Section 1.2

Objectives

- **Compare and contrast** independent and dependent variables.
- **Compare and contrast** experimentation and investigation.
- **Identify** the differences between mass and weight.
- **Explain** what scientific notation is and how it is used.

Review Vocabulary

experiment: procedure performed in a controlled setting to test a hypothesis and collect precise data

New Vocabulary

scientific methods
hypothesis
independent variable
dependent variable
control
Le Systeme International d'Unites (SI)
scientific notation

Methods of Scientists

Scientists use scientific methods to structure their experiments and investigations.

Real-World Reading Link Have you ever seen a distinct rock formation and wondered how it formed? Have you ever wondered why the soil near your home might be different from the soil in your schoolyard? If so, you have already begun to think like a scientist. Scientists often ask questions and make observations to begin their investigations.

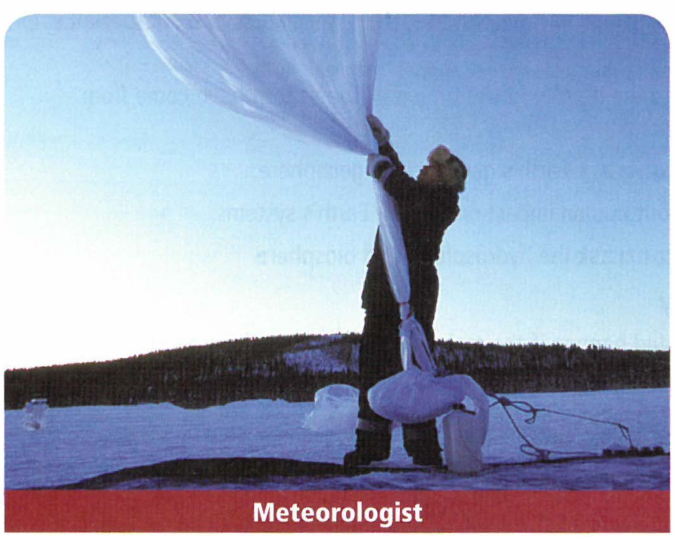
The Nature of Scientific Investigations

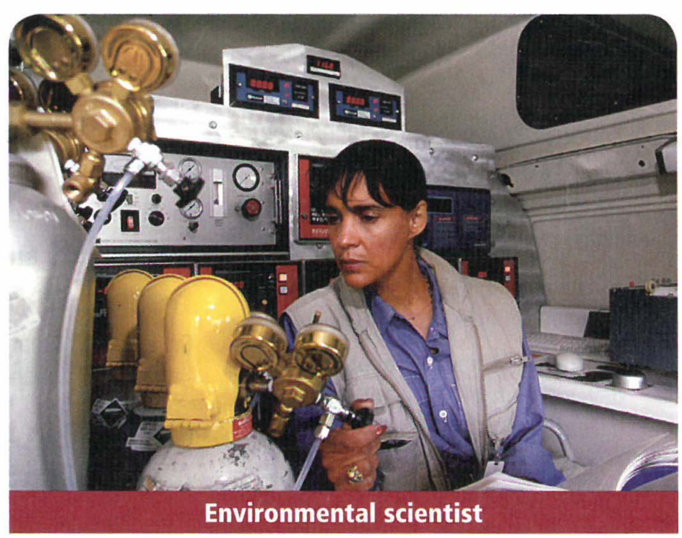
Scientists work in many different places to gather data. Some work in the field, and some work in a lab, as shown in **Figure 1.5.** No matter where they work, they all use similar methods to gather data and communicate information. These methods are referred to as scientific methods. As illustrated in **Figure 1.6,** **scientific methods** are a series of problem-solving procedures that help scientists conduct experiments.

Whatever problem a scientist chooses to pursue, he or she must gather background information on the topic. Once the problem is defined and the background research is complete, a hypothesis is made. A **hypothesis** is a testable explanation of a situation that can be supported or disproved by careful procedures.

It is important to note that scientific methods are not rigid, step-by-step outlines to solve problems. Scientists can take many different approaches to performing a scientific investigation. In many scientific investigations, for example, scientists form a new hypothesis after observing unexpected results. A researcher might modify a procedure, or change the control mechanism. And a natural phenomenon might change the direction of the investigation.

Figure 1.5 Whether a meteorologist gathers storm data in the field or an environmental scientist analyzes microbial growth in a lab, scientific methods provide an approach to problem-solving and investigation.

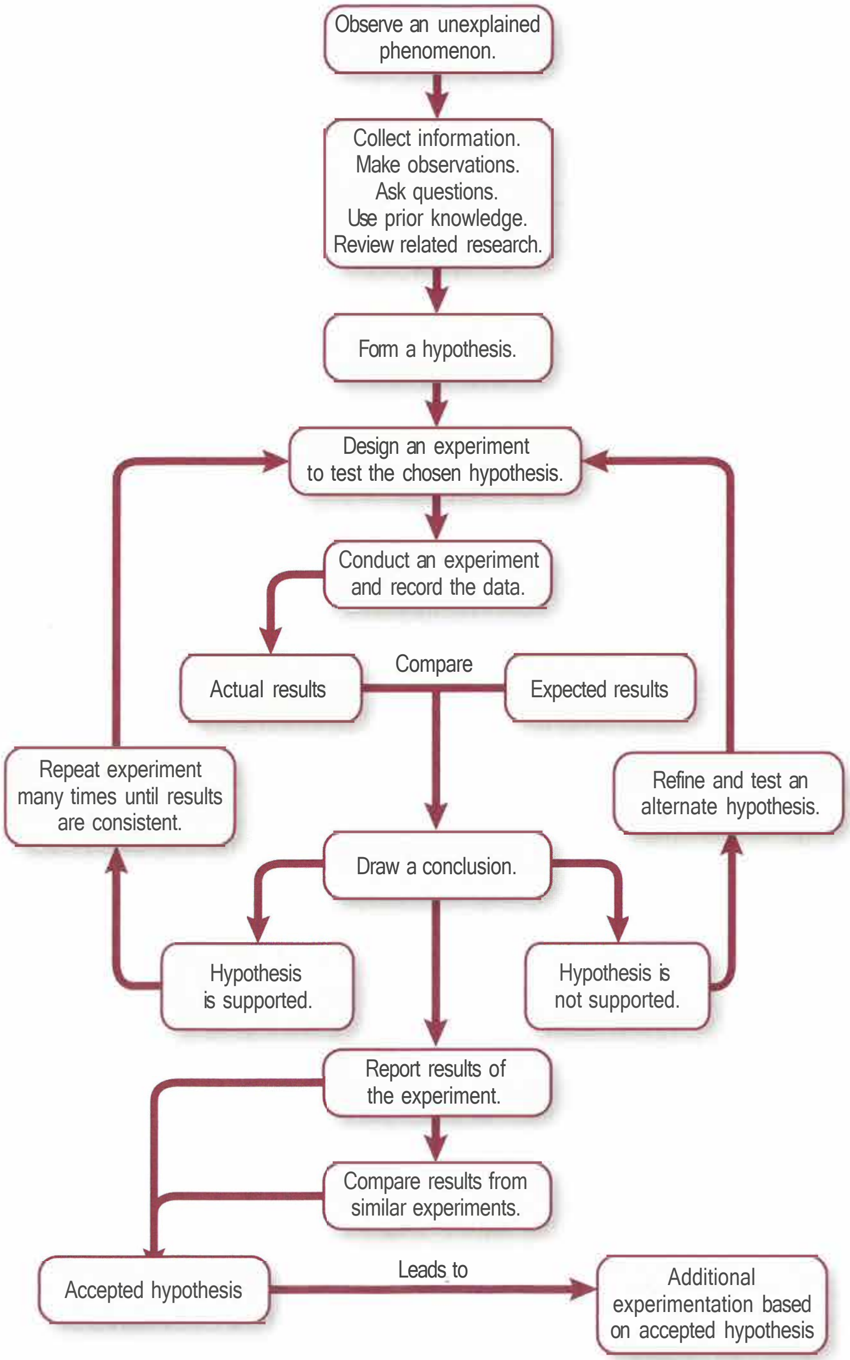




Visualizing Scientific Methods

NATIONAL GEOGRAPHIC

Figure 1.6 Scientific methods are used by scientists to help organize and plan their experiments and investigations. The flow chart below outlines some of the methods commonly used by scientists.



Concepts In Motion To explore more about scientific methods, visit glencoe.com.

Earth Science Online

MiniLab

Determine the Relationship Between Variables

How do the rates of heat absorption and release vary between soil and water? Different substances absorb and release heat at different rates.

Procedure

1. Read and complete the lab safety form.
2. Read the procedure and create a data table to record your temperature results.
3. Pour **soil** into **one container** until it is half full. Pour **water** into a **second container** until it is half full. Leave a **third container** empty.
4. Place **one thermometer** in the soil so that the bulb is barely covered. Use **masking tape** to secure **another thermometer** about 1 cm above the top of the soil.
5. Repeat Step 4 for the container with water.
6. In the empty container, place the bulb of one thermometer halfway into the cup and secure it with masking tape. Use the tape to secure another thermometer bulb about 2 cm higher than the first thermometer bulb.
7. Put the containers on a **sunny windowsill.** Record the temperature shown on each thermometer. Write these values in a table. Record temperature readings every 5 min for 30 min.
8. Remove the containers from the windowsill and continue to record the temperature on each thermometer every 5 min for 30 min.

Analysis

1. **Determine** Which substance absorbed heat more quickly? Which substance lost heat more quickly?
2. **Specify** What was your independent variable? What was your dependent variable?
3. **Identify** your control.

Experimentation An experiment is classified as an organized procedure that involves making observations and measurements to test a hypothesis. Collecting good qualitative and quantitative data is vital to the success of an experiment.

Imagine a scientist is conducting an experiment on the effects of acid on the weathering of rocks. In this experiment, there are three different samples of identical rock pieces. The scientist does not add anything to the first sample. To the second and third samples, the scientist adds two different strengths of acid. The scientist then makes observations (qualitative data) and records measurements (quantitative data) based on the results of the experiment.

A scientific experiment usually tests only one changeable factor, called a variable, at a time. The **independent variable** in an experiment is the factor that is changed by the experimenter. In the experiment described above, the independent variable was the strength of the acid.

A **dependent variable** is a factor that is affected by changes in the independent variable. In the experiment described above, the dependent variable was the effect of the acid on the rock samples.

Constants are factors that do not change during an experiment. Keeping certain variables constant is important to an experiment. Placing the same amount of acid on each rock tested, or using the same procedure for measurement, are two examples. A **control** is used in an experiment to show that the results of an experiment are a result of the condition being tested. The control for the experiment described above was the rock that did not have anything added to it. You will experiment with variables in the MiniLab on this page and in many other activities throughout this textbook.

Reading Check **Explain** the difference between a dependent and an independent variable.

Investigation Earth scientists cannot always control the aspects of an experiment. It would be impossible to control the rainfall or temperature when studying the effects of a new fertilizer on thousands of acres of corn. When this is the case, scientists refer to their research as an investigation. An investigation involves observation and collecting data but does not include a control. Investigations can often lead scientists to design future experiments based on the observations they have made.

Safety Many of the experiments and investigations in this book will require that you handle various materials and equipment. When conducting any scientific investigation, it is important to use all materials and equipment only as instructed. Refer to the *Reference Handbook* for additional safety information and a table of safety symbols.

Analysis and conclusions New ideas in science are carefully examined by the scientist who made the initial discovery and by other scientists in the same field. Processes, data, and conclusions must be examined to eliminate influence by expectations or beliefs, which is called bias. During a scientific experiment, all data are carefully recorded. Once an experiment is complete, graphs, tables, and charts are commonly used to display data. These data are then analyzed so that a conclusion can be drawn. Many times, a conclusion does not support the original hypothesis. In such a case, the hypothesis must be reevaluated and further research must be conducted.

VOCABULARY

ACADEMIC VOCABULARY

Bias
to influence in a particular, typically unfair, direction; prejudice
Their choice of teammates showed a bias toward their friends.

Measurement

Scientific investigations often involve making measurements. A measurement includes both a number and a unit of measure. Scientific investigations use a standard system of units called **Le Systeme International d'Unites** (SI), which is a modern version of the metric system. SI is based on a decimal system that uses the number 10 as the base unit. See **Table 1.2** for information on SI and metric units of measure commonly used in science.

Length The standard SI unit to measure length is the meter (m). The distance from a doorknob to the floor is about 1 m. The meter is divided into 100 equal parts called centimeters (cm). Thus, 1 cm is 1/100 of 1 m. One millimeter (mm) is smaller than 1 cm. There are 10 mm in 1 cm. Longer distances are measured in kilometers (km). There are 1000 m in 1 km.

Table 1.2 Measurement and Units

Measurement	SI and Metric Units Commonly Used in Science
Length	millimeter (mm), centimeter (cm), meter (m), kilometer (km)
Mass	gram (g), kilogram (kg), metric ton
Area	square meter (m^2), square centimeter (cm^2)*
Volume	cubic meter (m^3)*, milliliter (ml), liter (L) #
Density	grams per cubic centimeter (g/cm^3)*, grams per milliliter (g/mL)#, kilograms per cubic meter (kg/m^3)*
Time	second (s), hour (h)#
Temperature	kelvin (K)

* units derived from SI units • commonly used metric units

Mass The amount of matter in an object is called mass. Mass depends on the number and types of atoms that make up the object. The mass of an object is the same no matter where the object is located in the universe. The SI unit of mass is the kilogram (kg).

Weight Weight is a measure of the gravitational force on an object. Weight is typically measured with some type of scale. Unlike mass, weight varies with location. For example, the weight of an astronaut while on the Moon is about one-sixth the astronaut's weight on Earth. This is because the gravitational force exerted by the Moon on the astronaut is one-sixth the force exerted by Earth on the astronaut. Weight is a force, and the SI unit for force is the newton (N). A 2-L bottle of soft drink with a mass of 2 kg weighs about 20 N on Earth.

Reading Check **Compare** mass and weight.

Area and volume Some measurements, such as area, require a combination of SI units. Area is the amount of surface included within a set of boundaries and is expressed in square units of length, such as square meters (m^2).

The amount of space occupied by an object is the object's volume. The SI units for volume, like those for area, are derived from the SI units used to measure length. The basic SI unit of volume for a solid object is the cubic meter (m^3). Measurements for fluid volumes are usually made in milliliters (mL) or liters (L). Liters and milliliters are metric units that are commonly used to measure liquid volumes. Volume can also be expressed in cubic centimeters (cm^3)- 1 cm^3 equals 1 mL.

Figure 1.7
Major Events in Earth Science
Many discoveries during the twentieth and early twenty-first centuries revolutionized our understanding of Earth and its systems.

1900 — 1920 — 1940 — 1960

1907 Scientists begin using radioactive decay to determine that Earth is billions of years old. This method will be used to develop the first accurate geological time scale.

1913 French physicists discover the ozone layer in Earth's upper atmosphere and propose that it protects Earth from the Sun's ultraviolet radiation.

1925 Cecilia Payne's analysis of the spectra of stars reveals that hydrogen and helium are the most abundant elements in the universe.

1936 Inge Lehmann proposes that Earth's center consists of a solid inner core and a liquid outer core based on her studies of seismic waves.

1955 Louis Essen invents a highly accurate atomic clock that tracks radiation emitted and absorbed by cesium atoms.

Density The measure of the amount of matter that occupies a given space is density. Density is calculated by dividing the mass of the matter by its volume. Density is often expressed in grams per cubic centimeter (g/cm^3), grams per milliliter (g/mL), or kilograms per cubic meter (kg/m^3).

Time The interval between two events is time. The SI unit of time is the second. In the activities in this book, you will generally measure time in seconds or minutes. Time is usually measured with a watch or clock. The atomic clock provides the most precise measure of time currently known. Known as UTC, Coordinated Universal Time is based on the atomic clock element cesium-133 and is adapted to the astronomical demarcation of day and night. See **Figure 1.7** for more information on the invention of the atomic clock and other advances in Earth science.

Temperature A measure of the average kinetic energy of the particles that make up a material is called temperature. A mass made up of particles that vibrate quickly generally has a higher temperature than a mass whose particles vibrate more slowly. Temperature is measured in degrees with a thermometer. Scientists often measure temperature using the Celsius (°C) scale. On the Celsius scale, a comfortable room temperature is about 21 °C, and the normal temperature of the human body is about 37°C.

The SI unit for temperature is the kelvin (K). The coldest possible temperature, absolute zero, was established as OK or -273 °C. Since both temperature units are the same size, the difference between the two scales (273) is used to convert from one scale to another. For example, the temperature of the human body is 37°C, to which you would add 273 to get 310 K.

VOCABULARY

ACADEMIC VOCABULARY

Interval
space of time between two events or states
The interval for pendulum swings was three seconds.

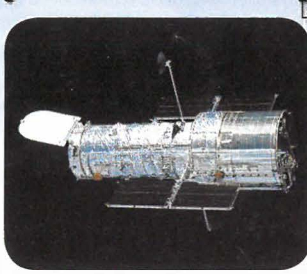
1962 Harry Hess's seafloor spreading hypothesis, along with the discoveries made about the ocean floor, lays the foundation for plate tectonic theory.

1979-1980 *Magsat,* a NASA satellite, takes the first global measurement of Earth's magnetic field.

2004 A sediment core retrieved from the ocean floor discloses 55 million years of Earth's atmospheric and climatic history. The sample reveals that the north pole once had a warm climate.

1970 1980 1990 2000 2010

1970 George Carruthers' ultraviolet camera and spectrograph, placed on the Moon's surface, analyzes pollutants in Earth's atmosphere and detects interstellar hydrogen.



1990 The *Hubble Space Telescope* goes into orbit, exploring Earth's solar system, measuring the expansion of the universe, and providing evidence of black holes.

concepts In MOtio"

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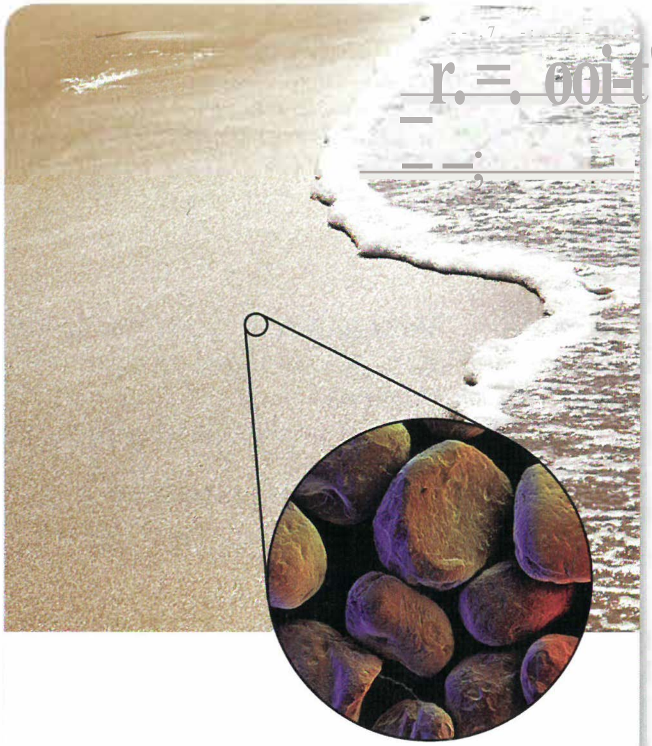

■ **Figure 1.8** On a 5-km-long beach, such as the one shown above, there might be 8 x 10^{15} grains of sand. The average size of a grain of sand is 0.5 mm.

Scientific Notation

In many branches of science, some numbers are very small, while others are very large. To express these numbers conveniently, scientists use a type of shorthand called **scientific notation,** in which a number is expressed as a value between 1 and 10 multiplied by a power of 10. The power of 10 is the number of places the decimal point must be shifted so that only a single digit remains to the left of the decimal point.

If the decimal point must be shifted to the left, the exponent of 10 is positive. **Figure 1.8** shows a beach covered in sand. The number of grains of sand on Earth has been estimated to be approximately 4,000,000,000,000,000,000,000. In scientific notation, this number is written as 4×10^{21}.

In astronomy, masses and distances are usually so large that writing out the numbers would be cumbersome. For example, the mass of Earth at 5,974,200,000,000,000,000,000,000 kg would be written as 5.9742×10^{24} kg in scientific notation.

If the decimal point in a number must be shifted to the right, the exponent of 10 is negative. The diameter of an atom in meters, for example, which is approximately 0.0000000001 m, is written as 1×10^{-10} m.

Section 1.2 Assessment

Section Summary

- Scientists work in many ways to gather data.
- A good scientific experiment includes an independent variable, dependent variable, and control. An investigation, however, does not include a control.
- Graphs, tables, and charts are three common ways to communicate data from an experiment.
- SI, a modern version of the metric system, is a standard form of measurement that all scientists can use.
- To express very large or very small numbers, scientists use scientific notation.

Understand Main Ideas

1. MAIN Idea **Explain** why scientific methods are important and why there is not one established way to conduct an investigation.
2. **Compare and contrast** the purpose of a control, an independent variable, and a dependent variable in an experiment.
3. **Calculate** Express 0.00049386 in scientific notation.
4. **Calculate** Convert the temperature 49°C to kelvin.
5. **Compare and contrast** volume and density.

Think Critically

6. **Construct** a plan to test the absorption of three different kinds of paper towels, including a control, dependent variable, and independent variable.
7. **Explain** which is more useful when comparing mass and weight on different planets.

Math in Earth Science

8. If you have 20 ml of water, how many cubic centimeters of water do you have?