Summer assignment Honors Biology 2023/2024

1. Read and outline the following sections: What is Science (1.1), Science in Context (1.2) and Patterns of Life (1.3).
2. The outlines should consist of 15 important facts/***each*** and should show an understanding of the content! Please study your outlines!
3. After your reading, please, answer the Lesson 1.1 Review questions 1-5 on pg.14.
4. All assignments will be collected and graded!
5. During the first week of school the Honors class will take quizzes about the assigned content!).

Have a great summer and a lot of fun!

All the best!

Mrs. Parvanov-Dawson

LESSON 1.1 What Is Science?

KEY QUESTIONS

- *What are the goals of science?*
- *What procedures are at the core of scientific methodology?*
- *What is a scientific theory?*

VOCABULARY
observation
inference
hypothesis
controlled experiment
independent variable
dependent variable
control group
data
theory

READING TOOL

List in order the parts of a typical experiment that uses scientific methodology. Use the headings in your text as a guide to fill in the chart in your **Biology Foundations Workbook.**

Humans have wondered about their place in the cosmos since the earliest time. How do we fit into the grand scheme of nature? How much power do we hold over nature? What are the limits to our abilities? These and other questions are more relevant today than ever before. This chapter begins our effort to show you how science tries to answer those questions.

What Science Is and Is Not

This book will help you understand how biologists try to make sense of nature. These pages are filled with many scientific "facts" and ideas. But one of the first things you should understand is that scientific knowledge is always changing. Some "facts" and ideas you'll find here may have changed since this text was written, and others will change soon. Why? Because scientists are constantly testing, debating, and revising scientific explanations of events in the natural world. That constant testing and revising helps explain why scientists don't "believe" in scientific facts or ideas. Scientists either understand and accept a particular scientific explanation of the natural world, or they reject that explanation. But if science is not a list of unchanging facts and beliefs, what is it?

The Nature of Science The term *science* is usually defined as the use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process. Most importantly, science is a process—an organized way of observing and asking questions about the natural world, developing those questions into testable explanations, and gathering and analyzing data that support or reject those explanations. The word *science* can also refer to the constantly growing and changing body of knowledge that the process of science generates.

How is science different from other ways of explaining how the world works? First, science deals only with the natural world. Scientific research never concerns, in any way, supernatural phenomena of any kind. Second, scientists collect and organize information in an orderly way, looking at events for patterns and connections of cause and effect. Third, scientists propose explanations based on evidence and understanding, not belief. Some ways that scientists study the natural world are shown in **Figure 1-1**.

The Goals of Science Science is based on the view that the physical universe is composed of interacting parts and processes. From a scientific perspective, all objects in the universe, and all interactions among those objects, are governed by universal natural laws. The same natural laws apply whether the objects and events are large (like a hurricane) or small (like the cells in your body).

Greek philosophers were among the first to try to explain the natural world in terms of events and processes they could observe. Modern scientists continue that tradition. ***One goal of science is to provide natural and testable explanations for events in the natural world. Science also aims to use explanations supported by data to understand patterns in nature, and to make useful predictions about natural events.***

VIDEO

Discover how scientists use scientific processes to discover the wide diversity of insects that live in people's homes.

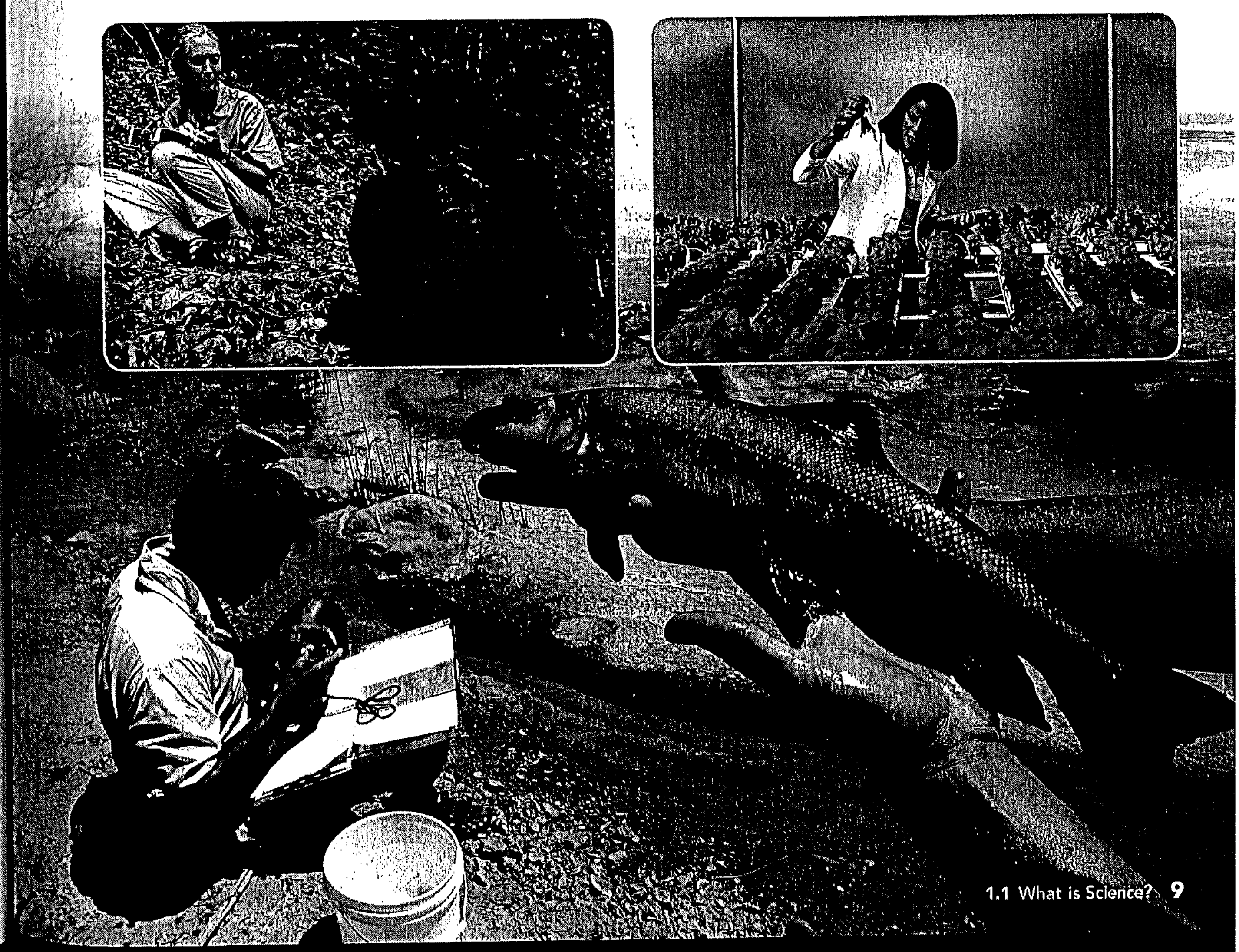
INTERACTIVITY

CASE STUDY

Figure 1-1

Studying the Natural World

How do chimpanzees interact with one another? What is the ideal temperature for basil plants in a hydroponics system? What kinds of fish live in the Colorado River? Researchers can use science to answer these questions and many others.



Science, Change, and Uncertainty Scientists have gathered lots of important information that helps cure and prevent disease, grow food, and link the world electronically. Yet much of nature remains a mystery. Almost every scientific discovery raises more questions than it answers. Often, research yields surprises that point future studies in new and unexpected directions. This constant change doesn't mean science has failed. On the contrary, it shows that science continues to advance.

That's why studying science means more than just memorizing what we know. It also means understanding what we don't know. You may be surprised to hear this, but science rarely "proves" anything. Scientists aim for the best understanding of the natural world that current methods can reveal. Uncertainty is always part of the scientific process, and is part of what makes science exciting!

We hope to show you that understanding science isn't just about learning "facts." We hope you'll gain some understanding of the spirit of scientific inquiry, of the way scientists think, and of both the process and excitement of discovery. Don't just memorize today's scientific facts and ideas. And please don't believe them, just because they are in a textbook! Instead, try to understand how scientists developed those ideas. Pose the kinds of questions scientists ask. Try to see the thinking behind the experiments we describe.

READING CHECK **Construct an Explanation** How is scientific knowledge different from other types of knowledge?

Scientific Methodology

INTERACTIVITY

Discover the power of scientific methodology.

Is science a mysterious process that only scientists do under special circumstances? Nope! You use scientific thinking all the time! Suppose your family's car won't start. What do you do? You use what you know about cars to ask questions. Is the battery dead? You test that idea by turning the key in the ignition. If the starter motor works but the engine doesn't start, you reject the dead battery idea. Is the car out of gas? A glance at the fuel gauge tests that idea. Again and again, you apply scientific thinking until the problem is solved—or until you run out of ideas and call a mechanic!

Scientists work in pretty much the same way. There isn't a single, cut-and-dried "scientific method." But there is a general style of investigation we call scientific methodology, which is a fancy way of saying "the way science works." ***Scientific methodology involves observing and asking questions, forming hypotheses, conducting controlled experiments, collecting and analyzing data, and drawing conclusions.*** Figure 1-2 shows how one research team used scientific methodology in its study of one particular species of marsh grass in a New England salt marsh.

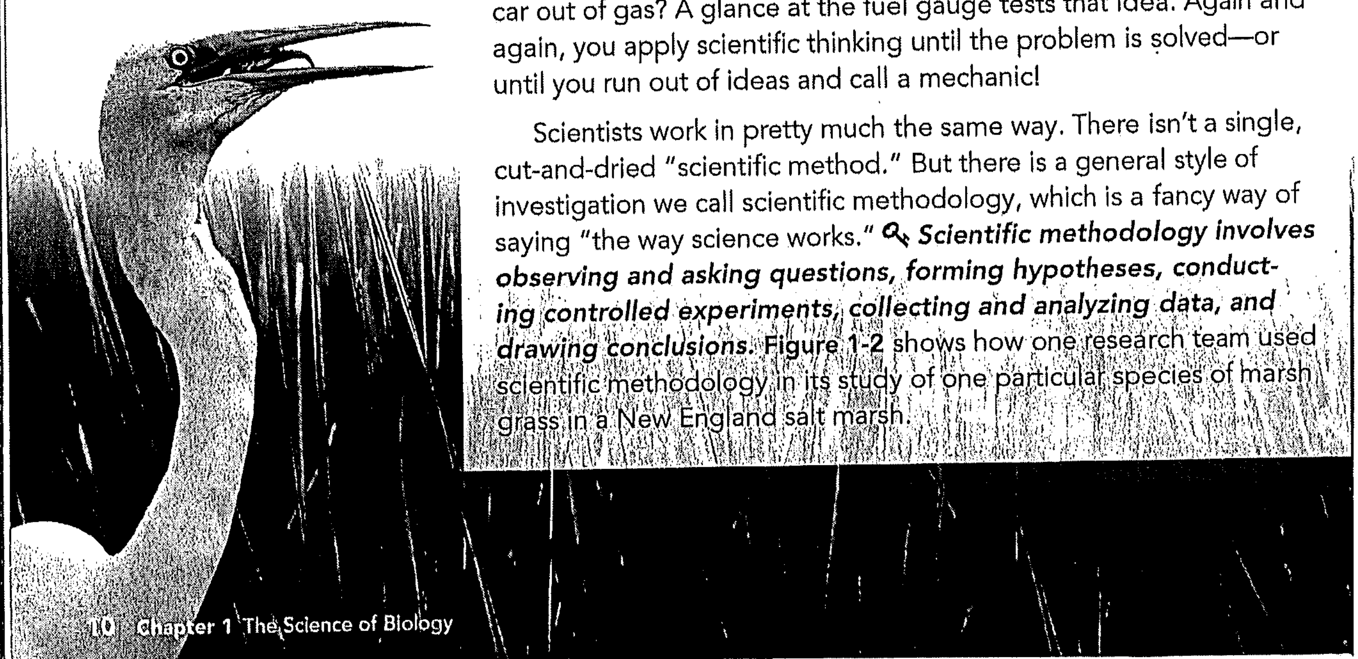
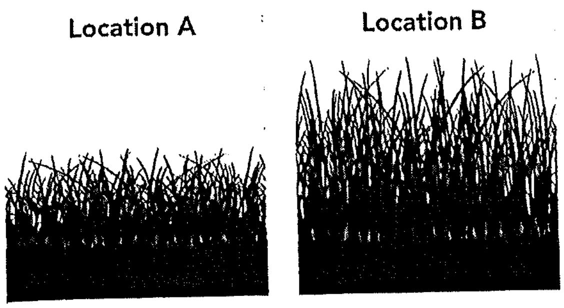


Figure 1-2

Salt Marsh Experiment

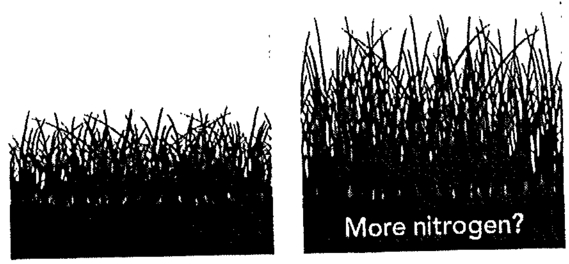
Salt marshes are coastal environments often found where rivers meet the sea. Researchers made an interesting observation about the way a particular species of marsh grass grows. They then applied scientific methodology to answer questions that arose from their observation.

1. OBSERVING AND ASKING QUESTIONS



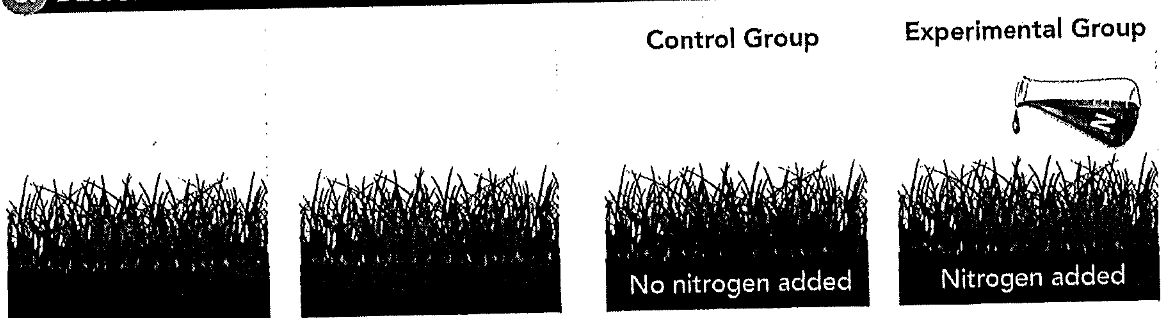
Researchers observed that marsh grass grows taller in some places than others. This observation led to a question: *Why do marsh grasses grow to different heights in different places?*

2. INFERRING AND HYPOTHESIZING



The researchers inferred that something limits grass growth in some places. It could be any environmental factor—temperature, sunlight, water, or nutrients. Based on their knowledge of salt marshes, they proposed a hypothesis: *Marsh grass growth is limited by available nitrogen.*

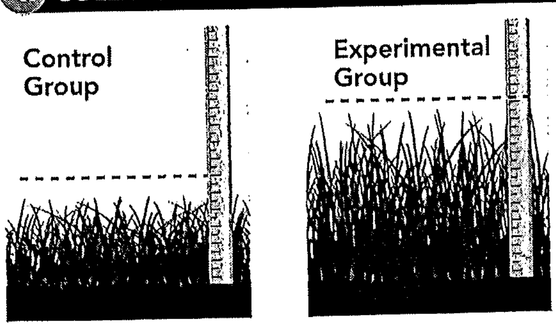
3. DESIGNING CONTROLLED EXPERIMENTS



The researchers selected similar plots of marsh grass. All plots had similar plant density, soil type, input of freshwater, and height above average tide level. The plots were divided into control and experimental groups.

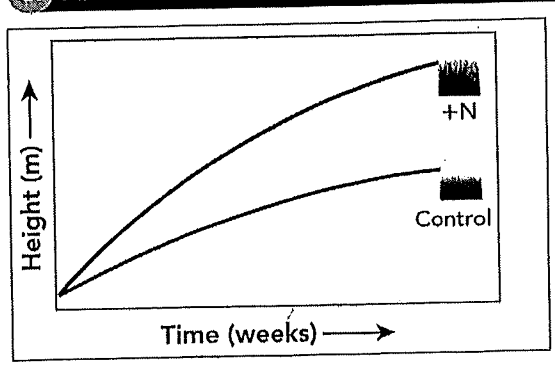
The researchers added nitrogen fertilizer (the independent variable) to the experimental plots. They then observed the growth of marsh grass (the dependent variable) in both experimental and control plots.

4. COLLECTING DATA



The researchers sampled all the plots throughout the growing season. They measured growth rates and plant sizes, and analyzed the chemical composition of living leaves.

5. ANALYZING CONCLUSIONS



Data from all plots were compared and evaluated by statistical tests. Data analysis confirmed that marsh grasses in experimental plots with additional nitrogen did, in fact, grow taller and larger than controls. The hypothesis and its predictions were supported.

READING TOOL

Make a chart that lists and describes the different steps of scientific methodology.

INTERACTIVITY

Try your hand at a simulation of a scientific investigation.

Observing and Asking Questions Scientific investigations begin with **observation**, the act of noticing and describing events or processes in a careful, orderly way. Of course, scientific observation involves more than just "looking." The right kind of observation leads to asking questions that no one has asked (or answered) before.

Inferring and Forming a Hypothesis After posing questions, scientists use further observations to make inferences. An **inference** is a logical interpretation based on what scientists already know. Inference, combined with a creative imagination, can lead to a hypothesis. A **hypothesis** is a tentative scientific explanation that can be tested by further observation or by experimentation. Scientific hypotheses must then be tested by gathering data that can either support or reject them.

Designing Controlled Experiments Testing hypotheses often involves designing experiments that measure factors that can change. These changeable factors are called variables. Some possible variables include temperature, light, time, and availability of nutrients. Ideally, a hypothesis should be tested by an experiment in which only one variable is changed. All other variables should be kept unchanged, or controlled. This is called a **controlled experiment**.

Controlling Variables It is important to control variables because if several variables are changed, researchers can't easily tell which variable is responsible for any results they observe. The variable deliberately changed is called the **independent variable**. The variable that is observed and that changes in response to the independent variable is called the **dependent variable**.

Control and Experimental Groups Typically, experiments are divided into control and experimental groups. A **control group** is exposed to the same conditions as the experimental group except for changes in the independent variable. Scientists always try to reproduce or replicate their observations by setting up several control and experimental groups, rather than just a single pair.

Collecting and Analyzing Data Scientists observe their experiments, gathering two main types of **data**. *Quantitative data* are numbers obtained by counting or measuring. In the marsh grass experiment, quantitative data could include the number of plants per plot; the length, width, and weight of each blade of grass; and so on. *Qualitative data* are descriptive and involve characteristics that cannot usually be measured. Qualitative data in the marsh grass experiment might include notes about whether the grass was growing upright or sideways, or whether one or another plot was disturbed by clam diggers.

Figure 1-3
Collecting Data

This scientist is collecting data on a coral reef in Indonesia.

Selecting Equipment and Technology Scientists collect and analyze data using tools that range from simple meter sticks to complex hardware that measures leaf nitrogen content. Data are often gathered directly by hardware controlled by computers running software that organizes and analyzes results. Statistical analysis helps determine if an experimental treatment is significantly different from controls.

Sources of Error Researchers must avoid errors in data collection and analysis. Tools used to measure the size and mass of marsh grasses, for example, have limited accuracy. Data analysis and sample size must be chosen carefully. The larger the sample size, the more reliably researchers can analyze variation within each group, and evaluate differences between experimentals and controls.

Interpreting Data and Drawing Conclusions Data analysis may lead to conclusions that support or refute the hypothesis being tested. Often, new data indicate that a hypothesis is on the right track, but is off-base about a few details. New questions lead to new and revised hypotheses, which are tested with new experiments that involve better control of variables or other changes in experimental design.

When Experiments Aren't Possible Not all hypotheses can be tested by experiments. Animal behavior researchers, for example, might propose hypotheses about how groups of animals interact in nature. These hypotheses are tested by field observations designed to disturb natural behavior as little as possible. Analysis of data from these observations may lead to new hypotheses that can be tested in different ways. If investigations suggest, for example, that members of a group are related to one another, genetic tests can gather data that support or reject that hypothesis.

Sometimes ethics prevent certain types of experiments. For example, in medical research, when a chemical is suspected as a cause of cancer, researchers do not purposely expose volunteers to the chemical. They study people who have already been exposed, using those who have not as the control group.

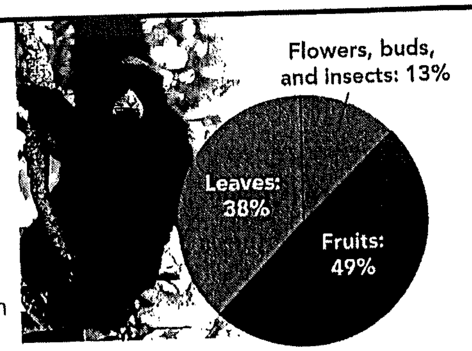
READING CHECK **Describe** What is the difference between quantitative data and qualitative data?

Analyzing Data

What's in a Diet?

The circle graph shows the diet of the siamang gibbon, a type of ape found in the rain forests of Southeast Asia.

1. **Analyze Graphs** According to the circle graph, which plant parts do siamangs rely on most as a food source?
2. **Form a Hypothesis** How would siamangs be affected if the rain forests they live in produced less fruit? Explain your reasoning.



Scientific Theories

BUILD VOCABULARY

ACADEMIC WORDS A scientific **theory** describes a well-tested explanation for a range of phenomena. Scientific theories are different from scientific laws, and it is important to understand that theories do not become laws. Laws, such as ideal gas laws in chemistry or Newton's laws of motion, are concise, specific descriptions of how some aspects of the natural world are expected to behave in a certain situation. In contrast, scientific theories, such as cell theory or the theory of evolution, are more dynamic and complex. Scientific theories encompass a greater number of ideas and hypotheses than laws, and are constantly fined-tuned through the process of science.

Researchers hope that data from many individual experiments add up to something bigger—a larger and more useful understanding of how the world works. That's where we encounter an important scientific term: **theory**. Many other terms you'll learn this year will be new to you, because they are used only in science. But the word *theory* is also often used in everyday life. That causes problems, because non-scientists use the word *theory* in a very different way than scientists do. When most people say, "I have a theory," they mean, "I have a hunch" or "I have a guess." When a friend says, "That's just a theory," she may mean, "People aren't too certain about that idea." Scientists would never use the word *theory* in that way. In those situations, a scientist would use the common words "guess" or "hunch" or a scientific term we've already discussed: *hypothesis*.

When scientists refer to gravitational theory or evolutionary theory, they do not mean "a hunch about gravity" or "a guess about evolution." ***In science, the word* theory *applies to a tested, highly-reliable scientific explanation of events in the natural world that unifies many repeated observations and incorporates durable, well-supported hypotheses that enable scientists to make accurate predictions.*** Charles Darwin developed lots of hypotheses over many years. It took a long time for him to assemble his thoughts and hypotheses into his theory of evolution by natural selection. Since then, evolutionary theory has predicted things Darwin couldn't have imagined, such as the evolution of bacteria that resist antibiotics and insects that are immune to pesticides. Today, evolutionary theory is the central organizing principle of all biological science.

Once a theory has been thoroughly tested and supported by many lines of evidence, it may become the dominant scientific view. But remember that no theory is absolute truth. Science is always changing; as new evidence is uncovered, a theory may be revised or replaced by a more useful explanation.

LESSON 1.1 Review

KEY IDEAS

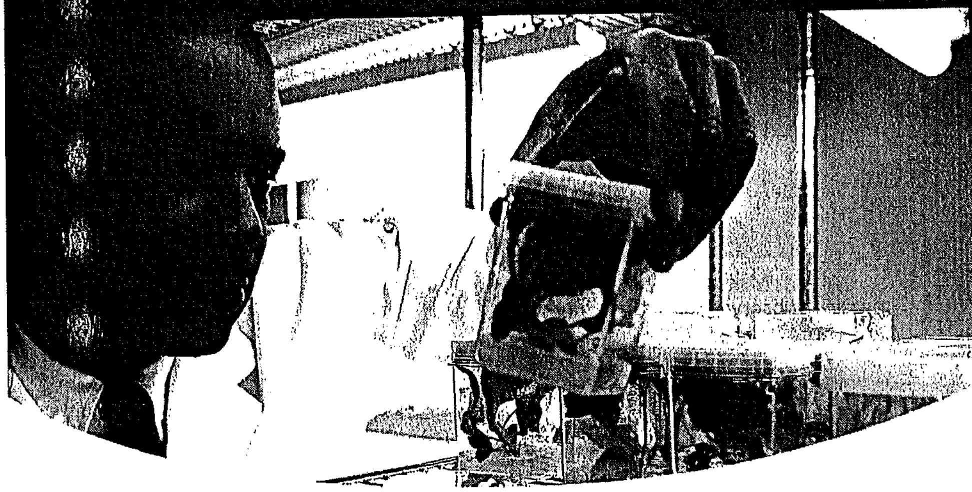
1. In your own words, define the term *science*.
2. Why are hypotheses so important to controlled experiments?
3. How does a theory differ from a hypothesis?

CRITICAL THINKING

4. **Form a Hypothesis** You observe mold growing on one side of a slice of bread, but not on the other side. Form a hypothesis to explain this difference in mold growth.
5. **Plan an Investigation** Design a controlled experiment to test the effect of water temperature on goldfish. Be sure to include your hypothesis, independent variable, and dependent variable, as well as the experimental and control groups in your experiment.

Science in Context

LESSON 1.2



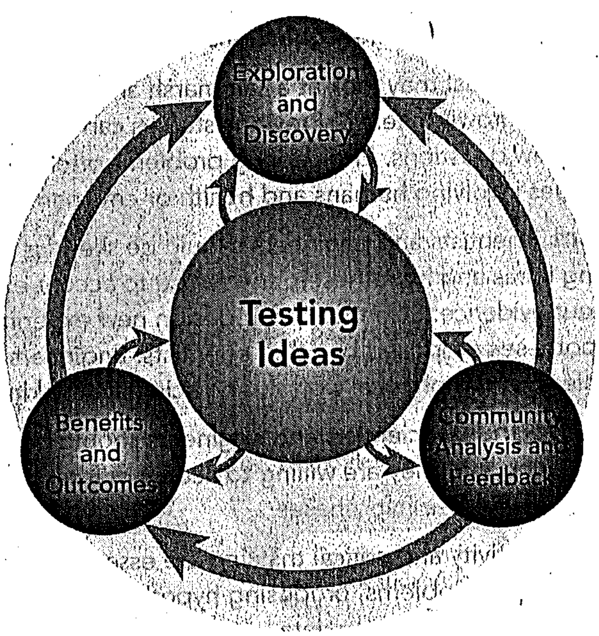
KEY QUESTIONS
- *What attitudes and experiences generate new ideas?*
- *Why is peer review important?*
- *What is the relationship between science and society?*
- *What practices are shared by science and engineering?*

VOCABULARY
bias

READING TOOL
Before you read, study **Figure 1-4**. As you read, list examples of each of the different aspects of science in the table in your **Biology Foundations Notebook.** Then use **Figure 1-9** to add examples for engineering.

The testing of ideas is the heart of science and engineering. In their quest for understanding, scientists engage in many different activities: They ask questions, make observations, seek evidence, share ideas, and analyze data. These activities are all part of the dynamic process of science.

The process of science typically consists of the components shown in **Figure 1-4**. Notice that the parts of the process do not proceed in a linear fashion. Real science usually involves many activities that loop back on themselves, building up knowledge as they proceed. In fact, science is at its heart a creative endeavor. Scientists take many different paths through the process depending on the questions they are investigating and the resources available to them.

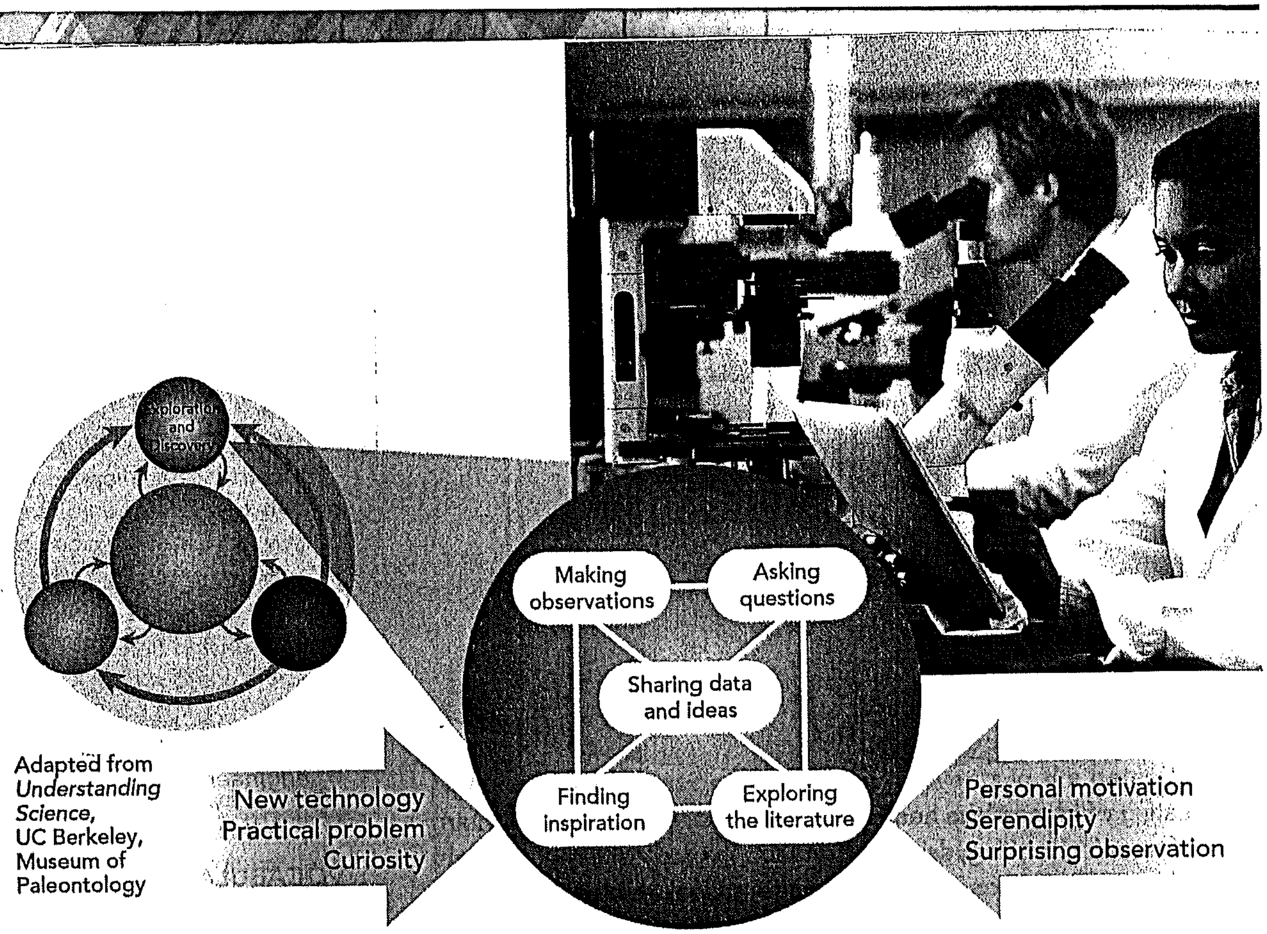


Adapted from *Understanding Science*, UC Berkeley, Museum of Paleontology

INTERACTIVITY

Figure 1-4
The Process of Science

As the arrows indicate, the different aspects of science are interconnected—making the process of science dynamic, flexible, and unpredictable.



Adapted from *Understanding Science*, UC Berkeley, Museum of Paleontology

Figure 1-5

Exploration and Discovery

Ideas in science can arise in many ways—from simple curiosity or from the need to solve a particular problem. Scientists often begin investigating by making observations, asking questions, talking with colleagues, and reading about previous experiments.

READING TOOL

Copy one of the concept maps in this lesson. Then, add specific examples to illustrate the processes it describes.

Exploration and Discovery

Usually, the testing of ideas begins with observations and questions. Those observations and questions come from a variety of different sources, as shown in **Figure 1-5**.

Scientific Attitudes Good scientists share scientific attitudes, or habits of mind, that lead them to exploration and discovery. ***Curiosity, skepticism, open-mindedness, and creativity help scientists and engineers ask new questions and define new problems.***

Curiosity A scientist may look at a salt marsh and ask, "What's that plant? Why is it growing here?" Previous studies can spark curiosity and lead to new questions. Engineering problems often arise from practical issues involving humans and health or environmental issues.

Skepticism Scientists and engineers should be skeptics who question existing ideas and hypotheses, and refuse to accept explanations without evidence. Scientists often design new experiments to test hypotheses proposed by other scientists. Engineers work to solve problems in the physical world using scientific thinking.

Open-Mindedness Scientists and engineers should be open-minded, meaning that they are willing to accept different ideas that may not agree with their hypotheses.

Creativity Creativity and critical thinking are essential for asking questions, defining problems, proposing hypotheses, and designing experiments that yield accurate data.

Practical Problems Ideas for scientific investigations often arise from practical problems involving humans and health or environmental issues. Salt marshes, for example, are vital nurseries for commercially important fish and shellfish. Yet salt marshes are under intense pressure from agriculture and from development. An engineer might wonder, "How would nearby construction affect the marsh and how can that impact be minimized?"

VIDEO

Listen to scientists discussing their work in extreme environments.

New Technology New technology often opens new ways of asking questions for both scientists and engineers. For example, portable, remote data-collecting equipment enables field researchers to monitor environmental conditions around the clock, in several different locations at once. This information allows researchers to pose and test new hypotheses.

READING CHECK **Describe** Describe a "fact" that you have heard or read that made you skeptical. Explain your reasons for doubt.

Community Analysis and Feedback

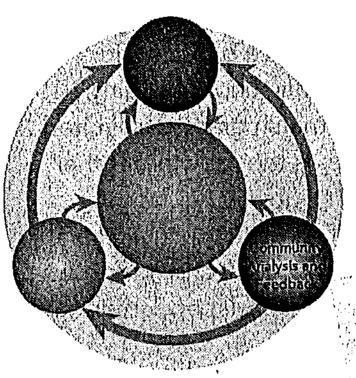
Scientists often collaborate in groups and communicate with other research groups. In order for research to be accepted, however, it must be officially shared with the scientific community. The communication must follow a variety of rules that ensure it is scientifically appropriate. Some of the steps that scientists use when communicating their results are shown in **Figure 1-6**.

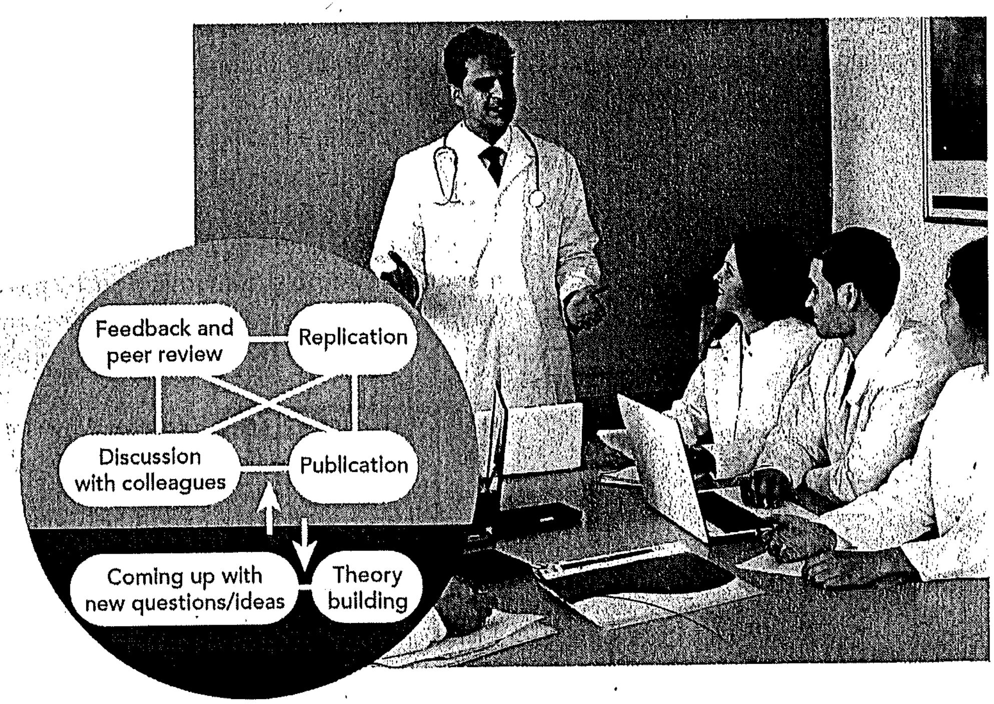
Scientists also share their work with the general public, especially when the results or information could benefit society. This communication is less formal, and can take the form of a newspaper or magazine article, television program, or blog post.

Figure 1-6

Community Analysis and Feedback

Communication is an important part of science. Scientists review and evaluate one another's work to ensure accuracy. Results from one study may lead to new ideas and further studies.





Adapted from *Understanding Science*, UC Berkeley, Museum of Paleontology

Quick Lab — Guided Inquiry

Replicating Procedures

1. Working with a partner, assemble ten blocks into an unusual structure. Write directions that others can use to replicate that structure without seeing it.
2. Exchange directions with another team. Replicate the team's structure by following their directions.
3. Compare each replicated structure to the original. Identify which parts of the directions were clear and accurate, and which were unclear or misleading.

ANALYZE AND CONCLUDE

1. **Evaluate** How could you have written better directions?
2. **Construct an Explanation** Based on what you have learned in this investigation, explain why it is important that scientists write procedures that can be replicated.

Peer Review Scientists share findings with other scientists by publishing their hypotheses, experimental methods, results, and analysis in scientific journals. Papers submitted to these journals are reviewed by anonymous, independent reviewers who work in the same field. Reviewers look carefully for mistakes, oversights, unfair influences, or fraud, in techniques and analysis. Their goal is to ensure that articles meet the highest standards of quality. This process is called peer review. ***Publishing articles in peer-reviewed scientific journals allows researchers to share ideas. It also allows other scientists to evaluate and test the data and analysis.*** Peer review does not guarantee that a piece of work is correct, but it does certify that the work meets standards set by the scientific community.

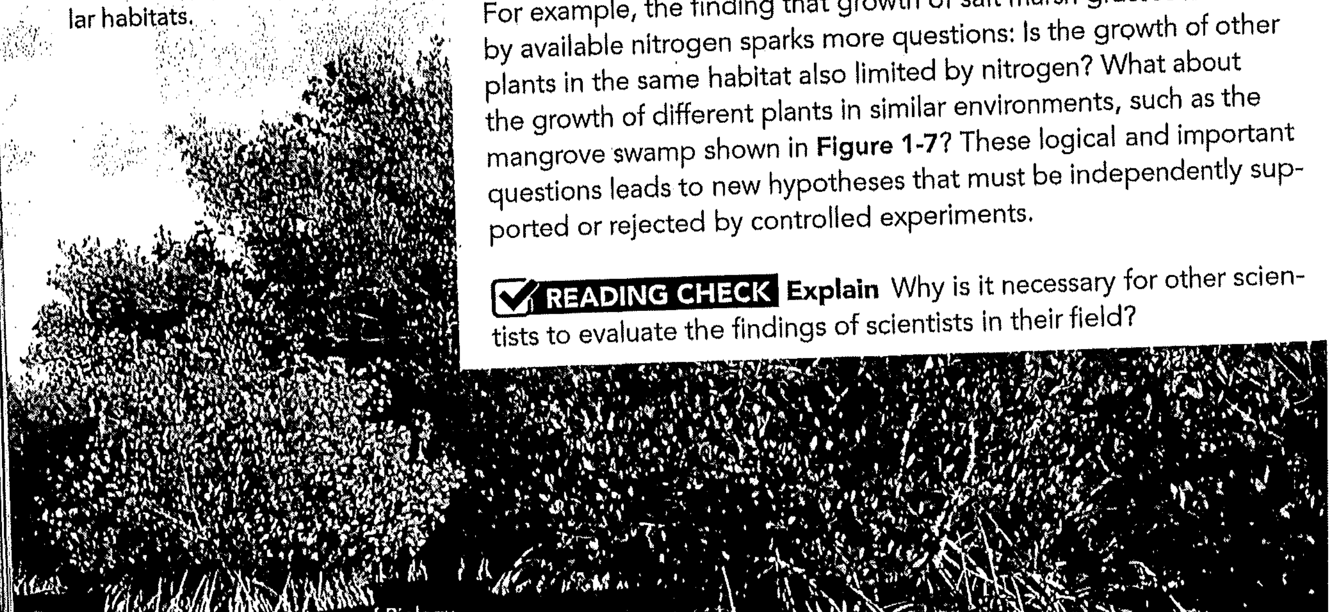
Sharing Knowledge and New Ideas After research has been published, it enters the dynamic marketplace of scientific ideas. How do new data fit into existing scientific understanding? For example, the finding that growth of salt marsh grasses is limited by available nitrogen sparks more questions: Is the growth of other plants in the same habitat also limited by nitrogen? What about the growth of different plants in similar environments, such as the mangrove swamp shown in **Figure 1-7**? These logical and important questions leads to new hypotheses that must be independently supported or rejected by controlled experiments.

READING CHECK **Explain** Why is it necessary for other scientists to evaluate the findings of scientists in their field?

Figure 1-7

Mangrove Swamp

In tropical areas, mangrove swamps serve as the ecological equivalents of temperate salt marshes. The results of the salt marsh experiment suggest that nitrogen might be a limiting nutrient for mangroves and other plants in these similar habitats.



Benefits and Outcomes

Scientists, engineers, and scientific information interact constantly with our society, our economy, our laws, and our moral principles, as shown in **Figure 1-8**. Think of medical issues relevant to your life and the lives of others close to you. That list may include effect of drugs and alcohol, high blood pressure, diabetes, AIDS, cancer, and heart disease. Science and engineering also play an important role in guiding decisions about health, social, and environmental issues. Should communities produce electricity using fossil fuels, nuclear power, solar power, wind power, or hydroelectric dams? How should chemical wastes be disposed of?

As journalist Dan Rather wrote in a *Scientific American* blog: "In the end, science is about hope; it's about expanding our horizons, and endeavoring to understand more. It is an instinct so deeply human, and an instinct we need now more than ever." (Copyright Scientific American, A Division of Nature America, Inc.)

CASE STUDY

INTERACTIVITY

Design a solar still using the engineering design process as it relates to science.

Science, Ethics, and Morality Useful answers to these questions require scientific information. But science alone is often not enough. In most cases, science and engineering can only tell us what is technically possible, or what we *could* do. Science and engineering alone can almost never tell us whether we *should or should not* do something. ***Applying scientific information involves understanding the role of science context in society and its limitations.***

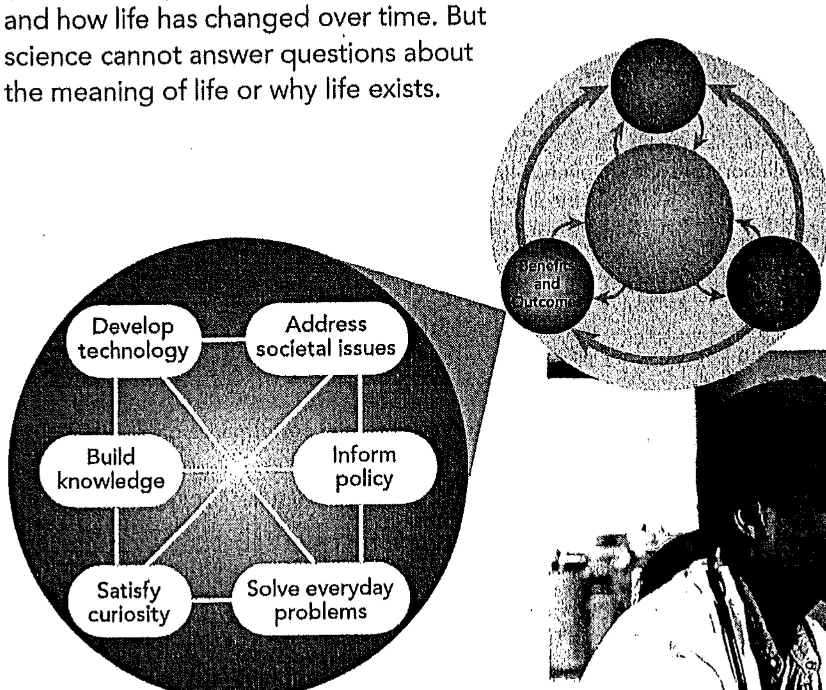
Science by itself does not automatically include ethical or moral viewpoints. When scientists explain "why" something happens, their explanation involves only natural phenomena. For example, biologists try to explain in scientific terms what life is, how life operates, and how life has changed over time. But science cannot answer questions about the meaning of life or why life exists.

CASE STUDY

Figure 1-8

Benefits and Outcomes

Science both influences society and is influenced by society.



Adapted from *Understanding Science*, UC Berkeley, Museum of Paleontology

INTERACTIVITY

Learn how the science and engineering practices are similar.

Avoiding Bias Scientists aim to be objective, but they have likes, dislikes, and biases. A **bias** is a personal, rather than scientific, point of view for, or against, something. Examples of biases include preferences for, or against, certain kinds of people or activities.

Given this background, it is no surprise that scientific data can be interpreted in different ways by scientists with different personal perspectives. Recommendations from scientists with personal biases may or may not be in the public interest. But if enough of us understand science, we can help make certain that science is applied in ways that benefit individuals and society.

READING CHECK **Explain** What might happen if a scientist were biased?

Science and Engineering Practices

In contrast to scientists, engineers design, and build machines and structures. Although this book focuses on the science of biology, many of the methods and practices—the things that scientists and engineers actually do—are very similar. As a result, when you practice and master science skills, you also are learning skills that are useful in engineering. For additional information about these skills, see the Science and Engineering Handbook.

If you wonder how the "testing ideas" part of science compares to the kinds of things that engineers do, look at **Figure 1-9**. ***Athough some of the specifics vary, the steps in scientific inquiry and engineering design are basically the same.*** Not surprisingly, engineers are trained in basic science as well as the principles of their profession.

Figure 1-9

Experimental Methodology

The experimental methodology used in scientific inquiry and engineering design are adaptations of the same approach to scientific research.

Scientific Inquiry	Engineering Design
Planned or chance observations, and/or personal or outside motivation generate a question	Colleagues and/or clients present a need to be solved through engineering design
Define/refine the question with colleagues/collaborators	Define/refine a design problem that addresses the need with colleagues and clients
Research how others may have answered the same question	Research how others may have solved the same design problem
Brainstorm hypotheses and choose one	Brainstorm design solutions and choose one
Design and conduct pilot experiment to test hypothesis; gather and analyze data	Design and create a prototype/model; test it to gather and evaluate performance data
Modify hypothesis and/or experimental protocol as needed based on analysis of data	Redesign prototype based on performance data
Conduct revised experiment; gather and analyze data	Test revised prototype; gather and evaluate performance data
Draw conclusion, write paper	Finalize design, make drawings
Submit paper for peer review; respond to consecutive feedback	Present best available solution to client; respond to client feedback
Publish the paper!	Build the project!

Developing and Using Models Both scientists and engineers use models, such as those shown in **Figure 1-10**. When you hear the word *model*, you may think of model trains or other representations of much larger objects. But there are many different kinds of models. Mathematical representations and computer simulations are examples, as are two-dimensional drawings, diagrams, and maps. In fact, the flowcharts used throughout this lesson are models. Models help visualize and summarize ideas and communicate ideas to others.

Using Mathematics and Computational Thinking Mathematics and computational thinking (the process of mathematical calculation) are also important tools. The relationships between variables are essential to the understanding of scientific phenomena. Ratios, rates, percentages, and unit conversions are used to analyze and interpret data. A mathematical representation can represent and model data; it can also support claims and explanations.

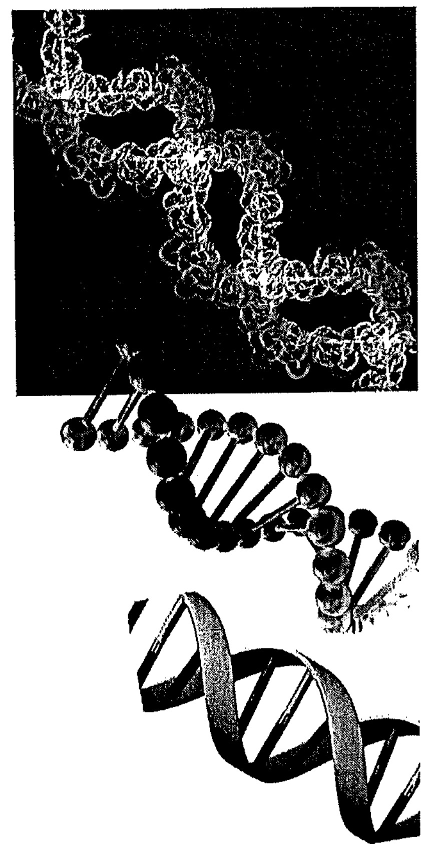
Constructing Explanations and Designing Solutions Scientists aim to construct explanations for events in the natural world that caused them to ask a question. After a scientist collects data, analyzes and interprets that data, and finds that it supports the hypothesis, the next step is to construct an explanation. An explanation describes how variables relate to one another, and it is supported by evidence. In engineering, the goal is to design a solution to a problem within certain constraints.

Engaging in Argument From Evidence In science, an argument is a reason or set of reasons used to persuade others that an idea is right or wrong. Once a scientist has constructed an explanation, the next step is to use evidence (analyzed and interpreted data) to persuade others that the explanation is correct. Part of this process is receiving critiques and responding thoughtfully. Engineers defend claims that a design solution is effective or evaluate competing design solutions.

Figure 1-10

Models

Models can be elaborate pictures that a computer generates (top), physical models, (middle), or illustrations (bottom). All three of these models show DNA, a molecule essential for life.



LESSON 1.2 Review

KEY QUESTIONS

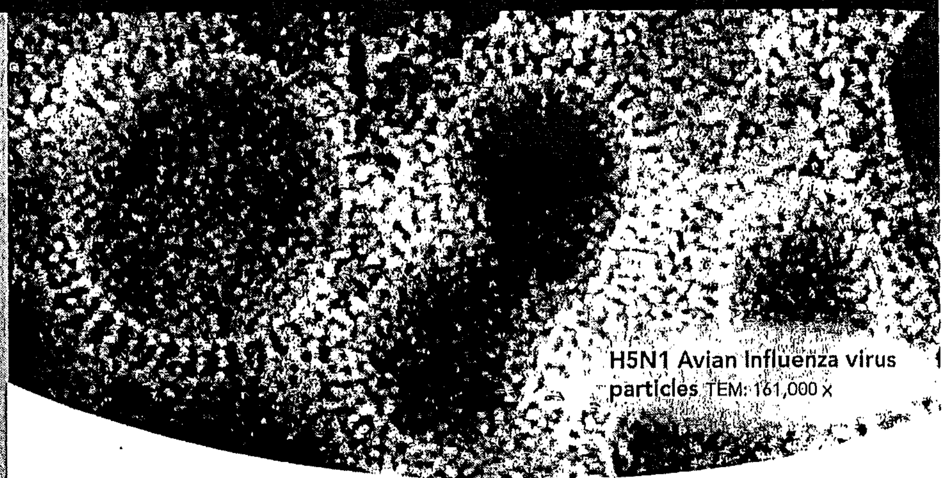
1. How are both curiosity and skepticism useful in science?
2. How can peer review help scientists improve their work?
3. How is the use of science related to its context in society?
4. Why is testing ideas an important part of all science and engineering practices?

CRITICAL THINKING

5. **Apply Concepts** An advertisement claims that studies of a new sports drink show it boosts energy. You discover that none of the study results have been peer-reviewed. What would you tell consumers who are considering buying this product?
6. **Apply Concepts** A study shows that a new pesticide is safe for use on food crops. The researcher who conducted the study works for the pesticide company. What potential biases may have affected the study?

LESSON 1.3

Patterns of Life



H5N1 Avian Influenza virus particles TEM 161,000 ×

KEY QUESTIONS

- *What characteristics do all living things share?*
- *What are the crosscutting concepts of biology?*
- *How do fields of biology differ in their approaches?*
- *How is the metric system important to science?*

VOCABULARY

biology
sexual reproduction
asexual reproduction
DNA
metabolism
stimulus
homeostasis
evolve

READING TOOL

Complete the chart in your **Biology Foundations Workbook** by writing the main idea and details from this lesson on the characteristics of life.

Think about some of the important and exciting news stories you've read or heard about recently. Bird flu spreads around the world, killing thousands of birds and threatening a human epidemic. Users of certain illegal drugs experience permanent damage to their brains and other parts of their nervous systems. Reports surface about the use of cloned human cells to grow new organs to replace those lost to disease or injury. These and many other stories involve **biology**—the science that employs scientific methodology to study living things. (The Greek word *bios* means "life," and *-logy* means "study of.")

Characteristics of Living Things

Biology is the study of life. But what is life? What distinguishes living things from nonliving matter? Surprisingly, it isn't as simple as you might think to describe what makes something alive. No single characteristic is enough to describe a living thing. Also, some nonliving things share one or more traits with organisms. For example, a firefly and a fire both give off light, and each moves in its own way. Mechanical toys, automobiles, and clouds (none of which are alive) move around, while mushrooms and trees (which are alive) stay in one spot. To make matters more complicated, some things, such as viruses, exist at the border between living and nonliving things.

Despite these difficulties, we can list characteristics that most living things have in common. ***Living things are made up of basic units called cells, reproduce, are based on a universal genetic code, grow and develop, obtain and use materials and energy, respond to their environment, maintain a stable internal environment, and evolve, changing over time.***

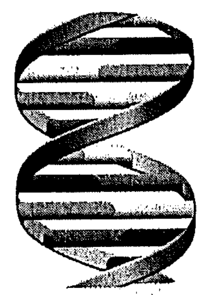
Made Up of Cells Living things, or organisms, are made up of small, self-contained units called cells. Cells are the smallest units of an organism that can be considered alive. Cells can grow, respond to their surroundings, and reproduce. Despite their small size, cells are complex and highly organized.

VIDEO

Learn about the characteristics of life and what it means to be alive.

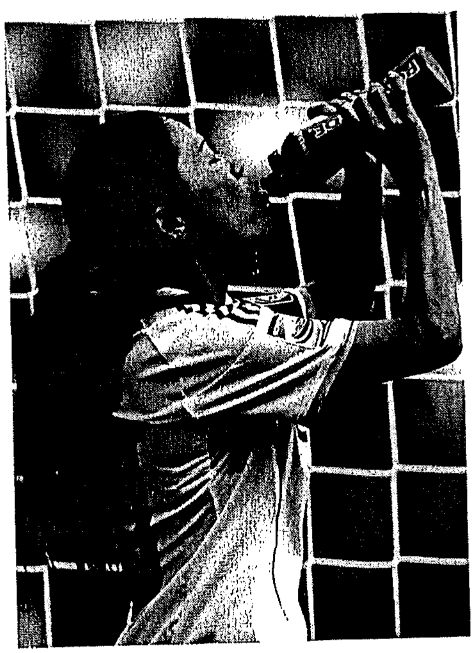
Reproduction All organisms produce new organisms through a process called reproduction. There are two basic kinds of reproduction: sexual and asexual. The vast majority of multicellular organisms reproduce sexually. In **sexual reproduction**, cells from two different parents unite to produce the first cell of the new organism. In **asexual reproduction**, the new organism has a single parent.

Based on a Universal Genetic Code Offspring usually resemble their parents. With asexual reproduction, offspring and their parents have the same traits. With sexual reproduction, offspring differ from their parents in some ways. Explaining how organisms inherit traits is one of the greatest achievements of modern biology. Biologists now know that the directions for inheritance are carried by a molecule called **DNA**. This genetic code, with a few minor variations, determines the inherited traits of every organism on Earth.



DNA helix

Growth and Development All living things grow during at least part of their lives. For some single-celled organisms, such as bacteria, growth is mostly a simple increase in size. Multicellular organisms, like this monarch butterfly, typically go through a process called development. During development, a single fertilized egg cell divides again and again to produce the many cells of mature organisms. As those cells divide, they change in shape and structure. This process is called differentiation, because it forms cells that look different from one another and perform different functions.



Need for Materials and Energy

Think of what an organism needs as it grows and develops. Just as a building grows taller because workers use energy to assemble new materials, an organism uses energy and a constantly supply of materials to grow, develop, and reproduce. Organisms also need materials and energy just to stay alive. The combination of chemical reactions as it carries out its life processes is called **metabolism**.

Response to the Environment

Organisms detect and respond to stimuli from their environment. A **stimulus** is a signal to which an organism responds. External stimuli, which come from the environment outside an organism, include factors such as light and temperature. In contrast, internal stimuli come from within an organism. This field of sunflowers is responding the the stimulus of sunlight.

Maintaining Internal Balance Even though conditions in the external environment may vary widely, most organisms must keep internal conditions, such as temperature and water content, fairly constant to survive. The relatively constant set of conditions is called **homeostasis.** Often internal stimuli help maintain homeostasis. For example, when your body needs more water to maintain homeostasis, internal stimuli make you feel thirsty.

Evolution Although individual organisms experience many changes during their lives, the basic traits they inherited from their parents usually do not change. As a group, however, any given kind of organism can **evolve**, or change over time.

Over a few generations, the changes in a group may not seem significant. But over hundreds of thousands or even millions of years, the changes can be dramatic. The ability of a group of organisms to change over time is invaluable for survival in a world that is always changing.

What About Viruses? Viruses are particles made up of proteins, nucleic acids, and sometimes lipids. Viruses depend entirely upon other living organisms for their existence, making them parasites. After infecting living things, viruses can reproduce, regulate gene expression, and evolve.

READING CHECK **Explain** Why is it important for organisms to maintain homeostasis?

Crosscutting Concepts in Biology

The units of this book seem to cover different subjects, but all biological sciences are tied together by themes and methods of study that cut across disciplines. These concepts overlap and interlock, and crop up throughout the book. You'll also notice that several of these concepts overlap with the characteristics of life or the nature of science.

The study of biology revolves around several crosscutting concepts: cause and effect; systems and system models; stability and change; patterns; scale, proportion, and quantity; energy and matter: flows, cycles, and conservation; and structure and function.

Cause and Effect: Mechanism and Explanation Science is not a list of facts, but "a way of knowing." The job of science is to use observations, questions, and experiments to explain the natural world in terms of natural forces and events, or cause and effect. Successful scientific research reveals rules and patterns that can explain and predict at least some events in nature. Science enables us to take actions that affect events in the world around us.

Systems and System Models Within the biosphere, all of the different parts of the system work together and interact with one another. Predation, competition, and symbiosis within an ecological community are examples of interactions that occur within a biological system. The regulation of blood pressure in the human body can be studied as interactions among the nervous, endocrine, excretory, and circulatory systems.

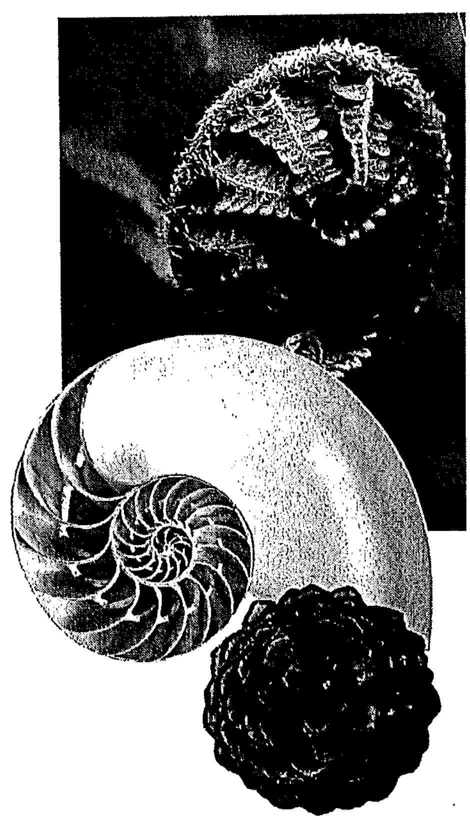
Stability and Change Living things maintain a relatively stable internal environment, a process known as homeostasis. For most organisms, any breakdown of homeostasis may have serious or even fatal consequences.

Patterns You can compare similar patterns among all sorts of objects in nature, such as those shown in **Figure 1-11**. Patterns can be either linear or cyclical. Linear patterns include the tendency for organ systems to become more complex as you move through vertebrates from fishes to mammals. Cyclical patterns include seasonal migrations of animals or movement of materials such as carbon and nitrogen through the environment.

Scale, Proportion, and Quantity Just about everything, from atoms to rocks to organisms, can be described in terms of structure. How something's structure is studied and described depends on the scale on which it is being studied. On a molecular scale, a scientist might study a human in terms of proteins in the body. On a global scale, a scientist might study humans in terms of their impact on the ozone layer.

Figure 1-11
Patterns in Nature

Throughout nature you will find patterns. Similar patterns can be in structures ranging from an unrolling fern frond to a shell to a pine cone.



Energy and Matter: Flows, Cycles, and Conservation

Living things obtain and use material and energy. Life requires matter that serves as nutrients to build body structures, and energy that fuels life's processes. Some organisms, such as plants, obtain energy from sunlight and take up nutrients from air, water, and soil. Other organisms, including most animals, eat plants or other animals to obtain both nutrients and energy. The need for matter and energy link all living things on Earth in a web of interdependent relationships.

Structure and Function Each major group of organisms has evolved its own particular body part "tool kit," a collection of structures that have evolved in ways that make particular functions possible. From capturing food to digesting it, and from reproducing to breathing, organisms use structures that have evolved into different forms as species have adapted to life in different environments.

READING CHECK **Apply Concepts** Give an example of a cause-and-effect relationship.

Fields of Biology

Living systems range from groups of molecules that make up cells to collections of organisms that make up the biosphere. ***Biology includes many overlapping fields that use different tools to study life from the molecular level to the planetary level.*** Here's a peek into a few of the largest and smallest branches of biology, some of which are shown in **Figure 1-12.**

Global Ecology Life on Earth is shaped by weather patterns and processes in the atmosphere so large that we are just beginning to understand them. We are also learning that activities of living organisms—including humans—profoundly affect both the atmosphere and climate. Humans now move more matter and use more energy than any other species on Earth. Global ecological studies, aided by satellite technology and supercomputers, are enabling us to learn about our global impact, which affects all life on Earth.

Biotechnology This field, created by the molecular revolution, is based on our ability to "edit" and rewrite the genetic code—in a sense, redesigning the living world to order. We may soon learn to correct or replace damaged genes that cause inherited diseases. Other research seeks to genetically engineer bacteria to clean up toxic wastes. Biotechnology also raises enormous ethical, legal, and social questions. Should we tamper with the fundamental biological information that makes us human?

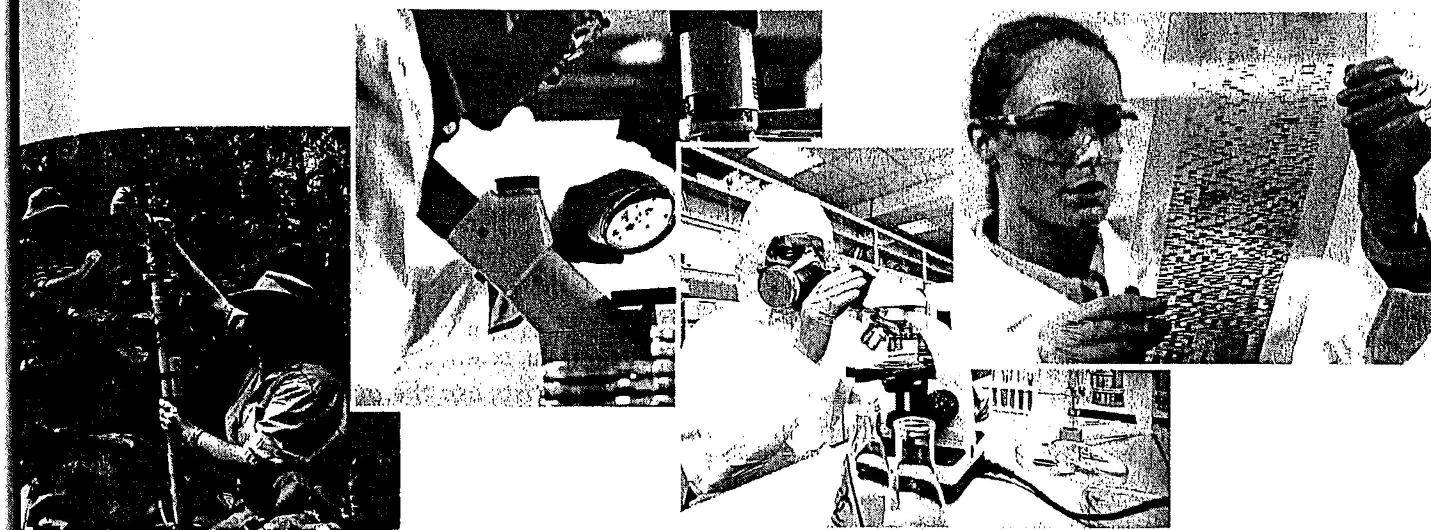


Figure 1-12

Fields of Biology

Biologists work in fields that include, from left to right, global ecology, biotechnology, ecology of infectious diseases, and molecular biology.

Building the Tree of Life Biologists have discovered and identified roughly 1.8 million different kinds of living organisms. That may seem like an incredible number, but researchers estimate that somewhere between 2 and 100 million more forms of life are waiting to be discovered around the globe—from caves deep beneath the surface, to tropical rain forests, to coral reefs and the depths of the sea. Identifying and cataloguing all these life-forms is enough work by itself, but biologists aim to do much more. They want to combine the latest genetic information with computer technology to organize all living things into a single universal "Tree of All Life."

Ecology and Evolution of Infectious Diseases HIV, bird flu, and drug-resistant bacteria may seem to have appeared out of nowhere, but the science behind their stories shows that relationships between hosts and pathogens are dynamic and constantly changing. Organisms that cause human disease have their own ecology, which involves our bodies, medicines we take, and our interactions with each other and the environment. Over time, disease-causing organisms engage in an "evolutionary arms race" with humans that creates constant challenges for public health around the world. Understanding these interactions is crucial to safeguarding our future.

INTERACTIVITY

Discover the different branches of life science in this activity.

Genomics and Molecular Biology These fields focus on studies of DNA and other molecules inside cells. The "molecular revolution" of the 1980s created the field of genomics, which is now looking at the entire sets of DNA code contained in a wide range of organisms. Ever more powerful computer analyses enable researchers to compare vast databases of genetic information in a fascinating search for keys to the mysteries of growth, development, aging, disease, cancer, and the history of life on Earth.

READING CHECK **Evaluate** Which of these fields of biology is of the greatest interest to you? Cite your reasons.

Performing Biological Investigations

You will soon have the opportunity to perform scientific investigations. Biologists, like other scientists, rely on a common system of measurement and practice safety procedures when conducting studies. As you study and perform experiments, you will become familiar with scientific measurement and safety procedures.

Scientific Measurement Because researchers need to replicate one another's experiments, and because many experiments involve gathering quantitative data, scientists need a common system of measurement. ***Scientists use the metric system when collecting data and performing experiments.*** The metric system is a decimal system of measurement whose units are based on certain physical standards and are scaled on multiples of 10. A revised version of the original metric system is called the International System of Units, or SI. The abbreviation *SI* comes from the French *Le Système International d'Unités.*

Because the metric system is based on multiples of 10, it is easy to use. Notice in **Figure 1-13** how the basic unit of length, the meter, can be multiplied or divided to measure objects and distances much larger or smaller than a meter. The same process can be used when measuring volume and mass. You can learn more about the metric system in the Lab Skills Handbook.

BUILD VOCABULARY

Prefixes The SI prefix *milli-* means "thousandth." Therefore, 1 millimeter is one-thousandth of a meter, and 1 milligram is one-thousandth of a gram.

Common Metric Units

Length	Mass
1 meter (m) = 100 centimeters (cm) 1 meter = 1000 millimeters (mm) 1000 meters = 1 kilometer (km)	1 kilogram (kg) = 1000 grams (g) 1 gram = 1000 milligrams (mg) 1000 kilograms = 1 metric ton (t)
Volume	**Temperature**
1 liter (L) = 1000 milliliters (mL) 1 liter = 1000 cubic centimeters (cm^3)	0°C = freezing point of water 100°C = boiling point of water

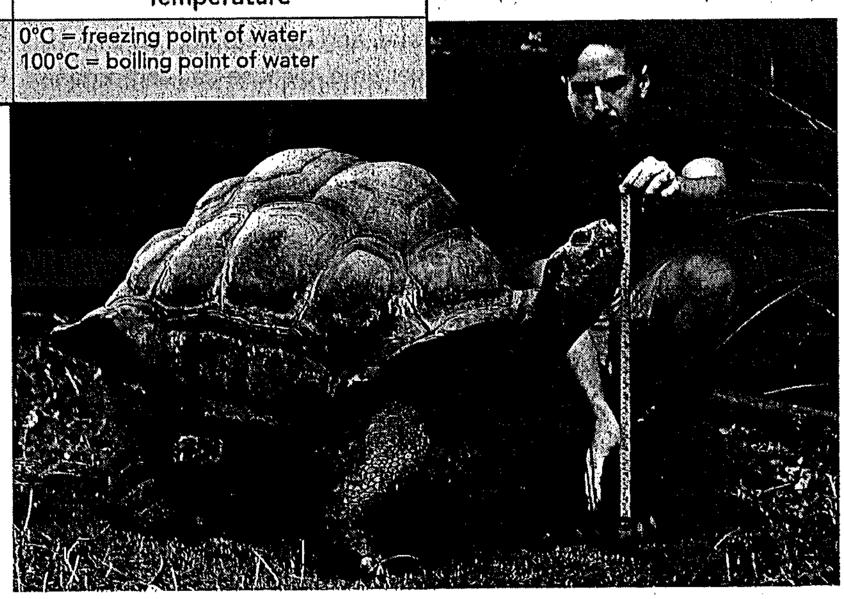


Figure 1-13

The Metric System

Scientists usually use the metric system in their work. This system is easy to use because it is based on multiples of ten. This scientist is measuring the tortoise while its neck is stretched.

Develop a Solution Lab

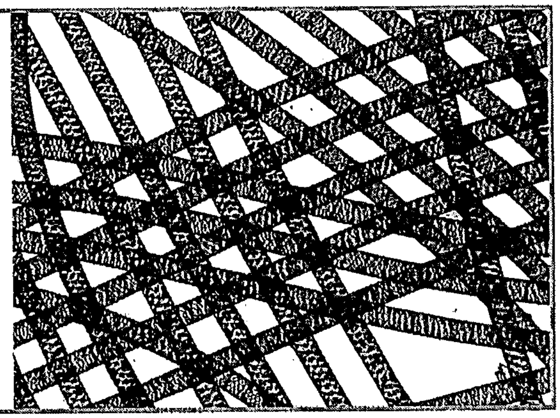
Open-ended Inquiry

Algae in the Water

Problem What are the ideal growth conditions for algae?

In this lab, you will plan and conduct an experiment to determine the effects of a variable, such as temperature or sunlight, on algae growth. Then you will propose ideas for a system for raising algae.

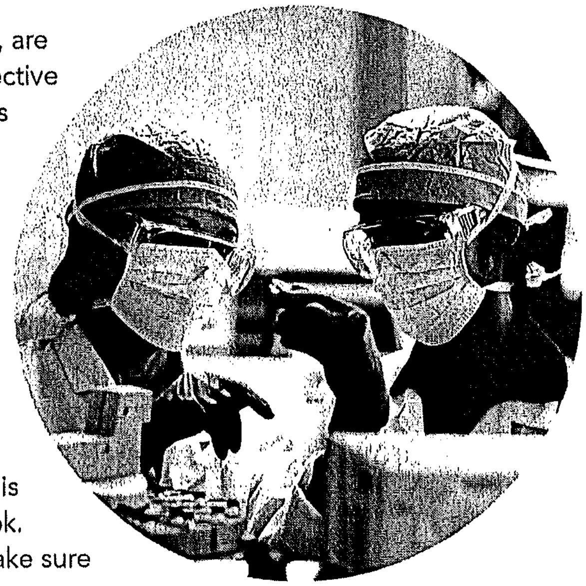
You can find this lab in your digital course.



Safety Scientists, such as those shown in **Figure 1-14**, are trained to use safety procedures, such as wearing protective glasses and gloves. Laboratory work may involve flames or heating elements, electricity, chemicals, hot liquids, sharp instruments, or breakable glassware. Laboratory work and fieldwork may involve contact with living or dead organisms—not just potentially poisonous plants and venomous animals but also disease-carrying organisms and substances contaminated with dangerous microorganisms.

Whenever you work in your biology laboratory, you must follow safe practices. Careful preparation is the key to staying safe. Before performing any activity in this course, study the safety rules in the Lab Skills Handbook. Before you start each activity, read all the steps and make sure you understand them, including safety precautions.

The single most important safety rule is to always follow your teacher's instructions and directions in this textbook. Anytime you are in doubt, ask your teacher for an explanation. And because you may come in contact with organisms you cannot see, it is essential that you wash your hands thoroughly with soap and warm water after every scientific activity. Remember that you are responsible for your own safety and that of your teacher and classmates. If you are handling live animals, you are responsible for their safety, too.



INTERACTIVITY

Figure 1-14

Safety in the Laboratory

These scientists are wearing protective glasses and gloves in keeping with the safety protocols in their lab.

LESSON 1.3 Review

KEY QUESTIONS

1. How do living things differ from nonliving things?
2. How do crosscutting concepts help unite the study of biology?
3. How can biology be studied at different scales, or levels?
4. Why do scientists use a common system of measurement?

CRITICAL THINKING

5. **Identify Patterns** To analyze the characteristics of life, why is it useful to identify patterns at the level of molecules and cells?
6. **Calculate** In an experiment, you need 250 grams of potting soil for each of 10 plant samples. How many kilograms of soil in total do you need?