1.1 Science and Technology

What Is Science?

Science is a way of learning about the natural world by making observations, asking questions, proposing answers, and then testing those answers. Scientists describe nature by using the knowledge they gain through experience. This knowledge, known as **empirical knowledge**, can be thought of as knowledge gained by the five senses (touch, smell, taste, vision, and hearing), and by tools and devices that extend the senses (e.g., microscopes, telescopes, sensors). Empirical knowledge (Figure 1) includes the knowledge gained by scientists in the process of scientific inquiry, as well as the knowledge gained by Aboriginal peoples, often referred to as Traditional Ecological Knowledge and Wisdom. **Traditional Ecological Knowledge and Wisdom (TEKW)** is the knowledge, experiences, and wisdom gained over many generations of close interaction with the living and non-living components of the environment.

Empirical knowledge is generally incomplete. It could be argued that complete knowledge is not achievable. We seldom know everything there is to know about a natural phenomenon, but we continue to learn as scientific inquiry progresses. Sometimes what we think we know is incorrect, so empirical knowledge is continuously being updated as new information becomes available.

STUDY TIP

Study smarter, not harder. As you read each section, look for the study tips in the margins of your student book. They will offer you practical tips on effective study and exam techniques.

(a)

(b)

Figure 1 Empirical knowledge that helps us understand the natural world comes from different sources. (a) A botanist uses scientific inquiry to learn more about plant life. (b) A Lillooet band member lands a sockeye salmon from the Fraser River using traditional Lillooet fishing techniques.

STUDY TIP

You'll notice that Chapter 1 includes many new terms. To get a head start on your studying, make vocabulary cards. On one side of the card, write the word (e.g., discovery). On the other side, write a brief definition (e.g., an observation no one has made before).

Science is often thought of as facts, laws, and theories. While this is partially true, science is much more than that. The main goal of science is to understand the natural world, and the result of this understanding is knowledge in the form of facts, laws, and theories. For example, we know that Earth revolves around the Sun. This is accepted as a scientific fact. It came from repeated observation and analysis of the Sun and the night sky. Science also refers to the processes that are used to gather knowledge about the natural world and organize it. Science, then, is both our present understanding of the natural world and the processes that lead to this understanding.

An observation of nature that no one has made before, or that no one has made in the same way before, is called a **discovery**. Scientists make discoveries by looking for patterns and regularities in nature (natural phenomena). These regularities are sometimes called laws of nature and, in some cases, laws are described mathematically. For example, Isaac Newton discovered a mathematical relationship between the force, F, and the acceleration, a, of an object whose mass is m. In general, if the force used to push (or pull) an object increases, its acceleration increases as well. This law is commonly known as Newton's Second Law of Motion, and it can be expressed mathematically as $F = ma$. The scientific community accepts Newton's Second Law of Motion because it is simple, understandable, and supported by empirical evidence.

Unlike a scientific law (which is determined by careful observation), a scientific theory, or scientific explanation, is the product of creativity and inventiveness. Scientists use scientific theories to try and explain natural phenomena whose root causes are not easily identifiable. To develop a theory, a scientist may first suggest an untested explanation, or hypothesis. For example, many years ago people noticed that certain diseases are contagious, but there was no satisfactory explanation for this observation. With the invention of the compound microscope in the seventeenth century, scientists discovered micro-organisms and hypothesized that some of these micro-organisms (called germs) might be the cause of infectious diseases. After conducting many experiments and gathering evidence to support this hypothesis, the transfer of germs was accepted as an explanation for the spread of infections, and the germ theory was developed.

LEARNING TIP

Set a purpose for your reading. As you read this section, read to answer the question posed in the heading. Share your answer with a partner.

Scientific theories, such as the germ theory, are tentative explanations. This means that they are subject to change when new scientific evidence indicates that a change is required. For example, the germ theory was changed once viruses were discovered. Viruses are non-living entities that are much smaller than bacteria and other micro-organisms, so that they cannot be seen under a typical light microscope. When viruses were discovered, many scientists hypothesized that they too could cause infectious diseases. After obtaining experimental evidence to support this hypothesis, the germ theory was revised to include viruses as potential causes of infections.

Classification of Science

There are many ways of classifying the activities that we refer to as science. Science tries to understand nature, which really means the whole universe. Science is usually divided into three main branches—life science, physical science, and Earth and space science (Figure 2).

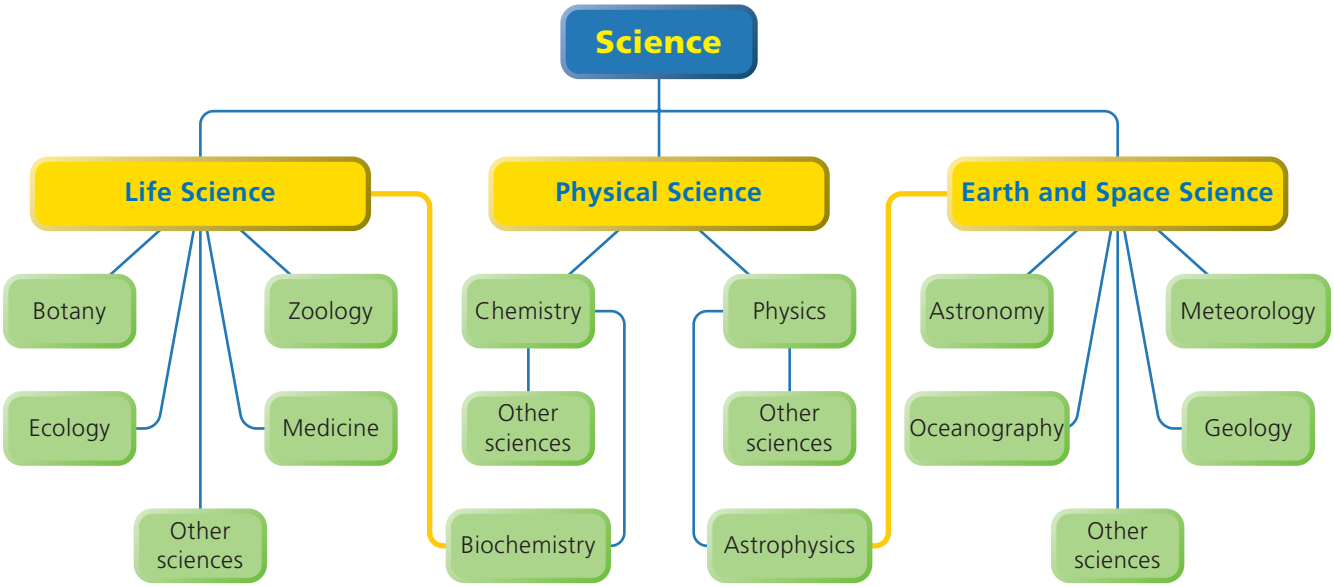


Figure 2 There are many separate branches of science, but there are also many interactions among the various branches.

Life science is the study of living things and is often referred to as biology. It has many branches, including botany, the study of plants; zoology, the study of animals; and ecology, the study of the natural environment. Medicine and agricultural science are also branches of life science because they deal with the study of living things.

Physical science has two main branches—chemistry and physics. Chemistry is the study of matter and its changes, and physics is the study of forces and energy.

The branches of Earth and space science include geology, the study of the physical nature and history of Earth; meteorology, the study of the atmosphere and weather; astronomy, the study of celestial objects (galaxies, stars, planets, comets, etc.); and oceanography, the study of oceans and ocean life.

This classification of the branches of science appears very simple and neat, like the drawers in which nuts and bolts are arranged in a hardware store. In reality, science is not quite so simple. As science progresses over time, the branches of science expand and collaborate so that they no longer fit into the neat categories. For example, chemists began to study chemicals (such as DNA) that make up living things. This resulted in the science of biochemistry, the study of the matter of living things. It is both a life science and a physical science. In the same way, geophysics, the study of forces that affect Earth, is both an Earth science and a physical science.

LEARNING TIP

Check in with your learning. Discuss with a partner how "what science is" has evolved dramatically over the last hundred years.

TRY THIS: Identifying Sciences

Skills Focus: analyzing, classifying, inferring, communicating

The branches of science and their interactions are too numerous to identify in this text. However, you can get an idea of the nature of a branch of science from its name.

1. Examine the following list of science branches and classify them as either a life, physical, and/or Earth and space science. (Some branches can fit into more than one category.)

A. For each of the sciences, analyze the name and write a one-sentence description that you think matches the science.

B. Compare your definitions with those of your classmates, and then, using a dictionary or the Internet, find a formal definition for each of the sciences. Compare your definitions with the formal definition.

aerobiology
analytical chemistry
astrobiology
astrochemistry
biophysics
electrostatics
environmental science
fluid dynamics
genetics
geochemistry
marine biology
materials science
microbiology
mineralogy
optics
sedimentology

What Is Technology?

Technology is the process by which humans develop ways to satisfy some of their needs and wants. People use skills and resources to develop processes and equipment that help them solve problems in everyday life. Professionals such as technologists, technicians, and engineers develop technologies through invention and innovation.

The term **invention** describes the creative development of a new device or process that helps people meet their needs or satisfy their wants. For example, people have invented beds to satisfy their need for comfortable rest. They have invented microwave ovens, refrigerators, freezers, and the canning process to meet their needs for cooking and preserving food. They have invented radios, televisions, telephones, computers, and the Internet to help them satisfy their desire for efficient communication. In general, inventions can be described as newly found solutions to problems in everyday life.

Some technological devices combine existing inventions in new ways to solve new problems. The modification of an existing technology to serve a new purpose is known as **innovation**. For example, the use of circular devices to facilitate movement originated in prehistoric times, and over many years has developed into the wheel. The invention of the wheel has led to its use in many innovative ways. It is now used in gears and pulleys; on trains, bicycles, carts, and automobiles; and as the rotating base of dials on a radio. You have probably innovated many times in your everyday life. If you have ever used a piece of chewing gum to stick a note on a wall, you've innovated!

Did You KNOW?

Technology at Home

Liquid Paper was invented by Bette Nesmith-Graham in 1951, while working as a typist. Using her kitchen and garage as a laboratory, she developed a paint-turpentine mixture she called "Mistakes Out" to hide her typing mistakes at the office. She later changed the name of her product to Liquid Paper and sold it out of her home for 17 years. In 1979, the Gillette Company purchased Liquid Paper for US$47.5 million.

TRY THIS: New Uses for Old Technology

Skills Focus: observing, analyzing, communicating

Many everyday devices are used for purposes other than those they were designed for. For example, a butter knife can be used as a screwdriver, a plaster knife, a scraper, or as an artist's knife.

1. In a small group, select one of the items from the following list and think "outside the box" to come up with at least 15 alternative uses for the object. Follow the brainstorming guidelines provided by your teacher.

cardboard box	bath towel	nail
spoon	sheet of paper	spoon
candle	craft stick	toothpick
fan	marble	old newspaper
pencil	drinking straw	2 L pop bottle
paper clip	rubber band	roll of cash register paper

2. After 10 min of brainstorming, refine your list of possible uses by eliminating duplication or combining ideas.
3. As a group, share the list of alternative uses for your object with the class.

A. Explain what "thinking outside the box" means to you.

B. Did you learn new ideas from other groups? What does this tell you about the nature of invention and innovation?

C. Suggest things you can do to improve your skill of looking at old ideas in new ways.

In 1959, Canadian inventor Joseph-Armand Bombardier combined a number of existing technologies to produce the world's first recreational snowmobile, called the Ski-Doo (Figure 3). While unique in its overall design, the snowmobile used a number of existing technologies in innovative ways. A pair of modified skies allowed the front end of the machine to slide over the snow, while handlebars (like those on a motorcycle) were used for steering. A rubber track, like that used for farm and military equipment, gripped the snow and allowed the vehicle to move forward. These features have been modified and improved over the years; notice the features of modern snowmobiles, shown in Figure 4.

Figure 3 Early models of the Ski-Doo snowmobile incorporated several innovations to produce a unique vehicle.

Science and Technology Work Together

Science and technology are very different activities, but we often hear about them together. This is because they are highly interrelated and often go hand in hand. Scientists rely on technologies to further their research and gain an understanding of natural phenomena. Technologists and engineers look for ways to use this knowledge for practical applications. For example, scientists want to know how certain kinds of materials, called superconductors, conduct electricity with almost no loss in energy. Technologists and engineers focus on how that knowledge can be applied in the design and construction of high-speed computers.

In some cases, technological inventions and innovations occur before the scientific principles are known. Alessandro Volta invented the battery in 1800, well before theories about current electricity were developed. Sometimes scientific discoveries are made because of technological inventions. For example, the invention of glass lenses led to the development

Figure 4 While the basic design is the same as the original vehicle, new features and materials have vastly improved the modern snowmobile.

of telescopes, which allowed astronomers to observe and learn more about our solar system and the universe. The telescope, in turn, led to more accurate astronomical observations and measurements. This contributed to the change from an Earth-centred scientific model of the universe to a Sun-centred model. You can see how science and technology often support each other.

Sometimes, technological inventions follow scientific discoveries. For example, the television was invented after scientists had created theories to explain the structure of the atom, and understood electrons, current electricity, and electromagnetism. The relationship between science and technology is mutually beneficial; scientific discoveries lead to technological advances, which lead to further scientific discoveries, and so on (Table 1).

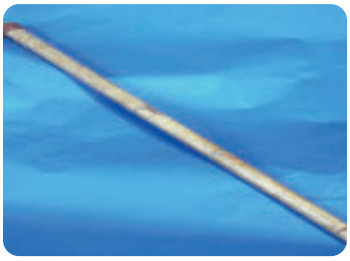
Table 1 Examples of the Science–Technology Relationship

Science	Technology	Example
Physicists explain how forces act on an object under a load.	Structural engineers and technologists design buildings, bridges, roads, and tunnels that can support specific loads.	suspension bridge 
Physiologists discover the biochemical reactions that keep organisms alive and healthy.	Technologists design life-support systems for astronauts and space stations.	astronaut suit 
Plant biologists learn how roots absorb nutrients from water and soil.	Engineers and technologists design hydroponic systems for efficient crop production in areas with poor soil.	hydroponic system 

Did You KNOW?

The First Telescope

Contrary to popular belief, the first telescope was not invented by Galileo. A spectacle maker, Hans Lipperhey, invented the telescope when he put a convex and a concave lens together to produce threefold (3×) magnification. In 1609, Galileo learned of the invention and immediately saw its potential. He began experimenting with different lens curvatures and arrangements, and achieved a magnification of 9×—an invaluable asset to scientific and military endeavours.



To learn more about the early development of the telescope, visit

www.science.nelson.com GO

In most cases, scientists do not foresee or predict how their discoveries will be used in the development of technologies. For example, in 1831, Michael Faraday found that if you push a magnet toward a wire, a current is generated (or induced) in the wire. When Faraday demonstrated this phenomenon to his peers, someone asked, "All this is very well, but of what use is this discovery?" He replied, "It is a newborn child. Of what use is a newborn child?" He had discovered electromagnetic induction. This discovery led to the development of electric motors and generators, and made possible all of the devices that use or produce electricity. But that was not the reason Faraday discovered electromagnetic induction; he was simply trying to better understand nature. He could never have imagined how dependent on electricity society would eventually become.

The development of plastics is a good example showing the relationship between science and technology. In 1928, X-ray technology enabled confirmation of the theory that polymers are long chains of chemical units (molecules). This theory had been proposed by German chemist Herman Staudinger in 1920, but was not accepted until the technology to observe and confirm his idea was available. With this new understanding of polymers and their molecular structure, technologists began producing a new class of polymers called "plastics." This included materials such as nylon, Teflon, polystyrene (e.g., Styrofoam), and acrylic—all of which are widely used in science and society today.

Medical researchers use biodegradable polymers to deliver drugs in situations where the drugs cannot be administered orally or by injection. To achieve this, the drugs are embedded within a polymer structure, and are gradually released as the polymer breaks down (Figure 5).

Many scientific discoveries and technological inventions occur by chance, or serendipity. **Serendipity** is the act of discovering or inventing something useful by accident. One famous example of serendipity in science is the discovery of background radiation. While tuning a powerful antenna used for astronomy experiments, American physicists Arno Penzias and Robert Wilson noticed a constant, low-level noise coming from the antenna. The noise was being formed by an invisible type of light energy (radiation), which was detected regardless of what direction the antenna was facing. Soon Penzias and Wilson realized that the radiation was present everywhere. They also discovered that they had stumbled on the best evidence to date supporting the Big Bang theory—a theory that explains how the entire universe was created in a huge explosion of matter and energy.

Serendipity can also occur in technology, as shown by the invention of Velcro (Figure 6). In 1948, George de Mestral, a Swiss engineer, returned from a walk in the woods and noticed that some burs were stuck to his cloth jacket and pants. He examined a bur under his microscope and noticed that it contained little green hooks that clung to fabric and fur. De Mestral immediately recognized the potential for a practical new fastener. After eight years of experimentation and development, he created Velcro, the first synthetic hook-and-loop fastener.

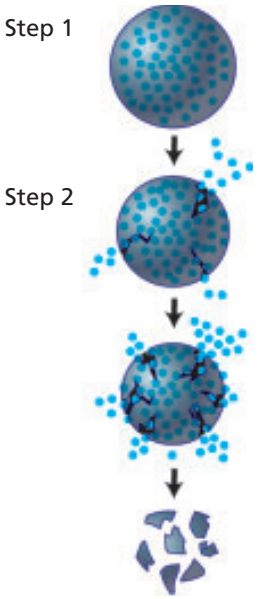
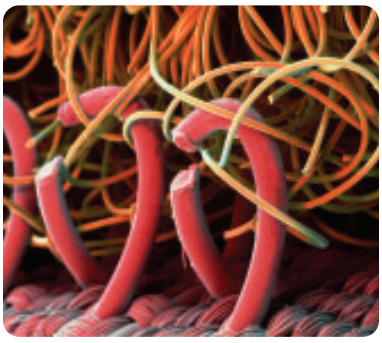


Figure 5 Drugs are embedded in biodegradable polymer particles (step 1). As the particles biodegrade, or break down, the drugs are released (step 2).

(a)



(b)

Figure 6 Technologies are often modelled after structures in nature. (a) The hooks on a bur were the model for the design of Velcro. (b) The magnified view of Velcro shows how the hooks get caught in the loops when the two strips are pressed together.