Chances are you are taking this course in physics because someone told you to take it, and it may not be clear to you *why* you should be taking it. One good reason for taking a physics course is that, first and foremost, physics provides a fundamental understanding of the world. Furthermore, whether you are majoring in psychology, engineering, biology, physics, or something else, this course offers you an opportunity to sharpen your reasoning skills. Knowing physics means becoming a better problem solver (and I mean *real* problems, not textbook problems that have already been solved), and becoming a better problem solver is empowering: It allows you to step into unknown territory with more confidence. Before we embark on this exciting journey, let's map out the territory we are going to explore so that you know where we are going.

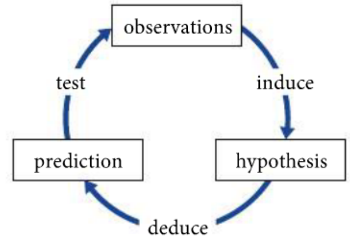
1.1 The scientific method

Physics, from the Greek word for "nature," is commonly defined as the study of matter and motion. Physics is about discovering the wonderfully simple unifying patterns that underlie absolutely everything that happens around us, from the scale of subatomic particles, to the microscopic world of DNA molecules and cells, to the cosmic scale of stars, galaxies, and planets. Physics deals with atoms and molecules; gases, solids, and liquids; everyday objects, and black holes. Physics explores motion, light, and sound; the creation and annihilation of matter; evaporation and melting; electricity and magnetism. Physics is all around you: in the Sun that provides your daylight, in the structure of your bones, in your computer, in the motion of a ball you throw. In a sense, then, physics is the study of all there is in the universe. Indeed, biology, engineering, chemistry, astronomy, geology, and so many other disciplines you might name all use the principles of physics.

The many remarkable scientific accomplishments of ancient civilizations that survive to this day testify to the fact that curiosity about the world is part of human nature. Physics evolved from *natural philosophy*—a body of knowledge accumulated in ancient times in an attempt to explain the behavior of the universe through philosophical speculation—and became a distinct discipline during the scientific revolution that began in the 16th century. One of the main changes that occurred in that century was the development of the **scientific method,** an iterative process for going from observations to validated theories.

In its simplest form, the scientific method works as follows (Figure 1.1): A researcher makes a number of observations concerning either something happening in the natural world (a volcano erupting, for instance) or something happening during a laboratory experiment (a dropped brick and a dropped Styrofoam peanut travel to the floor at different speeds). These observations then lead the researcher to formulate a **hypothesis,** which is a tentative explanation of the observed phenomenon. The hypothesis is used to predict the outcome of some related natural occurrence (how a similarly shaped mountain near the erupting volcano will behave) or related laboratory experiment (what happens when a book and a sheet of paper are dropped at the same time). If the predictions prove inaccurate, the hypothesis must be modified. If the predictions prove accurate in test after test, the hypothesis is elevated to the status of either a **law** or a **theory.**

Figure 1.1 The scientific method is an iterative process in which a hypothesis, which is inferred from observations, is used to make a prediction, which is then tested by making new observations.



A law tells us *what* happens under certain circumstances. Laws are usually expressed in the form of relationships between observable quantities. A theory tells us *why* something happens and explains phenomena in terms of more basic processes and relationships. A scientific theory is not a mere conjecture or speculation. It is a thoroughly tested explanation of a natural phenomenon, one that is capable of making predictions that can be verified by experiment. The constant testing and retesting are what make the scientific method such a powerful tool for investigating the universe: The results obtained must be repeatable and verifiable by others.

Exercise 1.1 Hypothesis or not?

Which of the following statements are hypotheses? (*a*) Heavier objects fall to Earth faster than lighter ones. (*b*) The planet Mars is inhabited by invisible beings that are able to elude any type of observation. (*c*) Distant planets harbor forms of life. (*d*) Handling toads causes warts.

SOLUTION (*a*), (*c*), and (*d*). A hypothesis must be experimentally verifiable. (*a*) I can verify this statement by dropping a heavy object and a lighter one at the same instant and observing which one hits the ground first. (*b*) This statement asserts that the beings on Mars cannot be observed, which precludes any experimental verification and means this statement is not a valid hypothesis. (*c*) Although we humans currently have no means of exploring or closely observing distant planets, the statement is in principle testable. (*d*) Even though we know this statement is false, it *is* verifiable and therefore is a hypothesis.

Because of the constant reevaluation demanded by the scientific method, science is not a stale collection of facts but rather a living and changing body of knowledge. More important, any theory or law *always* remains tentative, and the testing never ends. In other words, it is not possible to

CONCEPTS