a clear explanation of their findings.

2. What is the pH range of the solutions you tested? What do your results tell you about how acidic or basic most household solutions are?

   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. Which of your substances has the highest hydrogen (H+) ion concentration? Which has the lowest?

   The substance with the lowest pH has the highest H+ ion concentration, and the substance with the highest pH has the lowest H+ ion concentration. Students should be aware of the inverse relationship between pH and hydrogen ion concentration.

4. 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. It is not an aqueous solution with a hydrogen ion concentration.

Lesson

6

Meiosis and Introduction to Mendelian Genetics

Stop for a second and think about this question: "How did I become the way I am?" Although some of it has to do with the food you eat, your family and surroundings, and the people you hang out with, a lot of it arrived with you when you were born. You might be thinking, "I'm tall like my mother, but have the dark skin of my father." Or you might think, "I have no idea why I'm so short when both of my parents are above average height." Or, "My sister and I are both blond, but our parents have dark hair." How do we get these unexpected combinations of physical traits?

In this lesson and the next few, you will focus on those easily observable traits that have a clear genetic basis; in other words, you aren't going to explore why one person is shy and another outgoing. These are more complex, and are likely a combination of nature (genetics) and nurture (environment). You will be exploring the basics of genetics, which is what makes us sort of like, but sort of unlike, our parents.

ASSIGNMENT CHECKLIST

- ☐ Read chapter 6, "Meiosis and Mendel" (160–186).
- ☐ Answer ten Comprehension questions.
- ☐ Complete six Critical Thinking questions.
- ☐ Activity: Coin Toss Genetics
- ☐ Lesson 6 Lab: Modeling Meiosis

Before that, though, we need to start at the beginning, learning about the tiny gametes, the sperm and the egg, that create us (or our dog, our spider plant, our resident house flies, etc.). Welcome to meiosis! As you read about meiosis, you will see that it is not a quick process. Human egg cells take years to develop (from birth to fertilization), and human sperm cells take 24 days. The duration of meiosis is highly variable, as different species will go through periods of inactivity. Even in the male reproductive organs of a lily plant, meiosis takes 7 days!

Plan to spend about one and a half weeks on this lesson.

Learning Objectives

- Differentiate between the processes of mitosis and meiosis, and identify the factors involved in producing genetic variation
- Become familiar with the work of Gregor Mendel and the foundations of heredity
- Understand how genes and alleles determine genetic traits
- Investigate and experiment with the role of probability in the inheritance of traits

Assignments

Reading

Read chapter 6, "Meiosis and Mendel" (160–186).

Watch one or both of the following videos:

"Meiosis—Made Super Easy—Animation"
www.youtube.com/watch?v=nMEyeKQClqI

"Mitosis vs. Meiosis: Side by Side Comparison"
www.youtube.com/watch?v=zrKdz93WlVk

This is a good one if you are confused about the difference between mitosis and meiosis. Be sure to study the images in the reading as well.

Think About It

To learn, read; to know, write; to master, teach.

Hindu proverb

In this lesson, you will be learning many terms. In order to succeed with many of the questions here and in subsequent lessons, it is essential that you understand the meaning of these terms. Learn them in whichever way works for you. You may be good at writing definitions, drawing pictures, creating flash cards—it's your choice. One of the best ways to learn is by teaching. Use this opportunity to teach family members about the basics of genetics. Formulating good explanations for others is a very useful learning tool, and this topic in particular is something that people may take an interest in if it is explained well.

Asking good questions is also very important, so feel free to ask your teacher or home tutor if you are stumped. However, rather than say, "I don't understand this," try being more specific. Explain what you do understand, and try to refine your question. In other words, be proactive in your learning! The following terms will be important to know:

allele	genotype	genetic linkage
gene	phenotype	crossing over
homozygous	dominant	homologous chromosomes
heterozygous	recessive	
genome	probability	

You won't be asked the definition of these terms in this lesson, but it will become apparent soon enough if you don't take the time to learn them.

Comprehension

When answering comprehension questions, full sentences are not required when you are simply asked to name something, or identify genotypes or phenotypes. You'll notice there are many questions in this lesson, and most of them only need brief answers. The number of questions is intentional to make sure you understand the basics of Mendelian genetics. If you would like feedback on your question answers before you continue with the activity and lab, please share with your teacher.

1. Describe the difference between homologous chromosomes and sister chromatids.

   Homologous chromosomes are chromosomes with a similar structure and genes for the same traits, but the genes might not be identical. Sister chromatids are the two halves of a duplicated chromosome. They are exact copies, and are attached at the centromere. (163, 167)

2. The Y chromosome has the smallest number of genes. Do you have that chromosome?

   Only males have it, so answers will vary depending on the sex of the student.

3. Examine the steps of meiosis and answer the following questions. You might want to do this assignment *after* you complete the lab.

   a. Name the stage of meiosis during which sister chromatids are separated to opposite poles of the cell.

      Anaphase II

   b. In what ways are the chromosomes in telophase I of meiosis different from those in telophase of mitosis?

      In telophase I of meiosis, the sister chromatids have not yet separated. In telophase of mitosis, the sister chromatids have separated, forming single chromosomes.

   c. In which division of meiosis do the cells become haploid?

      In the first division, meiosis I (168–169)

4. Who was Gregor Mendel? (Write no more than two sentences.)

   Gregor Mendel was the "father of genetics." He laid the groundwork for genetics, discovering patterns of inheritance. (171)

5. Why were pea plants a good choice for Mendel's experiments?

   Pea plants were good to use because they reproduce quickly, mating was easily controlled, and their traits exist in two clearly distinct forms. (172)

6. Apply the terms ***homozygous***, ***heterozygous***, ***dominant***, or ***recessive*** to describe plants with the genotypes PP and Pp.

   PP is homozygous dominant, and Pp is heterozygous.

7. Identify the phenotypes of rabbits with the genotypes Bb and bb, where B = black fur and b = brown fur.

   The Bb rabbit is black, and the bb rabbit is brown.

8. Draw a Punnett square to show the offspring of two individuals who are heterozygous for freckles (Ff). Using it, predict both the phenotypic and genotypic ratios of the offspring. Submit both the Punnett square and your answers to your teacher. (Be sure to review how a ratio is written, as explained on pages 169 and 175 of your textbook, if necessary.)

   Students will draw Punnett squares. The phenotypic ratio is 3 freckles:1 no freckles. The genotypic ratio is 1FF:2Ff:1ff. (177)

9. Let's say you have a pea plant with round seeds. Round seeds are dominant, but you don't know if the genotype is RR or Rr. Explain how you would use a testcross to determine what the unknown parent genotype is. Use two Punnett squares to illustrate your results and help demonstrate your answer.

   Students are encouraged to use Punnett squares because the results are easily visible. The two crosses will be RR x rr and Rr x rr. In a testcross, the parent with the unknown genotype is crossed with a recessive genotype (rr, wrinkled seed plant). If the offspring are all round seeded, the parent is most likely RR. If the parent is Rr, about half of the offspring will have wrinkled seeds. (179)

10. Define the law of independent assortment.

    The law of independent assortment states that different traits are inherited separately. Allele pairs separate independently of each other during meiosis. (180)

Critical Thinking

1. Do you think the Y chromosome contains genes that are critical to an organism's survival? Explain your reasoning.

   No, because females don't have a Y chromosome, and they survive just fine! Students will likely add that Y chromosomes are necessary for the continuation of the species.

2. Refer to the analysis questions in the "Modeling and Recognizing the Stages of Mitosis" lab from lesson 5. What is the diploid number of chromosomes in a human? (Express this as $2n$ =___.) What is the haploid number in human gametes? (n =___) What is the diploid and haploid number in a dog?

   human: 2n = 46, n = 23

   dog: 2n = 78, n = 39

3. Why is it important that gametes are haploid cells?

   Two gametes fuse to form a new organism. Joining haploid gametes results in a new organism with the correct diploid number of chromosomes.

4. When Mendel performed his experiments, he had no understanding of DNA as genetic material. One thing he excelled at was careful observation. Review the scientific process of observation, forming hypotheses, testing hypotheses, and analyzing data. Use examples from Mendel's work to show how his work fits this pattern.

   Mendel observed the inheritance of certain either/or traits and questioned how they were inherited without becoming diluted. He hypothesized that he could learn more by selectively breeding plants and observing the offspring. He tested his hypothesis, crossing large numbers of plants. He analyzed his data carefully, looking for patterns and ratios, and continued to verify it by testing other traits in pea plants. (This is a tricky question, but it encourages the student to notice the scientific process, in one of its variations, at work.)

5. On figure 4.1 (175), you see that polydactyly is a dominant trait. What are the possible genotypes for someone to have this trait? (Use the letters D and d.) Knowing that there are few people who have this trait, what do you think that tells you about the relationship between dominance and commonality of a trait?

   The possible genotypes are DD and Dd. Dominance means that an allele is expressed if it is present, and it masks any recessive alleles. A recessive allele will only be expressed if two copies are present. Dominance does not mean that the trait is more common, or that it is better or stronger! This is a common misconception. Polydactyly is a dominant trait, but the allele is rarely found in populations. (175)

6. If crossing over were to happen on sister chromatids during meiosis, would it increase genetic diversity? Explain your response.

   No, sister chromatids are identical to each other, so there would be no change with crossing over.

Activity

Coin Toss Genetics

In this activity (full instructions are below), you will demonstrate how independent assortment works, and how the probability of a particular outcome of meiosis can be predicted.

The way genes behave during meiosis and fertilization can be simulated using two-sided coins, where heads represent the dominant allele (**A**) that results in normal skin and hair color, and tails represent the recessive allele (**a**) that results in albinism. Suppose a parent is heterozygous (**Aa**). Then, tossing a coin and checking whether it lands tails up or heads up represents the 50-50 chance that an egg or sperm produced by meiosis will include an **a** allele or an **A** allele.

To simulate reproduction between two heterozygous (**Aa**) parents, you and a friend will each toss a coin and the result of the pair of coin tosses will indicate the pair of alleles contributed to a baby by an egg and a sperm.

Students will perform the activity, and fill in the data table. This is good practice with the repetitive nature of collecting data as well as calculating probability.

Before You Begin

Construct a Punnett square to predict the probability of each outcome. Review page 181, where probability is described, and be sure you understand how probability is expressed (as a fraction or percent), compared with how a ratio is expressed. Enter your predicted probabilities, as both a fraction and a percentage, in the last row of the data table below. Also, put the predicted number in a family of four children. The first column is filled out for you.

Procedure

You can do this with a partner, or by yourself, creating a fictitious person to be your partner. Each person has one coin.

1. Each of you will toss your coin, and this pair of coin tosses will indicate the pair of alleles in the first child produced by a mating of two heterozygous (**Aa**) parents. Make three more pairs of coin tosses to determine the genotypes for the remainder of the children in this family of four children. Record how many of these four children had each of the three possible genotypes (**AA**, **Aa**, or **aa**) in the row labeled "first family of four children" in the data table below.
2. Now make four more pairs of coin tosses to indicate the alleles in a second family of four children. Record these genotypes in the second row in the table.
3. Do this two more times and record the results in the third and fourth rows of the table.
4. Add up your results to determine the total number of children from your coin tosses who had **AA**, **Aa**, and **aa** genotypes.
5. Using your totals in each column, calculate the percentage of each genotype in your population of 16. Record this in the data table.
6. For each family of four children produced by your coin toss matings, compare the results with the predictions from the Punnett square. Do the same for the totals. Next to each row, indicate the following:
    - Put a checkmark for any family that has the expected number of albino (**aa**) children.
    - Mark an arrow for any family that has no albino children.
    - Put an asterisk for any family that has two or more albino children.

Data Table: Genotypes of "Coin Toss" Children Produced by Two Heterozygous (Aa) Parents

	AA	Aa	aa
first family of four children			
second family of four children			
third family of four children			
fourth family of four children			
Totals			
Results (as a percent)			
Predictions based on Punnett square (fraction and percent)	$\frac{1}{4} = 25\%$ 1 child		

Analysis

1. For each family of four children produced by your coin toss matings, compare the results with the predictions from the Punnett square. Do the same for the totals. Present your answer as a written description.

   Answers will vary. It is likely that the results for each individual family will vary from the predictions. For the total, the results may be a little closer, but likely will still show some variation.

2. Can you explain any differences between your results and the predictions? How does this lab relate to independent assortment in meiosis?

   Differences are because the results are random. The result of each coin toss is not affected by any other coin toss. The same is true with independent assortment. Also, there is no predicting which sperm will fertilize which egg in nature; this is another source of variation.

3. You have 2 sample sizes here: your samples of 4 children in each family, and your total of 16 children. Which one more accurately matches the predictions based on the Punnett square? How do you think your results would compare to the predictions if you had a group of 100 children?

   The larger group should more accurately match the predictions. A sample size of 100 will yield results even closer to the predicted pattern.

Lab

Complete Lesson 6 Lab: Modeling Meiosis. This lab expands on the modeling you did in the previous lesson.

SHARE YOUR WORK

Notify your teacher when lesson 6 is submitted and ready for review. If you have any questions, please let your teacher know.

Name _____

LAB

6

Modeling Meiosis

In this lab, you will use the same materials that you used for the mitosis modeling lab in the previous lesson, but you will increase the number of chromosomes you are working with to represent homologous chromosomes.

Students will model meiosis, photographing each phase of meiosis I and II. There will be eight phases in total.

The Guiding Question

How can we create a model to demonstrate meiosis?

Materials

- pipe cleaners, 2 each of 4 different colors
- yarn
- beads

If you used food items in the last lab, you certainly may use them again, but you need to come up with two more pairs of sister chromatids that are distinguished somehow from the others. They can be different sizes, as before.

Before You Begin

Review the stages of meiosis as illustrated on pages 168–169 of your textbook. Note that you will also be modeling crossing over, so review how that works.

Procedure

1. Take each pair of chromatids, and connect them at the centromere as before. You will have four pairs of chromatids, each pair being a different color.
2. Decide which two colors are chromosomes from the father, and which are from the mother. Make a note of this.
3. As you model prophase I and the homologous chromosomes pair up, be sure each pair of homologous chromosomes has one from the father and one from the mother.

4. During prophase I, crossing over happens. You need to model this. There are several ways to do this. Note: Be sure that your sister chromatids are in every way identical before crossing over starts!
    - You can cut a segment of pipe cleaner and exchange with a segment on the homologous chromosome.
    - You can have the end of each sister chromatid marked by wrapping with colored yarn. You then exchange some of the yarn pieces with those on the homologous chromosome.
    - The end of each sister chromatid should be marked with a labeled piece of paper (A, B, etc.). You can then exchange these labels with those on some of the homologous chromosomes.
5. Now continue with your model, demonstrating each phase of meiosis. Photograph each phase, being sure to add labels either on the model when you take the photos, or as captions and labels on the photos. The parts of the cell should be labeled as well as the stages of mitosis.

    Students will submit their photos. If the student is not able to take photos for some reason, or the lab needs to be redone, labeled drawings will suffice.

Analyze and Conclude

1. How does the chromosome number of each of the four daughter cells compare to the original chromosome number?

    Each of the four daughter cells will have half the original chromosome number (they will each have two chromosomes).

2. Will all the gametes produced by one parent be identical?

    No, the gametes will not be identical because of crossing over and independent assortment.

3. When an egg and sperm fuse during sexual reproduction, the resulting cell is called a zygote. How many versions of each chromosome and each gene will be found in a zygote?

    There will be two versions of each chromosome (these are the homologous chromosomes) and each gene in a zygote; the zygote is diploid.

4. The pairing of the homologous chromosomes at the start of meiosis I is called ***synapsis***. How would the outcome of meiosis differ if synapsis did not occur? (It might be helpful to model this.)

    If synapsis did not occur, there would be no crossing over, resulting in less recombination and genetic variation. Also, the homologous chromosomes might not separate properly in meiosis I. Synapsis ensures that each new cell will get one member of each pair of homologous chromosomes.

Name _____

Biology—Lesson 6 Lab: Modeling Meiosis

Making Connections

Usually, when a scientist finishes a set of observations, many new questions come up. Think about meiosis and all of its phases, and come up with at least two questions that you could ask that could be explored with a model like yours. One way to think about it is with "what if " questions: what if this happened, or this didn't happen, or this happened differently, etc. Consider crossing over, independent assortment, and the infinite possibilities of genetic variation. Or you might consider a change in one of the phases. There are no wrong answers here, as long as it is something that you can test with your model. (A question like "How long does meiosis take?" is not testable with this model.)

Students' questions will vary. Hints are given to help the student along. Here are some samples, though there are many more possibilities:

- **What would happen if crossing over didn't occur?**
- **If the homologous chromosomes lined up differently in meiosis I, how would that affect the combination of chromosomes that the gamete receives from the mother and father?**
- **What would happen if cytokinesis didn't happen properly in one of the nuclei in meiosis II?**
- **What if crossing over happened two or three times in the same pair of homologous chromosomes?**
- **What would happen if anaphase I didn't work properly (or any of the other stages)?**

Lesson

17 Taxonomy

Taxonomy (the science of classification) is often undervalued as a glorified form of filing—with each species in its folder, like a stamp in its prescribed place in an album; but taxonomy is a fundamental and dynamic science, dedicated to exploring the causes of relationships and similarities among organisms. Classifications are theories about the basis of natural order, not dull catalogues compiled only to avoid chaos.

Stephen Jay Gould, *Wonderful Life: The Burgess Shale and the Nature of History*

ASSIGNMENT CHECKLIST

- ☐ Read chapter 18, "The Tree of Life" (530–550).
- ☐ Answer four Comprehension questions.
- ☐ Complete six Critical Thinking questions.
- ☐ Choose two:
  - Activity A: Library Taxonomy!
  - Activity B: Taxonomy of Mythical Creatures
  - Activity C: Construct a Cladogram
- ☐ Lesson 17 Lab: Bioinformatics

This quotation says a lot and gives due credit to the sometimes tedious science of classification. It is often perceived as boring and, as mentioned above, dull. But let's look at it in a new light! You are now embarking on a new unit, which will guide us into our study that will take up the rest of the course: all the forms of life that exist on Earth. In order to make sense of the complex diversity of life, scientists have devised a system of classification to categorize it all. This topic builds on our study of evolution, and just as with evolution study, as new discoveries are made, the taxonomic system flexes and changes. Consider it like the fluid mosaic model that you learned about when studying cell membranes (82). There is nothing rigid in taxonomy; it is a fluid model that changes with each new input.

As you will recall, to study the relationships between species, biologists study anatomical and molecular features, among others, and organize them into categories, showing how they evolved through time. If you review the concept map you made about the evidence for evolution in lesson 10, you will see the same features that you will now read about in this chapter—the criteria used to classify organisms.

Plan to spend one week on this lesson.

Learning Objectives

- Learn the Linnaean system of classification, and how it has been augmented and changed with new evolutionary analysis methods
- Practice using cladistics as a classification tool
- Use an online database to investigate evolutionary relationships using bioinformatics

Assignments

Reading

Read chapter 18, "The Tree of Life" (530–550), in your textbook.

Note: From now on, the lesson numbers will not align with the chapter numbers that you will be reading.

Optional reading: Check out the "Tree of Life" from *Thing Explainer,* by Randall Munroe, pages 533A–D. He explains "things" by using only the 1,000 most common words in the English Language. See if you can name any of the things he describes. Have fun!

Think About It

The father of the traditional system of classification we use today is Carolus Linnaeus. He was so passionate about his work that he changed his name from Carl to Carolus to make it into a Latin name. He even classified his private letters into groups and subgroups. Linnaeus at first didn't think that we really needed the species descriptor in addition to the genus, but later decided that it was very helpful. He had some groupings that now seem odd, such as placing the rhinoceros among the rodents. He also bravely suggested the relationship between humans and apes. This was a radical move in the eighteenth century.

Think about Linnaeus's contribution. Consider how such a "mistake" as the rhino/rodent grouping would add to the general understanding of the natural world. Somebody had to come along later, look at it with a skeptical eye, puzzle over it, collect new evidence, and reclassify the rhinoceros. This is science at work, and this is the fluid nature of the system described above. Can you think of anything you classify in your life and how your classification system changes as your knowledge and perspective change? Perhaps you classify people in a certain way, and perhaps you have a friend who sees them another way. What are your reasons for your system? Give this some thought and discuss it with your family, friends, or fellow students.

Comprehension

1. Come up with a mnemonic device to help you remember the seven levels of Linnaean classification, from kingdom to species. You can find many online, such as "Keeping Precious Creatures Organized For Grumpy Scientists," or "Keep Pond Clean Or Froggy Gets Sick." Check out some of these if you wish, but then come up with one of your own that you will remember. If you like, you can include domains as well, for the total of eight modern levels of classification.

   Answers will vary.

2. Describe the rules used in binomial nomenclature.

   Each species has a two-part scientific name using Latin words. The genus contains physically similar related species. Genus names are capitalized, and species names are not. Both are either italicized or underlined. The species name never appears alone. (533)

3. Choose a species that is not in the textbook, and list the eight levels of classification for that species, using proper nomenclature.

   Answers will vary. Be sure all eight levels are listed, and the genus and species name are italicized and properly written.

4. Describe the contribution of genetic research in reorganizing the classification structure of kingdoms, and the creation of domains.

   Carl Woese researched rRNA in prokaryotes, and found two genetically different groups of prokaryotes. This split the kingdom Monera into the kingdoms Bacteria and Archaea. Since the cell wall chemistry of these two groups was so very different (more so than the differences between the other kingdoms), he proposed a higher level of distinction, and the three domains were created. (547–548)

Optional Extra Credit

1. Referring to the Linnaean classification system, if two species belong to the same order, what other levels must they have in common?

   They have all the broader groups in common: class, phylum, and kingdom.

2. What is cladistics? Describe how derived characters are used to determine evolutionary relationships.

   Cladistics is a method of classifying organisms based on evolutionary relationships and common ancestry. Derived characters are traits that are shared by some species and are not in others. Species are organized by the numbers of derived characters they share. (539)

Critical Thinking

1. How is cladistics similar to the Linnaean system of classification? How are they different? Which system allows more room for revision as we learn more research techniques?

Both systems use similarities in organisms to classify them. They differ in that the Linnaean system uses physical similarities, and cladistics analyzes evolutionary relationships. Molecular evidence can be used in cladistics, thus it is the system that is likely to give the most current explanations. (535)

2. Which type of molecular clock would be most useful to examine the relationship between different species of the dog genus, *Canis*? Explain your choice.

   Mitochondrial DNA would be most useful for determining the evolutionary relationships of closely related species such as this because the mutation rate in mtDNA is very fast. Also, it is not subject to recombination because it is only passed on from the mother, so the lines can be traced very accurately. (546)

3. Given the traditional definition of species according to the biological species concept, explain why it is difficult to classify members of Bacteria and Archaea at the species level. Look up the traditional definition of species in your glossary if you are not perfectly familiar with it, and review section 5.4 (144) before you form your response.

   A species is defined as a group of organisms that can interbreed and produce fertile offspring. Bacteria reproduce asexually by binary fission, not by breeding to produce offspring. Also, they often transfer genes among themselves outside of typical reproduction. (144, 549)

4. List some of the extreme environments that Archaea inhabit. It is thought that Archaea were some of the first life-forms on Earth. Explain how the first part of the question supports this theory.

   Archaea exist in deep sea vents, hot geysers, Antarctic waters, and salt lakes. Early Earth had extreme environments such as these. (548)

5. Answer questions 23, 24, and 25 based on the cladogram image on page 552 of your textbook.

   23. These are represented by the hash marks 1, 2, 3, and 4

   24. Nodes are where the side branches intersect with the main branch, and they represent the common ancestor of every species in each clade.

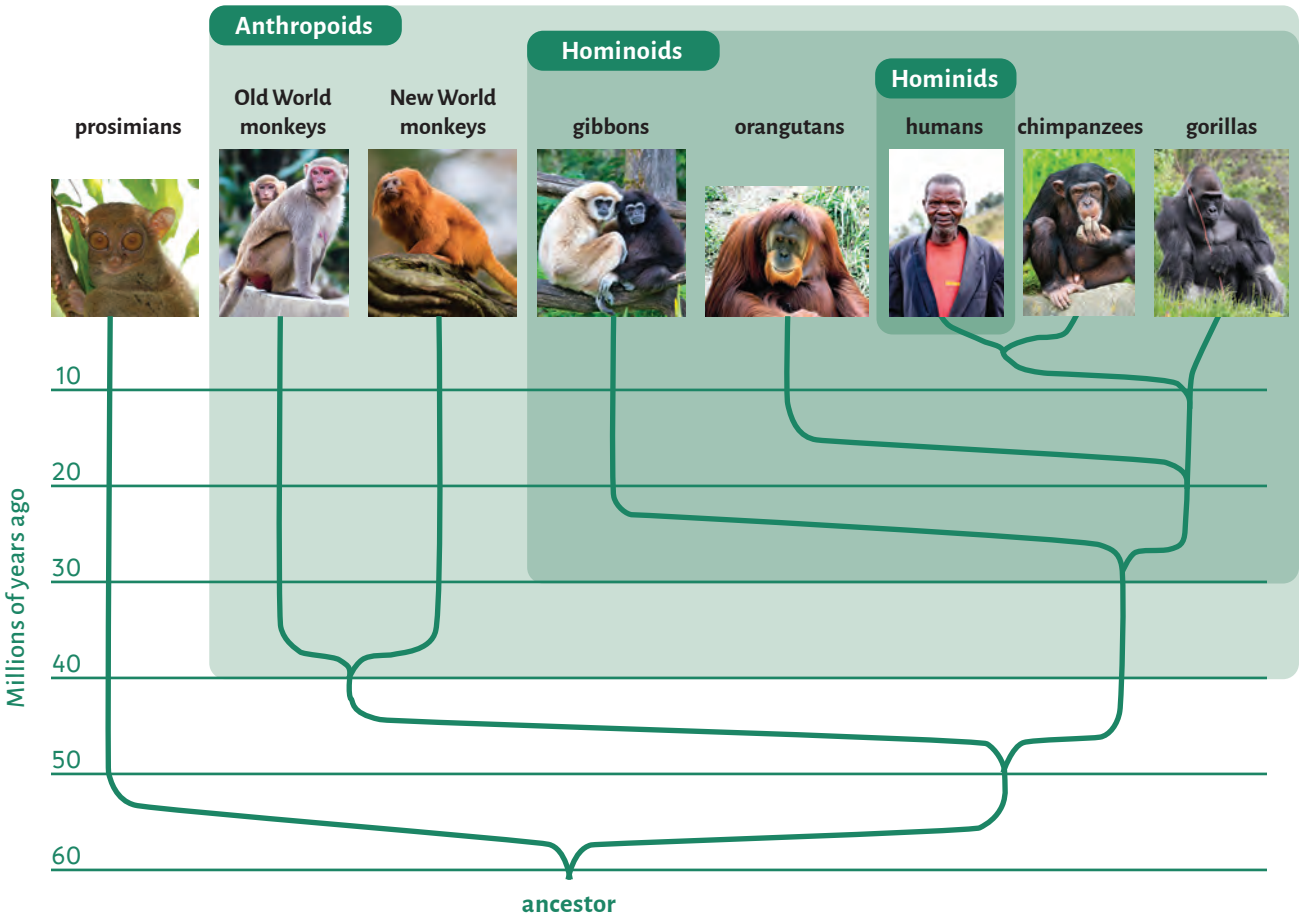
   25. There are three clades represented: one has A, B, C, and D; one has B, C, and D; and the third has C and D.

6. In lesson 12, you learned about *hominins*, which is a relatively new term in recent years. Previously, the most recent classification level of the great apes was hominids. New findings are constantly updating our knowledge of human history. Compare this older phylogenetic tree pictured below, showing the evolutionary relationships of primates, to the newer version that is in figure 6.2 (373) of your textbook. Describe the differences you see between the older and newer phylogenetic trees.

   Karyotype analysis of chromosomes and additional fossil evidence have restructured the history of primates. Previously, humans were thought to be most closely related to chimpanzees, and somewhat related to gorillas. These three species made up the Hominid group. Now, orangutans, formerly less related, have joined the Hominid group, and

humans are in a more narrow group called Hominins. More broadly, old world monkeys have been found to be more closely related to hominoids, and new world monkeys are the most distantly related to modern humans. There has been a lot of shifting around of these groups. Hominins are the only group that walk upright on two legs.

Evolutionary Relationships of Primates



Activities

Choose two of the following activities to complete.

A. Library Taxonomy

Go to the places in your home where you keep books. It is likely they are in some type of order so that a particular book can be found if need be. Look to see how they are categorized. For example, the books in your home might be divided into rooms (yours, your parents' room, the family room, etc.). In each location they might be grouped by subject (which ones are where?) or author. They might be grouped by size, which member of the family owns them, or any other type of classification. Describe the method used to categorize the books. Give an example of a particular book and tell how it came to be classified and placed where it is. (You may even want to use this as an opportunity to create order where there is none!)

Students will investigate and describe the organization system of books in their home. Encourage detail.

B. Taxonomy of Mythical Creatures

For this activity, you will practice classifying organisms based on their characteristics. Use the following list of mythological organisms to complete the analysis (found below).

- **Pegasus** stands six feet tall, has a horse's body, a horse's head, four legs, and two wings.
- **Centaur** stands six feet tall, has a horse's body with a human torso, a male human head, and four legs.
- **Griffin** stands four to six feet tall, has a lion's body, an eagle's head, four legs, two wings, fur on its body, and feathers on its head and wings.
- **Dragon** can grow to several hundred feet, has a snakelike body, from one to three reptile-like heads, fur on its body and head, scales, and has the ability to breathe fire.
- **Chimera** stands six feet tall, has a goat's body, snake's tail, four legs, a lion's head, fur on its body and head, scales on its tail, and has the ability to breathe fire.
- **Hydra** is several hundred feet long, has a long body with four legs and a spiked tail, 100 snake heads, scales, and is poisonous.

Analysis:

1. Identify the characteristics that you think are the most useful for grouping the organisms into separate groups.

   Answers will vary.

2. Classify the organisms into at least three groups based on the characteristics you think are most important. Each creature should belong to only one group.

   Answers will vary. Students may group the creatures according to size, presence of wings, fire breathing, etc.

3. Review the biological species concept again. Explain whether this can be used to classify these mythical organisms.

   The biological species concept cannot be used to classify them without knowledge of their breeding compatibility with other groups.

4. Look up these other ways of defining species: ecological species concept, morphological species concept, and phylogenetic species concept. Which one did you use in this exercise? Would any of the others be useful with the information you have?

   The morphological species concept uses physical and anatomical features to classify organisms. The ecological species concept defines species as closely related organisms adapted to a single niche. The phylogenetic species concept defines species as organisms that have a shared and unique evolutionary history. The morphological species concept was used, and is the only one possible with the information given.

C. Construct a Cladogram

After reviewing figure 2.2 (541) and Critical Thinking question 5 above, create your own cladogram, organizing anything you want. It could be books, creatures that you create, anything in your household, cars, something you collect that comes in different versions—your choice! The only rule is that you follow the rules for making a cladogram, with clades that break off of the main branch, derived characters, etc. You can use the cladogram in Critical Thinking #5 as a template, with the same number of clades, or create one with more clades. Try to create a cladogram with at least three clades. Be sure it is fully labeled, and add any explanation you feel you need to clarify it.

If you want to make sure you understand a cladogram before you embark on this, you might want to submit Critical Thinking #5 to your teacher before you begin.

Students will create their own cladogram, labeling it fully.

Lab

Complete Lesson 17 Lab: Bioinformatics. In this lab, you will be using bioinformatics to analyze the mtDNA of several land mammals, using the online database from the CSHL DNA Learning Center at the Cold Spring Harbor Laboratory in New York.

SHARE YOUR WORK

When lesson 17 is ready for review, please notify your teacher.

Name _____

LAB

17

Bioinformatics

In lesson 9, you learned about bioinformatics. Bioinformatics is the use of computer databases to store, organize, and analyze biological data. By comparing DNA sequences of different organisms, we can estimate how closely related they are. The more closely two organisms are related, the more similar their DNA sequences are. As you learned in this lesson, different types of DNA are used in comparisons. Mitochondrial DNA (mtDNA) changes at a faster pace than nuclear DNA, and is used to study relationships between closely related species. Nuclear DNA tends to degrade much faster than mtDNA. For that reason, forensic scientists have used mtDNA from hair, teeth, nails, and bone samples to solve many older cases.

The Guiding Question

How can bioinformatics be used to examine relatedness between species?

Hypothesize/Predict

Look at the data table below. Based on what you know about animal body structure, which was used in the past to determine species' relatedness, predict which pair of species in the data table you think are most closely related.

Procedure

1. Go to the CHSL DNA Learning Center website: dnalc.cshl.edu. Under "Resources" in the menu bar, choose "Websites," and then scroll down and click on "BioServers." (On your way, check out any of the other neat features of this website if you want.)
2. Once you are on the BioServer website, click "Enter" under "Sequence server." Click on "Manage groups." This will open another window with some class data on it. Ignore that, go to the drop-down menu at the top right, and choose "Non-human mtDNA." From there, select "Land mammal mtDNA" by checking the little box on the left, and click "OK" (not "View"). This will change the main window to start your comparisons.
3. Now you will choose the four species that are in the data table below. You can get them all ready to compare by choosing each species in one of the drop-down menus that come up each time

you enter a species. Once you have all of them ready, select only two at a time to compare, as indicated by the data table. Once you select two, click "Compare" (not "Open").

4. A new window will open with the two sets of mtDNA sequences aligned for comparison. Change the number so it shows 1,000 per page ("Show ____ per page"). Then, select "Trimmed" and click on "Redraw."
5. Now, record the number of base pairs shown in the first comparison in the column of the data table titled "Number of base pairs." This is the number that you see in bold print immediately above the data set: "Showing ____, starting from and ending at ____." Don't forget to trim and redraw with each comparison you do.
6. You are now ready for counting! Where the mtDNA nucleotides do not match, they will be highlighted in yellow. There are also dashes where a nucleotide is not present in that position. If there is more than one dash in a row, count the entire run of dashes as a single difference. You will be counting all the mismatches in this way, and writing the total in the data table. Before you start, practice with this sample set to make sure you are counting correctly.

```
C A T C A A C C C T T G C T C G T A A T G T C C C
C A T A ——————— T T A T G T A T A A T A ————
```

```
T C T T C T C G C T C C G G G C C C A T A C T A A
——————————————— G T A C A T A A A T T A A
```

There are 15 differences in these 2 lines. If you don't get 15 when you count them, reread the instructions and try again. Notice that the second line is a continuation of the first line, so the dashes in the first line continue right into the second, and should not be counted again (there are a total of only two differences due to missing nucleotides—dashes—in this sequence, one in the first line, and one in the first that continues to the second).

Once you are clear on how to do the counting, go back to the website and count the differences for your first comparison. Notice that you can print the page if you find that easier, as there are many rows to count.

7. Choose the next two species to compare, and follow the same procedure with each one. The "1,000 per page" should remain as your setting, but you will have to trim and redraw each time, and write the number of base pairs showing in the appropriate column.
8. Calculate the percentages of differences for each two species, and record that number in the table.

Percentage difference = (number of differences/number of base pairs) × 100

Name _____

Biology—Lesson 17 Lab: Bioinformatics

Students will likely predict that the Lipizzan horse and the Sika deer are most closely related because they are hoofed animals. They might also predict that the dog and hare are more closely related than other pairs.

Data Table: mtDNA Comparisons

mtDNA types compared	Number of differences	Number of base pairs	Percentage
Dog #1 and European brown hare #1	159	904	17.5%
Dog #1 and Sika deer #1	394	1,000	39%
Lipizzan horse #1 and European brown hare #1	129	420	31%
Lipizzan horse #1 and Sika deer #1	121	719	17%

Analyze and Conclude

1. Which two species in the table share the most recent common ancestor, based on these data? Does your data match your prediction?

   The Lipizzan horse and the Sika deer share the most common ancestor, based on these data. The dog and the hare also show a close relationship.

2. Which two species are the most distantly related, based on these data?

   According to the data, the dog and the Sika deer are the most distantly related.

3. Notice that both of the above questions have the caveat "based on these data." Mitochondrial DNA is very useful in determining evolutionary relationships, but it is not the only type of molecular evidence. Describe two other types of molecular evidence that can be used to investigate evolution.

   Scientists may compare rRNA, nuclear DNA, specific genes, and protein sequences.

4. If you were to compare the mtDNA of the Lipizzan horse and a dog, you would find only a 16 percent difference. Infer what this means about using mtDNA evidence alone when determining species relationships.

   Answers may vary. mtDNA evidence should be combined with other types of evidence, such as nuclear DNA, which might be better for studying distant relationships. mtDNA may be more useful for studying relationships within a species.

Biology—Lesson 17 Lab: Bioinformatics

Making Connections

Choose some other species to compare or different organisms within the same species (there is room in the data table for two more). You can go back to "Manage Groups" and choose another group. Human mtDNA is interesting. Spend five to ten minutes looking at a few more comparisons, and summarize what you find.

Students will look at some other pairs of species and comment on their findings. Humans have very few differences in mtDNA.

Lesson

23 Invertebrate Diversity

Nature has worked for a long, long time to make a leech, and we do not have something we've invented as scientists, engineers or doctors that has done better than what nature has done.

Dr. Stephen Sullivan, plastic surgeon at Rhode Island Hospital (Pappas)

You are now into the final unit of our study of biology this year. As you proceed through the next four lessons, you will notice more and more familiarity with the groups of animals discussed. The chapters start with the less complex animals (you might not even recognize them as animals!), and move into more complex body types and more recently evolved animals.

You might wonder why those simple animals still exist, when they could have evolved. Remember, an organism only evolves when there is a need for it. If there is a new habitat that requires different adaptations, a change of climate, a change in existing habitat, etc., there will be a selective advantage to changes in body form and function. Every life-form on Earth has adapted to its environment. For example, we may consider humans as highly evolved and more intelligent than a jellyfish, but could we drift along in the ocean, feeding on what comes our way, using very little energy to do so? Our complex body systems and big energy-consuming brains have wonderful advantages for our habitat, but would severely limit us elsewhere.

Welcome to the amazing diversity of animal life!

There is flexibility within this unit for you to go as deep as you want into learning about animal life on Earth. Take this opportunity to satisfy your curiosity!

ASSIGNMENT CHECKLIST

- ☐ Read Chapter 22, "Invertebrate Diversity" (640–668)
- ☐ Answer three Comprehension questions.
- ☐ Complete four Critical Thinking questions.
- ☐ Activity A: Invertebrates
- ☐ Activity B: Scatterplots
- ☐ Activity C: Comparative Analysis
- ☐ Activity D: Computer Modeling
- ☐ Choose one:
  - Lesson 23 Quick Lab A: External Anatomy of a Live Worm
  - Lesson 23 Quick Lab B: Virtual Earthworm Anatomy

Notice that on page 645, it is mentioned that there are over 30 phyla of animals. You might wonder, then, why there are only nine in figure 2.4 (649), and why in the next several lessons, you are only learning about these nine. This is because the vast majority of animals that we know of fall within these nine phyla. These are the major groups. As you proceed through the next four lessons, take notes of the characteristics of the major phyla of animals. You might want to create index cards for each phylum. This will help you organize your knowledge of the diversity of animal life.

Project Choice

Throughout lessons 23–26, there are several optional projects. Look through your options and choose one or more to complete in the next six weeks. Submit it at the end of lesson 26.

Alternatively, if you have something you want to study, a project you wish to create, or anything else related to these lessons, now is your chance! If you are designing your own project, make sure to discuss your plans with your teacher before you begin.

Lesson 23: Lab extension options

Lesson 24: Any of the options for Activity B that you didn't choose for the lesson

Lesson 25: Activity A or B, whichever one you didn't choose for the lesson

Lesson 26: Any of the activities that you didn't choose for the lesson

Take a moment to read the quote that begins this lesson. Leeches—those slimy things that can attach themselves to your skin when you're wading in water and make you freak out because you can't get them off—are a tool that has been used for centuries in medicine. In the last century, practitioners of modern medicine thought they could do better, relying on antibiotics and other medicines, and the use of leeches in medicine faded into obscurity. Recently, they have been rediscovered as a surgical tool, mostly for microsurgery and reconstructive surgery. Very often in these situations, there is no way for the blood to drain from a wound until new blood vessels grow. Enter the leech! They use amazing precision to clean wounds of congested deoxygenated blood until the wounds heal and new blood vessels grow. So if a leech ever attaches to your ankle when you are wading in the local stream, thank it for the good work it does (and remember that salt is the best way to get it off).

This lesson starts with an introduction to animals, including the evolutionary history of animals, and then goes into the simpler forms of invertebrates. You'll learn about seven of the major phyla of animals in this lesson (including leeches, of course).

Plan to spend two weeks on this lesson.

You will want to begin Activity A right away because you need two weeks to complete it.

Learning Objectives

- Gain an overview of the general characteristics of animals and animal diversity
- Learn about the new molecular evidence that is changing our understanding of animal phylogeny
- Explore the characteristics of several phyla of invertebrates through reading and hands-on dissection
- Practice with organizing complex information in chart form

Assignments

Reading

Read chapter 23, "Invertebrate Diversity" (640–668), in your textbook.

As you read, pay special attention to sections 1 and 2, which describe the basic characteristics of animals, and the newer research methods that have improved and changed our understanding of animals. Also pay attention to the diagrams (something you should always be doing). Figure 2.4 (649) sums up most of the information in section 2, so be sure to look at it closely. You might even want to bookmark it, in order to refer to it later when you are figuring out where an animal fits into the big picture.

Think About It

The phylogeny of animals shown in figure 2.4 mentioned above is entirely new within the last couple of decades, thanks to molecular evidence from ribosomal DNA and *Hox* genes. Below is a sample animal phylogenetic tree from the early 2000s. It shows some major milestones in the evolution of the animal body.

This was a good start! Notice that it was based on physical similarities and the development of types of tissues and body structures. Since then, our understanding of animal phylogeny has been refined and changed, as you see reflected in figure 2.4. Do you think it will continue to change in the next few decades?

In Activity C, you will be asked to take a close look at the "old" and the "new" phylogenetic trees and make some comparisons.

Mollusca
(clams, snails)

Arthropoda
(crustaceans, insects)

Chordata
(vertebrates)

(Photo credit: Bob Goldstein)

Nematoda
(roundworms)

Annelida
(segmented worms)

Echinodermata
(sea stars)

(Photo credit: Nick Hobgood)

(Photo credit: Orest)

Cnidaria
(jellyfish)

(Photo credit: Richard Ling)

Platyhelminthes
(flatworms)

(Photo credit: Yoruno)

Porifera
(sponges)

7 9 8 6 5 4 3 2 1

Protist ancestors

Evolutionary milestones

1. Multicellularity
2. Tissues
3. Bilateral symmetry
4. Body cavity
5. Coelom
6. Segmentation
7. Jointed appendages
8. Deuterostomes
9. Notochord

Comprehension Questions

Read and study all of these questions, and respond to question 1 and two other questions of your choice.

1. Describe the derived characters that all animals share.

   All animals are multicellular heterotrophs; they need to get nutrients from other organisms. Animal cells are supported by collagen, which combine to form strong and flexible fibers. Animals are diploid, and most reproduce sexually. Most animals have homeotic genes that control early development. (643–644)

2. What is the function of a gastrovascular cavity in jellyfish?

   The gastrovascular cavity is where food is digested by enzymes, and nutrients are absorbed. It also transports oxygen to the internal cells. (654)

3. Contrast the way planarians and tapeworms feed.

   Planarians have a gut cavity, through which nutrients are absorbed, and they actively hunt for food. Tapeworms have no gut. They absorb nutrients from the digested food in the vertebrate gut where they live. (656–657)

4. What is the advantage of having a complete digestive tract (which started in mollusks) as opposed to the gastrovascular cavity found in cnidarians or the simple gut tube in some flatworms?

   A complete digestive tract has two openings, so the food moves one way. It allows different areas of the gut to be specialized for different purposes, such as digestion and absorption. This is much more efficient, and animals can be more active. (658)

5. What characteristics make cephalopods unique among mollusks?

   Cephalopods have the most well-developed nervous system and eyes of all the mollusks. (659)

6. Classify the following as roundworms, segmented worms, or flatworms:

   a. leeches **segmented worms**

   b. tapeworms **flatworms**

   c. earthworms **segmented worms**

   d. pinworms **roundworms**

7. Describe how sea stars move.

   Sea stars use their water vascular system to move. A series of radial canals are filled with water. This water is used to fill the tube feet that are on each arm, causing them to extend and grab objects in order to move around. (Students should provide details.) (664)

Critical Thinking

1. How does the structure of animal cells allow animals to move?

   The absence of cell walls and the flexibility of collagen, which supports the cells, enable animals to move. (643)

2. Explain how *Hox* genes likely led to the diversity of animals and resulting speciation and evolution.

   ***Hox* genes regulate the formation of parts of a body. Any mutation in these genes could radically alter the body plan. This could add variation that might be selected over time, leading to diversification and speciation. (646)**

3. Why is it that radial animals cannot have complex organ systems?

   Radial animals do not have a mesoderm. They only have two layers of tissue, the ectoderm and endoderm. It is the mesoderm that develops into internal organ systems. (647)

4. What measures could a community take to prevent *Schistosoma* infections?

   The key to this answer is figure 4.2 (657). Eggs are passed into water from human feces. Better sewage treatment is necessary to keep larvae from getting back into the water supply. Water treatment could kill larvae.

Activities

Complete the activities below. There are four of them, but don't be intimidated because some are very quick.

A. Invertebrates

   For the next two weeks, take note of all the invertebrates that you have contact with in your daily activities. Discuss this with your family, and keep a list. See how long you can make your list, and remember, these are only the invertebrates you can see! At the end of two weeks, name what phylum each invertebrate belongs to.

B. Scatterplots

   Review the "Analyzing Scatterplots" data analysis exercise on page 667. There are no assignments due for this, but be sure you understand what a scatterplot is, and how to interpret data on them. For example, in graph 3, notice that the curve levels out as the shell diameter of the snails gets larger. This could be due to the fact that a larger heart can pump more blood with each beat than a smaller heart. These are the kinds of things to look for and draw inferences from in a scatterplot. Could you draw a straight line through the plotted data, or a curve, or neither?

   Students will familiarize themselves with scatterplots through the data analysis exercise. There are no submission requirements for this assignment.

C. Comparative Analysis

Look back at the "Think About It" discussion in this lesson. Open your book to figure 2.4 (649), and look at the "old" and the "new" phylogenetic trees side by side. Describe at least two things that have changed with the use of genetic analysis to organize the diversity of animals. Feel free to add any other observations you see—for example, what hasn't changed?

The two trees look different, but you cannot make assumptions about when the branching occurred, as there is no time scale included on either one. The older image implies that deuterostomes branched off at a certain point, and the new image has a distinct split between the bilaterally symmetrical animals into protostomes and deuterostomes.

A prominent difference is the placement of Annelida, which previously seemed to be more closely related to Arthropoda because they are segmented. Segmentation was originally assumed to be a milestone, which meant that everything that came after was segmented in some way. It turns out to be not so simple, and we can infer that segmentation occurred in Arthropoda and Annelida separately.

It is also notable that now segmented worms and flatworms seem to have much more in common than they used to. Also, it appears that radial and bilateral symmetry diverged at the same time, rather than bilaterally symmetrical animals branching off from radially symmetrical animals.

The very base of the phylogenetic trees, with Porifera having no tissues, and the development of tissues in all other animal forms, has not changed. Also, Chordates are still most closely related to Echinoderms.

D. Computer Modeling

As you've learned during this course, in scientific research and analysis, computers have found an indispensable niche, both for data analysis and modeling. We can use models to predict something local, such as the effects of introducing a new species to an area, or huge things such as climate change and the origin of the universe.

Your assignment is to visit NetLogo from the Center for Connected Learning (CCL) and Computer Based Modeling (Northwestern University) at the following website: ccl.northwestern.edu/netlogo/index.shtml.

NetLogo was first created in 1999 by Uri Wilensky at the Center for Connected Learning and Computer-Based Modeling, then at Tufts University. Since then, the CCL has moved to Northwestern University, and the program has been updated several times. Now it is used widely for education as well as research.

Read about the program, check the FAQs, and then download the program. From your downloaded version, you can find the library of sample models. These are also visible online, but you will want to access and run the models from your applications folder.

Explore the "Bug Hunt Camouflage" model and all its features. (You will be using this model for the lesson 24 lab.) When you click on the model, you will see a menu bar at the top, and one of

the tabs is "Info." Be sure you read this to get familiar with the purpose of the model and how to use it. Then spend some time with the model, trying out the different environments and settings. Recognize that this is a model, not a game (though it can be fun!). You can try to catch as many bugs as fast as you can, and this results in a scenario that we are all too familiar with—something we've seen with overhunting or overfishing. The prey then need time to recover. In this case, they are bugs, with a short generation time. Mutations and natural selection happen relatively quickly.

After you are very familiar with "Bug Hunt Camouflage," choose two more models to try out. These do not have to be related to biology—it is your choice! Give them the same thorough investigation as you did the first one. These take a little getting used to, so be patient with yourself as you learn the ropes.

Finally, write a summary of your experience. Which models did you try? Were any easier or harder to use? Do you see the usefulness of these models for education? For research?

You have now set yourself up for an easy transition when you return to this in the next lesson, when you will be exploring "Bug Hunt Camouflage" to practice scientific argumentation and peer review.

Lab

Complete one of the following labs:

- Quick Lab A: External Anatomy of a Live Worm
- Quick Lab B: Virtual Earthworm Anatomy

In this lab, you will be taking a close look at an earthworm. There are two choices for this lab: looking at a live earthworm that you dig up (preferred), or doing a virtual lab. If at all possible, try to find a real worm. (You may need to put this off until the weather warms up.)

SHARE YOUR WORK

If you choose Quick Lab A for this lesson, and need to postpone it until the weather warms up, just let your teacher know.

Submit lesson 23 to your teacher when it is complete.

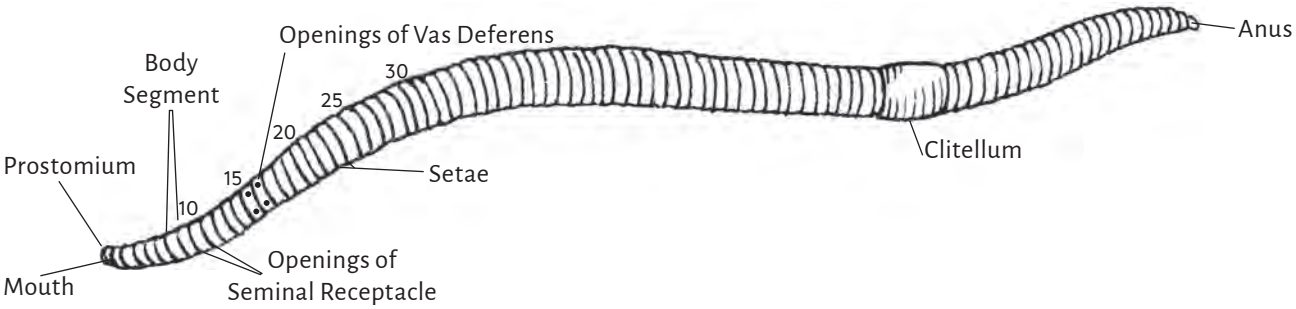
Name _____

LAB

23

Quick Lab A: External Anatomy of a Live Worm

Earthworms (*phylum Annelida*) show some of the important advancements in animal evolution that you are learning about. They have a *complete digestive tract* for efficient digestion, *segmentation* that allows efficient movement, and a *hydrostatic skeleton*. In this lab, you will explore the external anatomy of a worm.



Students will choose either Lab A or B, depending on the availability of an earthworm.

For Lab A, students will examine a worm, and prepare a labeled drawing of the worm. Descriptions of the worm's movement pattern should be included. Look for attention to detail. This is how a worm moves, using its two sets of muscles, circular and longitudinal muscles:

- **First, it grips the soil with some of its back setae, anchoring the back part.**
- **The body then gets longer and narrower (circular muscles squeezing). Since the back of the body is gripping the soil, the front part of the body moves forward.**
- **Then the front setae grip the soil and the back setae let go.**
- **Finally, the worm becomes shorter by contracting its longitudinal muscles. The back part moves forward.**

Students aren't expected to know these details, but should comment on the lengthening and shortening of different parts of the worm's body. This information will be learned if the student chooses the second Making Connections option.

Optional extension: Students may opt to do one of the Making Connections projects for extra credit.

Materials

- earthworm (the fatter, the better)
- shallow pie pan
- pencil with an eraser
- magnifier

Biology—Lesson 23 Quick Lab:
A: External Anatomy of a Live Worm

Procedure

1. Find a nice fat earthworm. Place it in a shallow pie pan while you study it.
2. Examine the earthworm with your magnifier. Locate the segments, mouth, anus, and clitellum (what does that do?). See if you can locate the setae or seminal openings as well. Use the eraser end of your pencil to prod the worm gently and keep it from crawling away.
3. Draw a sketch of your worm, labeling all the parts you can identify.
4. Observe its crawling motion. Describe how it moves.
5. Release your worm outside where you found it.
6. Submit your labeled diagram and description with your work for this lesson.

Making Connections (optional extra credit)

Choose one of the following to research, and write up your findings in a one-page report. Note: You may use this for your unit project option.

1. Did you know that earthworms are not native to many parts of the United States? They were wiped out in the northern United States with the last ice age, and the northern forests have evolved without them. With the arrival of the Europeans, however, nightcrawlers and many other worm species have been introduced. Some people who fish toss their extra worms in the soil, thinking they are doing good. However, these worms are actually quite harmful to northern forest soils. Do a little research on the effects of these invasive species on the forest soils, and report what you find.
2. Earthworms have quite an advanced system of locomotion. They don't need to wiggle back and forth as snakes do, and this is for a couple reasons: they have no backbone, and they have segments. The segments are an integral part of what allows earthworms to move. Research the mechanism behind earthworm movement. Feel free to include an illustration to help you explain the process.

If you are interested in these topics but are unsure if you have the time, please discuss options for flexibility with your teacher.

Name _____

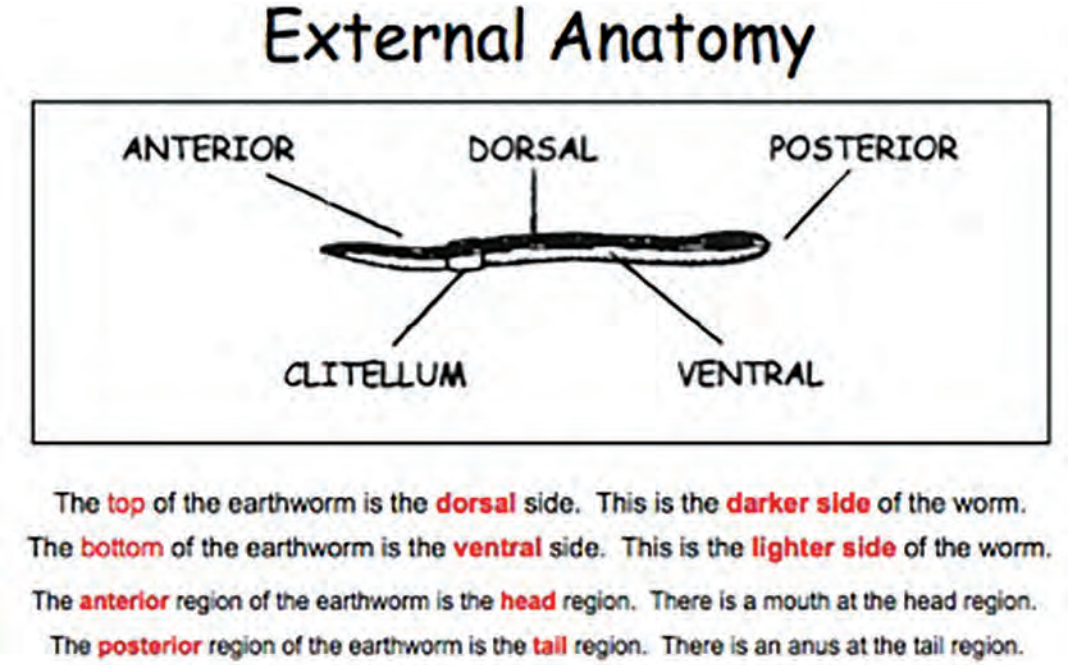
LAB

23

Quick Lab B: Virtual Earthworm Anatomy

Earthworms (*phylum Annelida*) show some of the important advancements in animal evolution that you are learning about. They have a *complete digestive tract* for efficient digestion, *segmentation* that allows efficient movement, and a *hydrostatic skeleton*. You will see all of these up close in this lab as we explore (virtually) both the internal and external anatomy of a worm.

1. Take a look at the external anatomy of an earthworm that is shown in the labeled diagram in Quick Lab A so you can be familiar with these structures. Also understand the anatomical terms in the following diagram, as you will hear these throughout the videos.



(Image credit: luzierscience.weebly.com)

View this video of an earthworm dissection:

"Dissection 101: Detailed Earthworm Dissection Video"

opb.pbslearningmedia.org/resource/41b655c3-2791-4b66-89df-04fa972f0563/detailed-earthworm-dissection-video

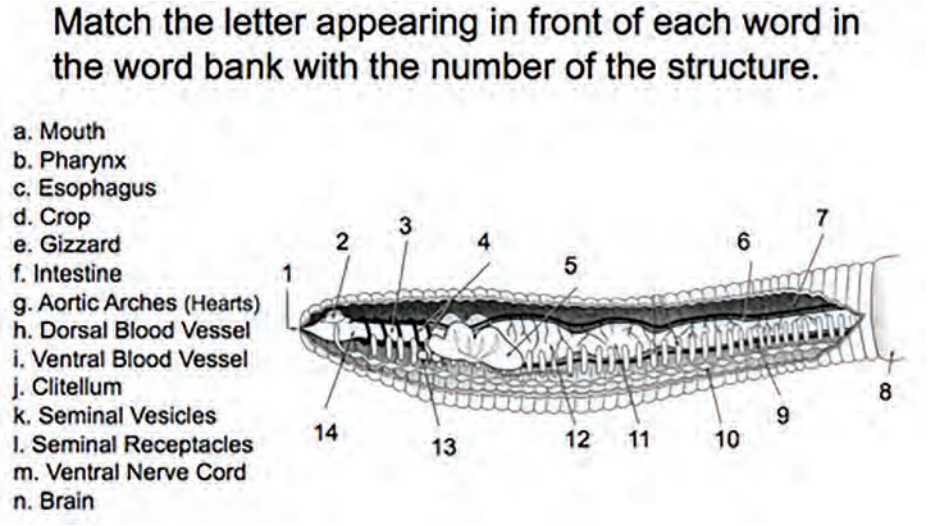
Biology—Lesson 23 Quick Lab:
B: Virtual Earthworm Anatomy

2. Here is another good video* that is highly recommended. It includes diagrams to help you see some of the more challenging structures in the earthworm.

   "Biology Lab: Earthworm Dissection"

   www.youtube.com/watch?v=aCnwF6vtE2g

3. When you are ready, see if you can identify the anatomical structures in the earthworm diagram below. As needed, go back to the videos for assistance.



(Image credit: luzierscience.weebly.com)

When you are done, compare your answers with the answer key at the end of this lab. How did you do? Did you need to make any corrections?

Students should report on how well they did labeling the earthworm anatomy diagram, and if they needed to go back to the video to help identify the parts. This is a self-directed activity.

Optional Extra Credit (answer any or all)

a. What are the two sets of muscles that help an earthworm move? Describe what they each do.

   The two sets of muscles are longitudinal muscles and circular muscles. When the circular muscles contract, the segment lengthens and gets narrower (as the muscles squeeze it). When the longitudinal muscles contract, the segment shortens and becomes thicker.

*Did you notice that in both of the videos, earthworms are described as being very good for the soil ecology? This is true—sometimes—but not in the forests of the northern United States, where they are not a native species and are destroying the soil food web. See the Making Connections options to learn more.

Biology—Lesson 23 Quick Lab: B: Virtual Earthworm Anatomy

b. What is the advantage of segmentation?

Segmentation is an important evolutionary advancement that allows a lot of control over the movement of a worm. Each segment can elongate or shorten individually, allowing complex movement. Segmentation also allows different functions to occur in different parts of the worm.

c. What does the hydrostatic skeleton do for the earthworm?

The hydrostatic skeleton provides support for the earthworm using water pressure.

d. Earthworms are hermaphrodites. What does that mean?

A hermaphrodite has both male and female reproductive organs.

Making Connections (optional extra credit)

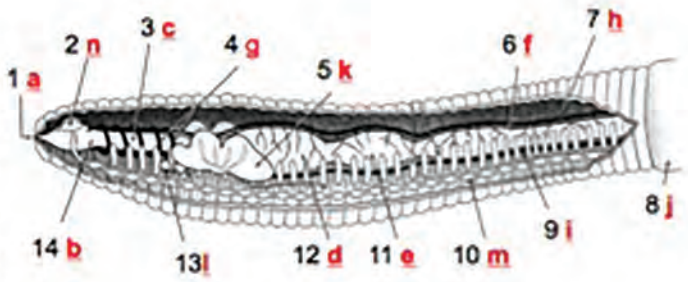
Choose one of the following to research, and write up your findings in a one-page report. Note: You may use this for your unit project option.

1. Did you know that earthworms are not native to many parts of the United States? They were wiped out in the northern United States with the last ice age, and the northern forests have evolved without them. With the arrival of the Europeans, however, nightcrawlers and many other worm species have been introduced. Some people who fish toss their extra worms in the soil, thinking they are doing good. However, these worms are actually quite harmful to northern forest soils. Do a little research on the effects of these invasive species on the forest soils, and report what you find.
2. Earthworms have quite an advanced system of locomotion. They don't need to wiggle back and forth as snakes do, and this is for a couple reasons: they have no backbone, and they have segments. The segments are an integral part of what allows earthworms to move. Research the mechanism behind earthworm movement. Feel free to include an illustration to help you explain the process.

If you are interested in these topics but are unsure if you have the time, please discuss options for flexibility with your teacher.

Match the letter appearing in front of each word in the word bank with the number of the structure.

a. Mouth
b. Pharynx
c. Esophagus
d. Crop
e. Gizzard
f. Intestine
g. Aortic Arches (Hearts)
h. Dorsal Blood Vessel
i. Ventral Blood Vessel
j. Clitellum
k. Seminal Vesicles
l. Seminal Receptacles
m. Ventral Nerve Cord
n. Brain



(Image credit: luzierscience.weebly.com)

Appendix

Biology Materials List and Lab Kit

Below you will find all the materials required for the lab activities in this course. Most of the items should be commonly available, and you may even have them around the house already. The first materials list is sorted by lesson and lab, so items that are used in several labs (such as a calculator or dish detergent) will be repeated. Items in red are those that are included in the Oak Meadow Biology Lab Kit, which is available from the Oak Meadow bookstore. The complete lab kit contents are listed below.

The second list of materials are sorted alphabetically by item. The list includes only those items that you will have to procure yourself (the lab kit items are not in this list since it is assumed you will already have the lab kit). Both materials lists show the same information; they are simply arranged differently so that you can plan your labs in the way that works best for you.

Before you purchase or gather your materials, read through the entire lab so you have a better idea of what you need (and why). Some lessons have a choice of labs and some labs have a choice of materials, so you may not need everything listed here.

Contents of Oak Meadow Lab Kit

QTY	
4	beads
1	beaker, glass, 250 mL
1	digital scale
1	eyedropper
1	funnel
1	graduated cylinder, 100 mL
1	magnifier, folding (double large)
2	microscope slides
1	pH indicator paper
12	pipe cleaners
1	ruler, metric
1	safety goggles
1	screen, 3-inch circle
1	test tube
1	thermometer
1	tweezers

Materials List (sorted by lesson)

You can assume that paper and pencil will be needed for most labs, and often water. Sometimes people are needed for your lab as well, but they are not listed as materials.

Lesson	Lab Title	Materials (items in red are included in the Oak Meadow lab kit)
1	**Walking Crooked!**	• measuring tape or string, 10 meters long • 5–10 markers to imitate "bread crumbs" to mark your path, such as popcorn, small plastic toys, dry beans, etc. • blindfold
2	**Determining the pH of Common Substances**	• pH indicator paper • 6 common household substances (choose from this list): lemon juice window cleaner coffee vinegar bleach mouthwash cola or other type of soda milk baking soda dissolved in water orange juice or other fruit juice tea dish detergent
3	**Observing Osmosis in an Egg Cell**	• 3 raw eggs • white vinegar • corn syrup • 3 clear glasses • digital scale • rubber gloves, optional

Lesson	Lab Title	Materials (items in red are included in the Oak Meadow lab kit)
4	**Examining the Effect of Light Intensity on Photosynthesis**	• test tube • beaker • liquid measuring cup • funnel • 2–3 sprigs of elodea • sodium bicarbonate solution ($NaHCO_3$) (2 teaspoons baking soda in 500 mL of water) • source of bright light • watch • metric ruler
5	**Modeling and Recognizing the Stages of Mitosis**	• pipe cleaners, 2 each of 2 different colors • Twizzlers, 2 longer pieces and 2 shorter pieces • yarn • shoestring licorice • 2 beads • 2 marshmallows
6	**Modeling Meiosis**	• pipe cleaners, 2 each of 4 different colors • yarn • beads
8	**Demonstration Lab: DNA Extraction**	• strawberry • isopropyl alcohol (10 mL) • dish detergent (10 mL) • salt ($\frac{1}{4}$ tsp) • heavy duty ziplock bag • screen, 3-inch circle • graduated cylinder for measuring • beaker • small clear glass • tweezers • spoon
11	**Practicing with Histograms and Distribution Curves**	• graph paper (found in the appendix) • colored pencils
13	**Random Quadrat Sampling in the Field**	• quadrat building materials (see instructions in lesson 13)

Lesson	Lab Title	Materials (items in red are included in the Oak Meadow lab kit)
	Simulated Random Quadrat Sampling	• 2 small containers • scissors
14	**Analyzing Predator-Prey Interactions**	• graph paper (found in the appendix) • colored pencils (optional)
	Modeling Succession	• 1 quart glass jar with a lid • $\frac{1}{2}$ quart of milk (2 cups) • pH strips • small picnic cooler
16	**Modeling the Effects of Habitat Fragmentation**	• 2 8 x 11 grids (3 are included in the lesson) • calculator • colored pencils • black pen
18	**Make Your Own Yogurt**	• $\frac{1}{4}$ cup of plain yogurt with active cultures • 1 quart milk • thermometer • stainless steel or ceramic saucepan • wire whisk • bowl big enough to contain the saucepan • ice cubes and water • 1-quart glass jar • small picnic cooler (preferred) or oven
19	**Quantifying Mold Growth**	• 1 or 2 slices of bread • eyedropper • sealable plastic lunch bags • digital scale
22	**Flower Dissection**	• monocot flower • dicot flower • tweezers • magnifier • tape • camera

Lesson	Lab Title	Materials (items in red are included in the Oak Meadow lab kit)
22	**Inquiry Lab: Observing the Effects of Ethylene on Ripening Fruit**	• 6 green bananas • 1 apple • 2 paper bags
	Inquiry Lab: Transpiration Rate	• 2–3 bunches of celery with leaves attached • jars • red food coloring and water • metric ruler
23	**Quick Lab: External Anatomy of a Live Worm**	• earthworm (the fatter, the better) • shallow pie pan • pencil with an eraser • magnifier
25	**Quick Lab: Modeling the Action of a Swim Bladder**	• beaker • cold, clear, carbonated soft drink or seltzer • 2 dry raisins
	Exploring External Fish Anatomy (see alternate materials below)	• live goldfish or other aquarium fish • beaker
	Exploring External Fish Anatomy (alternate materials)	• a whole fish bought from the grocery store • shallow pie pan or plate • magnifier • tweezers • 2 microscope slides • dish detergent • small glass
26	**Comparing Bone Density**	• boiled fish bone • boiled chicken bone • small boiled beef bone or bone piece • graduated cylinder • digital scale • screwdriver • hammer • safety goggles • magnifier

Lesson	Lab Title	Materials (items in red are included in the Oak Meadow lab kit)
27	**Using an Ethogram to Describe Animal Behavior**	• an animal (pet, farm animal, or zoo animal) • watch • calculator
	Observing Nonverbal Human Communication	• watch • calculator

Alphabetical List of Materials Not Included in Lab Kit

You will not necessarily need all the items on this list; some are optional items and some lessons provide a choice of lab.

ITEM	LESSON/LAB
animal (pet, farm animal, zoo animal, for observation)	Lesson 27 Lab: Using an Ethogram to Describe Animal Behavior
apple	Lesson 22 Lab: Inquiry Lab: Observing the Effects of Ethylene on Ripening Fruit
baking soda	Lesson 2 Lab: Determining the pH of Common Substances Lesson 4 Lab: Examining the Effect of Light Intensity on Photosynthesis
bananas, 6 green	Lesson 22 Lab: Inquiry Lab: Observing the Effects of Ethylene on Ripening Fruit
black pen	Lesson 16 Lab: Modeling the Effects of Habitat Fragmentation
bleach	Lesson 2 Lab: Determining the pH of Common Substances
blindfold	Lesson 1 Lab: Walking Crooked!
bone, boiled fish	Lesson 26 Lab: Comparing Bone Density
bone, boiled chicken	Lesson 26 Lab: Comparing Bone Density
bone, boiled beef (piece)	Lesson 26 Lab: Comparing Bone Density
bowl	Lesson 18 Lab: Make Your Own Yogurt
bread	Lesson 19 Lab: Quantifying Mold Growth
calculator	Lesson 16 Lab: Modeling the Effects of Habitat Fragmentation Lesson 27 Lab: Using an Ethogram to Describe Animal Behavior Lesson 27 Lab: Observing Nonverbal Human Communication
camera	Lesson 22: Flower Dissection
carbonated soft drink or seltzer, clear	Lesson 25 Activity: Quick Lab: Modeling the Action of a Swim Bladder
celery with leaves attached	Lesson 22 Lab: Inquiry Lab: Transpiration Rate
coffee	Lesson 2 Lab: Determining the pH of Common Substances
cola or other type of soda	Lesson 2 Lab: Determining the pH of Common Substances
colored pencils	Lesson 11 Lab: Practicing with Histograms and Distribution Curves Lesson 14 Lab: Analyzing Predator-Prey Interactions Lesson 16 Lab: Modeling the Effects of Habitat Fragmentation
containers, 2 small	Lesson 13 Lab: Simulated Random Quadrat Sampling
corn syrup	Lesson 3 Lab: Observing Osmosis in an Egg Cell
dish detergent	Lesson 2 Lab: Determining the pH of Common Substances Lesson 8 Lab: Demonstration Lab: DNA Extraction Lesson 25 Lab: Exploring External Fish Anatomy

ITEM	LESSON/LAB
earthworm	Lesson 23 Lab: Quick Lab: External Anatomy of a Live Worm
eggs, 3 raw	Lesson 3 Lab: Observing Osmosis in an Egg Cell
elodea, 2–3 sprigs	Lesson 4 Lab: Examining the Effect of Light Intensity on Photosynthesis
fish, whole (dead, from grocery store)	Lesson 25 Lab: Exploring External Fish Anatomy
fish, live, goldfish or other aquarium fish	Lesson 25 Lab: Exploring External Fish Anatomy
flower, dicot	Lesson 22 Lab: Flower Dissection
flower, monocot	Lesson 22 Lab: Flower Dissection
glass jar, 1 quart	Lesson 14 Lab: Modeling Succession Lesson 18 Lab: Make Your Own Yogurt
glasses, 1–3 small	Lesson 3 Lab: Observing Osmosis in an Egg Cell Lesson 8 Lab: Demonstration Lab: DNA Extraction
hammer	Lesson 26 Lab: Comparing Bone Density
ice cubes	Lesson 18 Lab: Make Your Own Yogurt
isopropyl alcohol	Lesson 8 Lab: Demonstration Lab: DNA Extraction
jars	Lesson 22 Lab: Inquiry Lab: Transpiration Rate
lemon juice	Lesson 2 Lab: Determining the pH of Common Substances
licorice, shoestring	Lesson 5 Lab: Modeling and Recognizing the Stages of Mitosis
liquid measuring cup	Lesson 4 Lab: Examining the Effect of Light Intensity on Photosynthesis
marshmallows	Lesson 5 Lab: Modeling and Recognizing the Stages of Mitosis
measuring tape or string	Lesson 1 Lab: Walking Crooked!
milk	Lesson 2 Lab: Determining the pH of Common Substances Lesson 14 Lab: Modeling Succession Lesson 18 Lab: Make Your Own Yogurt
mouthwash	Lesson 2 Lab: Determining the pH of Common Substances
orange juice or other fruit juice	Lesson 2 Lab: Determining the pH of Common Substances
paper bags, 2	Lesson 22 Lab: Inquiry Lab: Observing the Effects of Ethylene on Ripening Fruit
pencil with an eraser	Lesson 23 Lab: Quick Lab: External Anatomy of a Live Worm
pie pan, shallow	Lesson 23 Lab: Quick Lab: External Anatomy of a Live Worm Lesson 25 Lab: Exploring External Fish Anatomy
picnic cooler, small	Lesson 14 Lab: Modeling Succession Lesson 18 Lab: Make Your Own Yogurt
plastic bag, heavy duty ziplock	Lesson 8 Lab: Demonstration Lab: DNA Extraction

ITEM	LESSON/LAB
plastic lunch bags, sealable	Lesson 19 Lab: Quantifying Mold Growth
quadrat building materials (see lesson 13)	Lesson 13 Lab: Random Quadrat Sampling in the Field
raisins, 2 dry	Lesson 25 Activity: Quick Lab: Modeling the Action of a Swim Bladder
red food coloring and water	Lesson 22 Lab: Inquiry Lab: Transpiration Rate
rubber gloves, optional	Lesson 3 Lab: Observing Osmosis in an Egg Cell
salt	Lesson 8 Lab: Demonstration Lab: DNA Extraction
saucepan, stainless steel or ceramic	Lesson 18 Lab: Make Your Own Yogurt
scissors	Lesson 13 Lab: Simulated Random Quadrat Sampling
screwdriver	Lesson 26 Lab: Comparing Bone Density
spoon	Lesson 8 Lab: Demonstration Lab: DNA Extraction
strawberry	Lesson 8 Lab: Demonstration Lab: DNA Extraction
tape	Lesson 22 Lab: Flower Dissection
tea	Lesson 2 Lab: Determining the pH of Common Substances
Twizzlers	Lesson 5 Lab: Modeling and Recognizing the Stages of Mitosis
vinegar, white	Lesson 2 Lab: Determining the pH of Common Substances Lesson 3 Lab: Observing Osmosis in an Egg Cell
watch	Lesson 4 Lab: Examining the Effect of Light Intensity on Photosynthesis Lesson 27 Lab: Using an Ethogram to Describe Animal Behavior Lesson 27 Lab: Observing Nonverbal Human Communication
window cleaner	Lesson 2 Lab: Determining the pH of Common Substances
wire whisk	Lesson 18 Lab: Make Your Own Yogurt
yarn	Lesson 5 Lab: Modeling and Recognizing the Stages of Mitosis Lesson 6 Lab: Modeling Meiosis
yogurt, plain with active cultures	Lesson 18 Lab: Make Your Own Yogurt