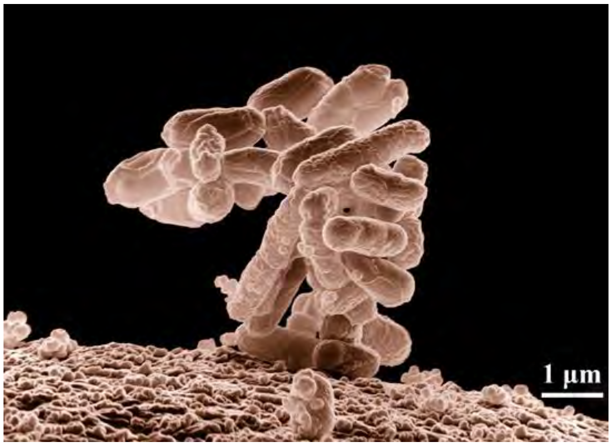

Figure 1.19 In this micrograph, the bacterium is visualized using a scanning electron microscope and digital colorization. (credit: Eric Erbe; digital colorization by Christopher Pooley, USDA-ARS / Concepts of Biology OpenStax)

The Nature of Science

Science can be defined as knowledge about the natural world. It is a precise way of learning about the world and is largely responsible for the technological revolutions that have taken place. There are, however, areas of knowledge and human experience that the methods of science cannot be applied to. These include such things as answering moral questions, aesthetic questions, or spiritual questions. Science cannot investigate these areas because they are outside the realm of natural phenomena and cannot be observed and measured.

The **scientific method** is a method of research with defined steps that includes careful observation and experiments. The steps of the scientific method will be examined in greater detail later, but one of the most important aspects of the scientific method is the testing of hypotheses. A **hypothesis** (plural hypotheses) is a suggested explanation for a scientific question or an observation, which can be tested. A good hypothesis should be clear and concise. It should also lead to **predictions,** which are statements that describe what should happen if the hypothesis is correct and supported. A hypothesis should also be **falsifiable**, meaning the hypothesis can be incorrect if data that is collected refutes the hypothesis. An example of a hypothesis that is not falsifiable is, "Chicago is the most beautiful city in the world." There is no experiment that might show this statement is false. Once a hypothesis has undergone rigorous testing, and large amounts of data have been collected by multiple research groups who have drawn the same or similar conclusions, the hypothesis is referred to as a theory. In science, a **theory** is a confirmed explanation for a set of observations or phenomena that has been thoroughly tested and supported with substantial amounts of data. In this way, it is very different than a hypothesis. However, like hypotheses, theories are testable, falsifiable, and lead to predictions. A scientific theory is the foundation of scientific knowledge. Also, in many scientific disciplines (less so in biology), there are scientific laws, often expressed in mathematical formulas. Scientific laws describe how elements of nature will behave under certain specific conditions. There is not a strict process that a hypothesis must go through to become a theory or a law. Hypotheses are the day-to-day material that scientists work with, and they are developed within the context of theories. Laws are concise descriptions of parts of the world that are amenable to formulaic or mathematical description.

Natural Sciences

Those fields of science related to the physical world and its phenomena and processes are considered natural sciences. There is no complete agreement when it comes to defining what the natural sciences include (Figure 1.20). For some experts, the natural sciences are astronomy, biology, chemistry, earth science, and physics. Other scholars choose to divide natural sciences into life sciences and physical sciences. Life sciences study living things and include biology. Physical sciences study nonliving matter and include astronomy, physics, and chemistry. Some disciplines, such as biophysics and biochemistry, build on two sciences, and are interdisciplinary.

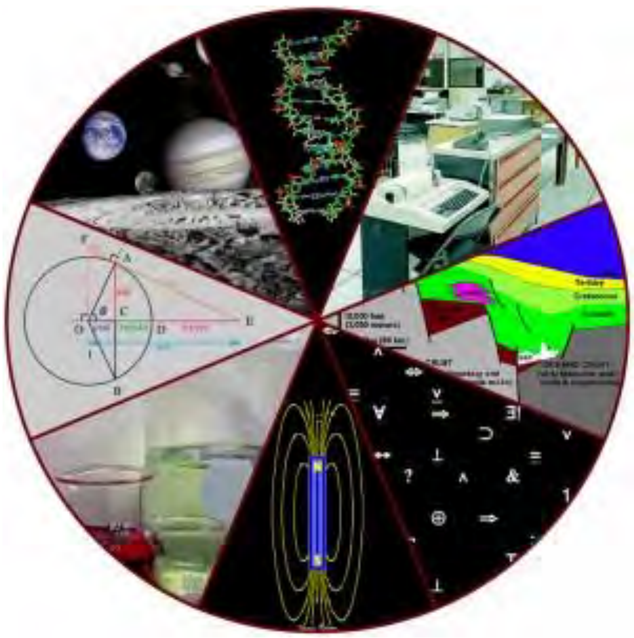

Figure 1.20 Some fields of science include astronomy, biology, computer science, geology, logic, physics, chemistry, and mathematics. (credit: "Image Editor" Flickr / Concepts of Biology OpenStax)

Scientific Inquiry

One thing is common to all forms of science: the ultimate goal is to obtain knowledge. Curiosity and inquiry are the driving forces for the development of science. Scientists seek to understand the world and the way it operates. Two methods of logical thinking are used: inductive reasoning and deductive reasoning.

Inductive reasoning is a form of logical thinking that uses related observations to arrive at a general conclusion. This type of reasoning is common in descriptive science. A life scientist such as a biologist makes observations and records them. These data can be **qualitative**, which is descriptive or categorical, or they can be **quantitative**, consisting of numbers. From many observations, the scientist can infer conclusions, inductions, based on evidence. Inductive reasoning involves formulating generalizations inferred from careful observation and the analysis of a large amount of data. Brain studies often work this way. Many brains are observed while people are doing a task. The part of the brain that lights up, indicating activity, is then demonstrated to be the part controlling the response to that task.

Deductive reasoning or deduction is the type of logic used in hypothesis-based science. In deductive reasoning, the pattern of thinking moves in the opposite direction as compared to inductive reasoning. **Deductive reasoning** is a form of logical thinking that uses a general principle or law to predict specific results. From those general principles, a scientist can extrapolate and predict the specific results that would be valid so long as the general principles are valid. For example, a prediction would be that if the climate is becoming warmer in a region, the distribution of plants and animals should change. Comparisons have been made between distributions in the past and the present, and the many changes that have been found are consistent with a warming climate. Finding the change in distribution is evidence that the climate change conclusion is valid.

Both types of logical thinking are related to the two main pathways of scientific study: descriptive science and hypothesis-based science. Descriptive or discovery science aims to observe, explore, and discover. Hypothesis-based science begins with a specific question or problem and a potential answer or solution that can be tested. The boundary between these two forms of study is often blurred because most scientific endeavors combine both approaches. Observations lead to questions, questions lead to forming a hypothesis as a possible answer to those questions, and then the hypothesis is tested. Thus, descriptive science and hypothesis-based science are in continuous dialogue.

Hypothesis Testing

Biologists study the living world by posing questions about it and seeking science-based responses. This approach is common to other sciences as well and is often referred to as the scientific method.

The scientific method typically starts with an observation that leads to a question. Observations can be made using any or all of an individual's general senses such as touch and/or their special senses such as vision. (Students planning to take Anatomy and Physiology will learn more about your different senses.) Let’s think about a scenario that starts with an observation and apply the scientific method to address the observation. One Monday morning, a student arrives in class and quickly discovers that the classroom is too warm. That is an observation that also describes a problem: the classroom is too warm. The student then asks a question: “Why is the classroom so arm?”

Recall that a hypothesis is a testable explanation to the question. Several hypotheses may be proposed. For example, one hypothesis might be, “The classroom is warm because no one turned on the air conditioning.” But there could be other responses to the question, and therefore other hypotheses may be proposed. A second hypothesis might be, “The classroom is warm because there is a power failure, and so the air conditioning doesn’t work.”

Once a hypothesis has been formulated, a prediction can be made. A prediction is similar to a hypothesis, but it typically has the format “If . . . then . . . .” For example, the prediction for the first hypothesis might be, “*If* the student turns on the air conditioning, *then* the classroom will no longer be too warm.”