Chapter 1

About Science

THE MAIN IDEA

Science is the study of nature's rules

1.4 The Natural World

Through science we have already learned much about nature. That said, as any scientist would tell you, there is still much more we have yet to learn. Science is a work in progress. The understandings we have one year will not necessarily be the understandings we have the next year.

For example, it is common to think of a fact as something unchanging and absolute. But in science, a fact is something agreed upon by competent observers as being true. Interestingly, what humans accept to be factual changes over time as we learn new ideas. It was once an accepted fact that the universe is unchanging and permanent. Today, we recognize the fact that the universe is expanding and evolving.

A hypothesis is a suggested explanation for an observable phenomenon. A hypothesis becomes a scientific hypothesis when, and only when, it can be tested through experiments. The more tests that the scientific hypothesis passes, the greater the confidence we have that the hypothesis is true. However, if the hypothesis fails even one test, then the hypothesis is taken to be false. A new, more encompassing hypothesis is needed.

READING CHECK
When does a hypothesis become a scientific hypothesis?

It was once believed that mass is lost as wood burns, because, clearly, ashes weigh less than the wood that burned. The 18th-century French chemist Antoine Lavoisier (1743–1794), however, was skeptical (**Figure 1.8**). To him it appeared that burning wood lost

CONCEPT **CHECK**

Which statement is a scientific hypothesis?

1. The Moon is made of Swiss cheese.
2. Human consciousness arises from an essence that is undetectable.

CHECK YOUR ANSWER Both statements attempt to explain observed phenomena, so both are hypotheses. Only statement (1) is testable, however, and therefore only statement (1) is a scientific hypothesis.

Λ Figure 1.8
Antoine Lavoisier, shown here with his wife, Marie-Anne, who assisted him in many of his experiments, was a concerned citizen as well as a first-rate scientist. He established free schools, advocated the use of fire hydrants, and designed street lamps to make travel through urban neighborhoods safer at night.

mass because it was losing gases to the atmosphere. He went on to hypothesize that during any chemical change, such as burning, mass transforms from one substance to another, but it is always conserved. This means that the total mass before the reaction is equal to the total mass after the reaction. To test this hypothesis he conducted experiments during which burn- ing took place in a sealed chamber. He found that the chamber and its contents weighed the same before and after the burning. The old hypothesis didn't fit this observation. Lavoisier's new hypothesis was a better alternative.

When a hypothesis has been tested and supported by experimental data over and over again and has not been contradicted, it may become formally stated as a scientific law, or principle. Lavoisier's conservation of mass hypothesis was repeatedly confirmed over many years, so it became known as the law of mass conservation, which we discuss in more detail in Chapter 9. But remember, the goal of science is to describe the rules of nature as accurately as possible. Ideally, a scientific law matches perfectly with the rules of nature. In practice, however, our so-called "laws" are merely our best approximations. If a scientific law is eventually found to be inaccurate through reproducible and verifiable evidence, then the law—in order to be closer to reality—must be modified or changed.

In the early 20th century, for example, it was found that mass actually does change ever so slightly during a chemical reaction. The law of mass conservation, therefore, is not perfectly accurate. The change in mass during a chemical reaction, however, is exceedingly small and not easily measured. The law of mass conservation, therefore, still holds practical value, which is why it is still widely embraced. Scientists use the word theory in a way that differs from its usage in everyday speech. In everyday speech, a theory is no different from a hypothesis—an explanation for an observable phenomenon. A scientific theory, on the other hand, is a well-tested explanation that unifies a broad range of observations within the natural world. Physicists, for instance, speak of the theory of relativity and use it to explain how we are held to Earth by gravity and how a strong gravitational field causes time to slow down. Biologists speak of the theory of natural selection and use it to explain both the unity and the diversity of life. Chemists speak of the theory of the atom and use it to explain how mass is seemingly conserved in a chemical reaction and how one material can transform into another.

Theories are a foundation of science, but, like facts, hypotheses, and laws, they are not fixed. Rather, they evolve as they go through stages of redefinition and refinement so as to mirror nature as accurately as possible. Since it was first proposed 200 years ago, for example, the theory of the atom has been repeatedly refined as new evidence about atomic behavior has been gathered. Those who know little about science may argue that scientific theories have little value because they are always being modified. Those who understand science, however, see it differently. Science is self-correcting, and its theories grow stronger as they are modified. A summary of what we mean by a scientific fact, hypothesis, law, and theory is provided in **Table 1.1**.

The domain of science is restricted to the observable natural world. While scientific methods can be used to debunk various claims, science has no way of verifying testimonies involving the supernatural. The term supernatural literally means "above nature." Science works within nature, not above it. Likewise, science is unable to answer such philosophical questions as "What is the purpose of life?" or such religious questions as "What is the nature of the human spirit?" Though these questions are valid and have great importance to us, they rely on subjective personal experience and do not lead to testable hypotheses.

fyi FOR YOUR INFORMATION

Critical thinking is the ability to evaluate claims in a rational manner. Creative thinking is the ability to make connections to come up with new ideas.

TABLE 1.1 A Summary of Scientific Terms

Scientific Fact—An agreed upon truth about the natural world.
Example: Wood burns.

Scientific Hypothesis—A testable explanation for an observable phenomenon.
Example: Wood transforms mostly to gaseous materials as it burns.

Scientific Law—An experimentally confirmed description of the natural world.
Example: The mass of the products of a reaction equals the mass of the reactants.

Scientific Theory—A well-tested explanation that unifies many observations.
Example: Matter is made of tiny particles called atoms that are not destroyedduring a chemical transformation.

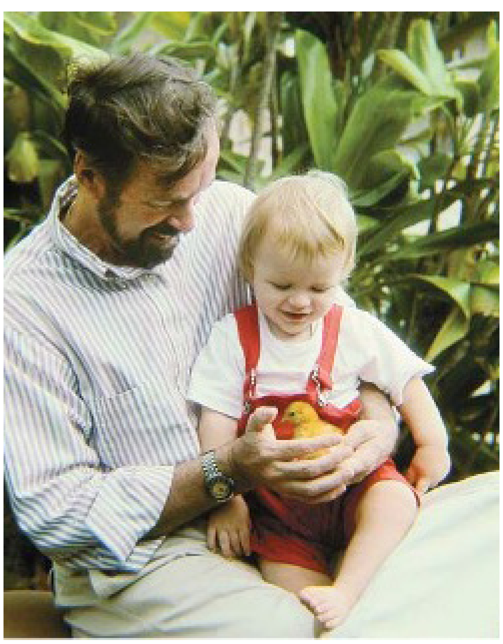
∧ Figure 1.9
The tree Ayano hugs is made primarily from carbon dioxide and water, the very same chemicals Ayano releases through her breath. In return, the tree releases oxygen, which Ayano uses to sustain her life. We are one with our environment down to the level of atoms and molecules.

Why Should We Learn Science?

Just as you can't enjoy a ball game, computer game, or party game until you know its rules, so it is with nature. Because science helps us learn the rules of nature, it also helps us appreciate nature. You may see beauty in a tree, but you'll see more beauty in that tree when you realize that it was created from substances found not in the ground but primarily in the air—specifically, the carbon dioxide and water put into the air by respiring organisms such as yourself (**Figure 1.9**). Learning science builds new perspectives and is not unlike climbing a mountain. Each step builds on the previous step, while the view grows evermore astounding (**Figure 1.10**).

There are also many practical reasons for which we should become familiar with science. Consider what the world was like before the advent of scientific thinking, around the time of Galileo in the late 1500s. Since that time, science has revealed much about the workings of the natural universe. With this knowledge arose society-changing technologies. For transportation, we've gone from horses to trains to cars to airplanes to spaceships. With the development of agriculture and advances in medicine, the human population has grown from about 500 million to over 8 billion. The materials we've developed provide for everything from skyscrapers to computers to the medicines that protect our health and prolong our lives. For better or for worse, science has had and will continue to have a huge impact on society.

We are now awakening to the fact that the resources of our planet are limited. Should we pay no attention and consume and pollute as we wish? Should we abandon the understandings of nature we've gained through science and merely hope for the best? Or should we embrace these understandings and move toward living on this planet in a sustainable fashion? Are the decisions we now and will soon face better met with ignorance or with knowledge?



< Figure 1.10
"Wow, Great Uncle Paul! Are we like unhatched chicks, ready to poke through our shells to a new environment and new understanding of our place in the universe?"