Is this picture a colorful work of abstract art, or is it something else? Imagine shrinking down to a tiny size, so small you could enter a blood vessel. The picture shows what you might see rushing toward you. Do you know what the red objects are? If you guessed red blood cells, you are right. What about the knobby green objects? Watch out for these! They are viruses that have invaded the blood. When you read this book, you will take an exciting journey into the realm of blood cells, viruses, and just about everything else that is related to life. You will learn how your own body works, what makes living things unique, and what you and viruses have in common. This first chapter explains how scientists learn about the natural world and introduces you to biology, the science of life.
Lesson Objectives
• Identify the goal of science.
• Describe how scientists study the natural world.
• Explain how and why scientists do experiments.
• Describe types of scientific investigations.
• Explain what a scientific theory is.

Vocabulary
• dependent variable
• evidence
• experiment
• hypothesis
• independent variable
• model
• observation
• prediction
• science
• scientific investigation
• scientific law
• scientific method
• scientific theory

Introduction
Did you ever wonder why giraffes have such long necks or how birds learn to sing their special songs? If you ever asked questions such as these about the natural world, then you were thinking like a scientist. The word science comes from a Latin word that means “knowledge.” Science is a distinctive way of gaining knowledge about the natural world that starts with a question and then tries to answer the question with evidence and logic. Science is an exciting exploration of all the whys and hows that any curious person might have about the world. You can be part of that exploration. Besides your curiosity, all you need is a basic understanding of how scientists think and how science is done, starting with the goal of science.

The Goal of Science
The goal of science is to understand the natural world. To achieve this goal, scientists make certain assumptions. They assume that:
• Nature can be understood through systematic study.
• Scientific ideas are open to revision.
• Sound scientific ideas withstand the test of time.
• Science cannot provide answers to all questions.

Nature Can Be Understood
Scientists think of nature as a single system controlled by natural laws. By discovering natural laws, scientists strive to increase their understanding of the natural world. Laws of nature are expressed as scientific laws. A scientific law is a statement that describes what always happens under certain conditions in nature. An example of a scientific law is the law of gravity, which was discovered by Sir Isaac Newton. The law of gravity states that objects always fall towards Earth because of the pull of gravity. Based on this law, Newton could explain many natural events. He could explain not only why objects such as apples always fall to the ground, but he could also explain why the moon orbits Earth. Isaac Newton discovered laws of motion as well as the law of gravity. His laws of motion allowed him to explain why objects move as they do.

Did Newton discover the law of gravity when an apple fell from a tree and hit him on the head? Probably not, but observations of nature are often the starting point for new ideas about the natural world.

Scientific Ideas Can Change
Science is more of a process than a set body of knowledge. Scientists are always testing and revising their ideas, and as new observations are made, existing ideas may be challenged. Ideas may be replaced with new ideas that better fit the facts, but more often existing ideas are simply revised. For example, when Albert Einstein developed his theory of relativity, he didn’t throw out Newton’s laws of motion. Instead, he showed that Newton’s laws are a part of a bigger picture. In this way, scientists
gradually build an increasingly accurate and detailed understanding of the natural world.

Scientific Knowledge Can Withstand the Test of Time
Many scientific ideas have withstood the test of time. For example, about 200 years ago, the scientist John Dalton proposed atomic theory—the theory that all matter is made of tiny particles called atoms. This theory is still valid today. There are many other examples of basic science ideas that have been tested repeatedly and found to be true. You will learn about many of them as you study biology.

Science Cannot Answer All Questions
Science rests on evidence and logic, so it deals only with things that can be observed. An observation is anything that is detected either through human senses or with instruments and measuring devices that extend human senses. Things that cannot be observed or measured by current means—such as supernatural beings or events—are outside the bounds of science. Consider these two questions about life on Earth:
  • Did life on Earth evolve over time?
  • Was life on Earth created through another method?
The first question can be answered by science on the basis of scientific evidence and logic. The second question could be a matter of belief. Therefore, it is outside the realm of science.

The Scientific Method
There are basic methods of gaining knowledge that are common to all of science. At the heart of science is the scientific investigation, which is done by following the scientific method. A scientific investigation is a plan for asking questions and testing possible answers. It generally follows the steps listed in Figure below.
Steps of a Scientific Investigation. A scientific investigation typically has these steps.

**Making Observations**
A scientific investigation typically begins with observations. You make observations all the time. Let’s say you take a walk in the woods and observe a moth, like the one in Figure below resting on a tree trunk. You notice that the moth has spots on its wings that look like eyes. You think the eye spots make the moth look like the face of an owl.
Does this moth remind you of an owl?

**Asking a Question**
Observations often lead to questions. For example, you might ask yourself why the moth has eye spots that make it look like an owl’s face. What reason might there be for this observation?

**Forming a Hypothesis**
The next step in a scientific investigation is forming a hypothesis. A **hypothesis** is a possible answer to a scientific question, but it isn’t just any answer. A hypothesis must be based on scientific knowledge, and it must be logical. A hypothesis also must be falsifiable. In other words, it must be possible to make observations that would disprove the hypothesis if it really is false. Assume you know that some birds eat moths and that owls prey on other birds. From this knowledge, you reason that eye spots scare away birds that might eat the moth. This is your hypothesis.

**Testing the Hypothesis**
To test a hypothesis, you first need to make a prediction based on the hypothesis. A **prediction** is a statement that tells what will happen under certain conditions. It can be expressed in the form: If A occurs, then B will happen. Based on your hypothesis, you might make this prediction: If a moth has eye spots on its wings, then birds will avoid eating it.

Next, you must gather evidence to test your prediction. **Evidence** is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Assume that you gather evidence by making more observations.
of moths with eye spots. Perhaps you observe that birds really do avoid eating the moths. This evidence agrees with your prediction.

**Drawing Conclusions**
Evidence that agrees with your prediction supports your hypothesis. Does such evidence prove that your hypothesis is true? No; a hypothesis cannot be proven conclusively to be true. This is because you can never examine all of the possible evidence, and someday evidence might be found that disproves the hypothesis. Nonetheless, the more evidence that supports a hypothesis, the more likely the hypothesis is to be true.

**Communicating Results**
The last step in a scientific investigation is communicating what you have learned with others. This is a very important step because it allows others to test your hypothesis. If other researchers get the same results as yours, they add support to the hypothesis. However, if they get different results, they may disprove the hypothesis. When scientists share their results, they should describe their methods and point out any possible problems with the investigation. For example, while you were observing moths, perhaps your presence scared birds away. This introduces an error into your investigation. You got the results you predicted (the birds avoided the moths while you were observing them), but not for the reason you hypothesized. Other researchers might be able to think of ways to avoid this error in future studies.

**Experiments**
An experiment is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory. Some experiments can be very simple, but even the simplest contributed important evidence that helped scientists better understand the natural world.
A laboratory experiment studying plant growth. What might this experiment involve?

**KQED: Medicine From the Ocean Floor**

Some experiments are much more sophisticated than those shown above. For example, scientists at the University of California, Santa Cruz are using robots to sort through thousands of marine chemicals in search of cures for diseases like cholera, breast cancer, and malaria.

**Variables**

An experiment generally tests how one variable is affected by another. The affected variable is called the **dependent variable**. In the plant experiment shown above, the dependent variable is plant growth. The variable that affects the dependent variable is called the **independent variable**. In the plant experiment, the independent variable is fertilizer—some plants will get fertilizer, others will not. In any experiment, other factors that might affect the dependent variable must be controlled. In the plant experiment, what factors do you think should be controlled? *(Hint: What other factors might affect plant growth?)*

**Sample Size and Repetition**

The sample in an experiment or other investigation consists of the individuals or events that are studied. Typically, the sample is much smaller than all such individuals or events that exist in the world. Whether the results based on the sample are true in
general cannot be known for certain. However, the larger the sample is, the more likely it is that the results are generally true. Similarly, the more times that an experiment is repeated and the same results obtained, the more likely the results are valid. This is why scientific experiments should always be repeated.

**Other Types of Scientific Investigations**

Experiments are sometimes hard or even impossible to do. For example, a scientist who is studying an extinct animal cannot experiment with the animal because it no longer exists. The scientist must rely instead on evidence in the natural world, such as fossils that the extinct animal left behind.

**Natural Studies**

When scientists do studies in nature, they usually cannot control factors that might affect the variables they are investigating. This is a drawback, because it may make the observations difficult to interpret. Without controls, it may not be possible to determine which of many factors explain the observations. For example, assume you are studying how plants grow in a forest or field. You cannot control the amount of sunlight or rain water the plants receive, so it will be difficult to determine which factors most influence plant growth. On the other hand, a natural study shows what actually occurs in nature. Therefore, it may provide a truer picture of what happens in the real world than an experiment does.

**Modeling**

Another way to gain scientific knowledge without experiments is by making and manipulating models. A model is a representation of part of the real world. Did you ever build a model car? Scientific models are something like model cars; they represent the real world but are simpler than the real world. This is one reason that models are especially useful for investigating complex systems. By using a model, scientists can better understand how the real system works.

Models represent complex systems in nature. They make the systems easier to understand. These are simple conceptual models. Models of very complex systems are often based on mathematical equations or computer simulations. Like a hypothesis, a model must be evaluated. It is assessed by criteria such as how well it represents the real world, what limitations it has, and how useful it is. The usefulness of a model depends on how well its predictions match observations of the real world. Even when a model’s predictions match real-world observations, however, it doesn’t prove that the model is true or that it is the only model that works.
Scientific Theories
With repeated testing, some hypotheses may eventually become scientific theories. A scientific theory is a broad explanation for events that is widely accepted as true. To become a theory, a hypothesis must be tested over and over again, and it must be supported by a great deal of evidence. People commonly use the word theory to describe a guess about how or why something happens. For example, you might say, “I think a woodchuck dug this hole in the ground, but it’s just a theory.” Using the word theory in this way is different from the way it is used in science. A scientific theory is more like a fact than a guess because it is so well-supported. There are several well-known theories in biology, including the theory of evolution, cell theory, and germ theory. You will read about all three of these theories in the next lesson.

KQED: Bio-Inspiration: Nature as Muse
For hundreds of years, scientists have been using design ideas from structures in nature. Now, biologists and engineers at the University of California, Berkeley are working together to design a broad range of new products, such as life-saving milli-robots modeled on the way cockroaches run and adhesives based on the amazing design of a geckos foot. This process starts with making observations of nature, which lead to asking questions and to the additional aspects of the scientific process.

Lesson Summary
• The goal of science is to understand the natural world through systematic study. Scientific knowledge is based on evidence and logic.
• Scientists gain knowledge through scientific investigations. A scientific investigation is a plan for asking questions and testing possible answers.
• Scientists use experiments to test hypotheses under controlled conditions. Experiments are often done in a lab.
• Other types of scientific investigations include natural studies and modeling. They can be used when experiments are difficult to do.
• Scientific theories are broad explanations that are widely accepted as true. This is because they are supported by a great deal of evidence.

Lesson Review Questions
Recall
1. What is science? What is the goal of science?
2. Outline the steps of a scientific investigation.
3. What is a scientific hypothesis? What characteristics must a hypothesis have to be useful in science?
4. Give an example of a scientific question that could be investigated with an experiment. Then give an example of scientific question that could not be investigated in this way.

5. What might be an advantage of collecting evidence in a natural setting rather than in a lab?

Apply Concepts
6. Identify the independent and dependent variables in the following experiment:
   A scientist grew bacteria on gel in her lab. She wanted to find out if the bacteria would grow faster on gel A or gel B. She placed a few bacteria on gel A and a few on gel B. After 24 hours, she observed how many bacteria were present on each type of gel.

Think Critically
7. Explain why science cannot provide answers to all questions.

8. Contrast how the term *theory* is used in science and in everyday language.

9. Explain how a hypothesis could become a theory.

Points to Consider
The Points to Consider at the end of each lesson in this book will help you relate what you just learned to what is coming next. The questions will help guide you to the next lesson or chapter. Before reading the next lesson of this chapter, consider these points:

- Remember the opening photo of red blood cells and green viruses? The blood cells are cells of a living thing. Do you think that the viruses are living things? Why or why not?
- Lab experiments are the main method of gathering evidence in some branches of science. Why might lab experiments not be the best way to study living things, such as wild animals?