What Is Geology?

Earth is a large and complicated place. How do scientists study it? The answer is that no one scientist studies all parts of Earth. Instead, different scientists study different parts of the planet. The study of different parts of Earth is called Earth science. There are many different branches, or types, of Earth science.

Geology is one branch of Earth science. Geology is the study of the origin, history, and structure of Earth. It also includes the study of the processes that shape Earth. A scientist who studies geology is called a geologist.

In most cases, a geologist studies one specific part of the Earth. For example, volcanologists study volcanoes. Seismologists study earthquakes. Paleontologists study the history of life on Earth.

What Is Oceanography?

Another branch of Earth science is oceanography. Oceanography is the study of the sea. Scientists who study oceanography are called oceanographers.

Like geologists, oceanographers may focus on certain areas of oceanography. For example, biological oceanographers study the living things in the oceans. Chemical oceanographers study the amounts of different chemicals in ocean water.
**What Is Meteorology?**

Meteorology is a branch of Earth science that deals with Earth's atmosphere, especially weather and climate. Scientists who study meteorology are called meteorologists.

Many meteorologists try to forecast, or predict, the weather. In most cases, weather forecasts help to make our lives more comfortable. Sometimes, meteorologists can help save people's lives by predicting severe weather, such as hurricanes and tornadoes. These predictions can warn people to leave an area before severe weather strikes.

**What Is Astronomy?**

Astronomy is the study of the universe. Astronomers are scientists who study stars, asteroids, planets, and other objects in space.

Most objects in space are very far away. Therefore, astronomers depend on technology to help them study these objects. For example, astronomers may use telescopes to study distant stars and planets.

You may wonder why astronomy is a branch of Earth science if astronomers study objects far from the Earth. The reason is that many astronomers use information about other planets and stars to learn more about the Earth. For example, some astronomers study ancient stars in the universe. The information they gather can help them to predict how changes in our sun may affect the Earth.
What Are Some Other Branches of Earth Science?

Geology, oceanography, meteorology, and astronomy are the four main branches of Earth science. However, there are many other branches of Earth science.

ENVIRONMENTAL SCIENCE

Environmental science is the study of how humans interact with the environment. Environmental scientists help people learn ways to preserve the environment and to use resources wisely.

ECOLOGY

Ecology is the study of relationships between living things and their environments. Ecologists study communities of organisms and their environments to better understand how organisms behave. Ecologists work in many fields, including agriculture and forestry.

GEOCHEMISTRY

Geochemistry combines the studies of geology and chemistry. Geochemists study the chemicals that make up Earth materials such as rocks, minerals, and soil. They can use this information to learn how the Earth materials formed. Geochemists may also study the effects of human-made chemicals on the environment.

GEOGRAPHY AND CARTOGRAPHY

Geography is the study of the surface features of the Earth, such as continents, rivers, and mountains. Many geographers work in cartography, or map-making. Cartographers use information from photographs and computers to make maps. They may also study the ways that areas change with time.
Section 1 Review

SECTION VOCABULARY

| astronomy | the scientific study of the universe |
| geology | the scientific study of the origin, history, and structure of Earth and the processes that shape Earth |
| meteorology | the scientific study of Earth’s atmosphere, especially in relation to weather and climate |
| oceanography | the scientific study of the ocean, including the properties and movements of ocean water, the characteristics of the ocean floor, and the organisms that live in the ocean |

1. List What are the four major branches of Earth science?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

2. Infer What kind of Earth scientist would most likely study thunderstorms? Explain your answer.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3. Explain Why is astronomy a branch of Earth science?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

4. Compare How is environmental science different from ecology?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

5. Explain Why do astronomers depend on technology?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

6. Define What is geography?

________________________________________________________________________
After you read this section, you should be able to answer these questions:

- What are the steps used in scientific methods?
- How is a hypothesis tested?
- Why do scientists share their findings with others?

How Do Scientists Learn About the World?

Imagine you are standing in a thick forest. Suddenly, you hear a booming noise, and you feel the ground shake. You notice a creature’s head looming over the treetops. The creature’s head is so high that its neck must be 20 m long! Then, the whole animal comes into view. Now you know why the ground is shaking. The giant animal is *Seismosaurus hallorum*, the “earthquake lizard.”

This description of *Seismosaurus hallorum* is not just from someone’s imagination. Since the 1800s, scientists have gathered information about dinosaurs and their environment. Using this knowledge, scientists can infer what dinosaurs may have been like hundreds of millions of years ago.

How do scientists piece all the information together? How do they know if they have discovered a new species of dinosaur? Asking these questions is the first step in using scientific methods to learn more about the world.

*Seismosaurus hallorum* was one of the largest dinosaurs that ever lived.

Math Focus

1. Make Comparisons

When a *Seismosaurus* held its head up as high as it could, it could have been 25 m tall. What fraction of *Seismosaurus’s* height is your height? Give your answer as a decimal.
Scientific Methods in Earth Science

What Are Scientific Methods?

Scientific methods are a series of steps that scientists use to answer questions and to solve problems. Although each question is different, scientists can use the same methods to find answers.

Scientific methods have several steps. Scientists may use all of the steps or just some of them. They may even repeat some of the steps.

The goal of scientific methods is to come up with reliable answers and solutions. These answers and solutions must be able to stand up to the testing of other scientists.

Why Is It Important to Ask a Question?

Asking a question helps scientists focus on the most important things they want to learn. The question helps to guide the research that the scientist does.

David D. Gillette is a scientist who studies fossils. In 1979, he began to study some fossil bones from New Mexico. He knew they came from a dinosaur, but he did not know which kind.

Gillette began his study by asking, “What kind of dinosaur did these bones come from?” We will use a table to follow Gillette as he tried to answer his question using scientific methods.

<table>
<thead>
<tr>
<th>Step in scientific methods</th>
<th>How did David Gillette apply this step?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking questions</td>
<td>He wondered what kind of dinosaur the bones came from.</td>
</tr>
</tbody>
</table>
How Do Scientists Form a Hypothesis?

When scientists want to investigate a question, they form a hypothesis. A hypothesis (plural, hypotheses) is a possible answer to a question. It is sometimes called an educated guess.

The hypothesis is a scientist's best answer to the question. However, a scientist can't just assume that a hypothesis is the correct answer. The scientists must test the hypothesis to see if it is true.

From his observations and knowledge about dinosaurs, Gillette formed a hypothesis about the bones. He thought that the bones came from a kind of dinosaur that had not been discovered yet. To test his hypothesis, Gillette had to do a lot of research.

<table>
<thead>
<tr>
<th>Step in scientific methods</th>
<th>How did David Gillette apply this step?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forming a hypothesis</td>
<td></td>
</tr>
</tbody>
</table>

How Do Scientists Test a Hypothesis?

To see if an idea can be proven scientifically, scientists must test the hypothesis. They do this by gathering data. Data (singular, datum) are pieces of information gathered through observation or experimentation. Scientists use data to learn if their hypotheses are correct.

**TESTING WITH EXPERIMENTS**

To test a hypothesis, a scientist may perform a controlled experiment. A controlled experiment tests only one factor, or variable, at a time. No other variables change. By changing only one variable, scientists can see the results of changing just one thing.

For example, suppose a scientist does an experiment to learn the temperature that a rock melts at. The scientist uses several samples of the same kind of rock. She heats each sample to a different temperature and records whether the rock melts. The type of rock does not change, but the temperature does. Therefore, temperature is the variable.
KEEPING ACCURATE RECORDS

During experiments, scientists must keep accurate records of everything that they do and observe. This includes failed attempts, too. Keeping detailed records helps scientists to show that their results are accurate. Accurate records can also help other scientists to repeat an experiment.

TESTING WITHOUT EXPERIMENTS

Sometimes, it is not possible to do a controlled experiment. In such cases, scientists depend on observation to test their hypotheses. By observing nature, scientists can collect large amounts of data. If the data support a hypothesis, the hypothesis is probably correct.

To test his hypothesis, Gillette took hundreds of measurements of bones. He also visited museums and talked with other scientists.

To test his hypothesis, Gillette took hundreds of measurements of the sizes and shapes of the bones.

How Do Scientists Analyze Results?

When scientists finish collecting data, they must analyze the results. Analyzing results helps scientists explain their observations. Their explanations are based on the evidence they collect.

To arrange their data, scientists often make tables and graphs. Gillette organized his data in a table that compared the sizes and shapes of his dinosaur bones. He compared his measurements to measurements of bones from known dinosaurs. When he analyzed his results, he found that the mystery dinosaur’s bones did not match the bones of any known dinosaur.
Scientific Methods in Earth Science continued

<table>
<thead>
<tr>
<th>Step in scientific methods</th>
<th>How did David Gillette apply this step?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyzing results</td>
<td></td>
</tr>
</tbody>
</table>

What Are Conclusions?

After analyzing results, a scientist must decide if the results agree with, or support, the hypotheses. This is called *drawing conclusions*. Finding out that a hypothesis is not true can be as valuable as finding out that a hypothesis is true.

Sometimes, the results do not support the hypothesis. When this happens, scientists may repeat the investigation to check for mistakes. Scientists may repeat experiments hundreds of times. Another option is to ask another question and make a new hypothesis.

From all his work, Gillette concluded that the bones found in New Mexico were from an unknown dinosaur. From his data, he learned that the new dinosaur was about 35 m long and had a mass of 30 to 70 metric tons. The dinosaur definitely fits the name Gillette gave it—*Seismosaurus hallorum*, or the “earthquake lizard.”

<table>
<thead>
<tr>
<th>Step in scientific methods</th>
<th>How did David Gillette apply this step?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing Conclusions</td>
<td></td>
</tr>
</tbody>
</table>

Why Do Scientists Share Their Findings?

After finishing a study, scientists share their results with others. They write reports and give presentations. They can also put their results on the Internet.

Sharing information gives other scientists the chance to repeat the experiments for themselves. If other scientists get different results, more studies must be done to find out if the differences are important.

In many cases, the results of an investigation are reviewed year after year as new evidence is found. In the case of *Seismosaurus*, the debate still continues. Some scientists think that *Seismosaurus* is a new genus of dinosaur. Other scientists think that it belongs to the genus *Diplodocus*. As scientists gather more data on the fossil bones, they may change their conclusions.

TAKE A LOOK
10. Identify In the table, fill in the way that David Gillette analyzed his results.

Critical Thinking
11. Infer How can finding out that a hypothesis is not true be useful for a scientist?

TAKE A LOOK
12. Identify In the table, fill in David Gillette’s conclusions about his dinosaur bones.

READING CHECK
13. Describe Why is it important for scientists to share their results?
Section 2 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th>hypothesis</th>
<th>a testable idea or explanation that leads to scientific investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>scientific methods</td>
<td>a series of steps followed to solve problems</td>
</tr>
</tbody>
</table>

1. **Describe**  How can a scientist test a hypothesis if it is not possible to do a controlled experiment?

2. **Explain**  Why is it important for scientists to ask questions?

3. **Apply Procedures**  You observe that your tongue sticks to a very cold ice pop when you lick it. You ask yourself, “Why does my tongue stick to the ice pop?” Make a hypothesis about why your tongue sticks to the ice pop.

4. **Identify**  How could you share the results of an experiment with the rest of your class? Give three ways.

5. **Infer**  Why might a scientist need to repeat a step in scientific methods?
What Are Models?

Why do scientists use crash-test dummies to learn how safe cars are? By using crash-test dummies, scientists can learn how to make cars safer without putting real people in danger. A crash-test dummy is a model of a person. A *model* is something scientists use to represent an object or event in order to make it easier to study.

Scientists use models to study things that are very small, like atoms, or things that are very large, like Earth. Some scientists use models to predict things that haven’t happened yet, or to study events that happened long ago. Some models, like crash-test dummies, allow scientists to study events without affecting or harming the things they are studying.

Models are very useful for scientists. However, you cannot learn everything by studying a model, because models are not exactly like the objects they represent.

**PHYSICAL MODELS**

*Physical models* are models that you can see or touch. Many physical models look like the things they represent. Other physical models may look different from the things they represent. For example, a map is a physical model of Earth. However, a flat map looks very different from the round Earth!

A globe is a physical model of the Earth.

**READING CHECK**

1. **Identify** Give two reasons scientists use models.

2. **Define** What is a physical model?
MATHEMATICAL MODELS

A mathematical model is made up of data and mathematical equations. A mathematical equation shows how data are related to each other. Some mathematical models are simple. They can help you calculate things such as how far a car will travel in an hour. Other models are more complicated. These models can contain a lot of data related by complicated equations.

Meteorologists often use mathematical models called climate models to help them study the Earth’s climate. Most climate models include large amounts of data. The data may be measurements of temperatures or amounts of rainfall.

Climate models use equations to represent different parts of Earth’s climate. For example, some equations represent the way that ocean water moves. Others represent the way that the amount of carbon dioxide in the air changes with time.

You may wonder how scientists can use models that contain so many data and equations. Scientists use computers to help them process these complicated models. Because computers can deal with large amounts of data, they can solve many mathematical problems at once. Computers can do complicated calculations more quickly and accurately than people can.

Climate models, like most mathematical models, do not make exact predictions. Instead, they estimate what may happen. Scientists and lawmakers can use the estimates to help them plan for the future.

READING CHECK

3. Define What is a mathematical model?

4. Explain Why do scientists use computers to process many mathematical models?

TAKE A LOOK

5. Identify What are two kinds of data that may be part of a climate model?

The climate model in this picture was produced by a computer. The computer combined huge amounts of data and equations into the climate model. Without computers, scientists would not be able to use complicated models like this.
CONCEPTUAL MODELS

A conceptual model is a diagram, drawing, or spoken description of how something works or is put together. Conceptual models may be made of many different hypotheses. Each hypothesis is supported by scientific methods. For example, the conceptual model below shows how mercury moves through the environment. Scientists have used scientific methods to learn how mercury from coal burning can affect humans.

Mercury released into the air from burning coal

Air

Soil

Water

Crops

Fish

People

Health effects from mercury poisoning

Why Do Scientists Use Models?

Scientists often use models to help explain or support scientific laws and theories. A scientific law is a statement or equation that can predict what will happen in certain situations. A scientific theory is an explanation that connects and explains many observations.

<table>
<thead>
<tr>
<th>Name</th>
<th>What it is</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific theory</td>
<td>an explanation that connects and explains evidence and observations</td>
</tr>
<tr>
<td>Scientific law</td>
<td>a statement or equation that predicts what will happen in a certain situation</td>
</tr>
</tbody>
</table>

Scientific theories are based on observations. They explain all of the observations about a topic that scientists have at a certain time. However, scientists are always discovering new information. This new information may show that a theory is incorrect. When this happens, the theory must be changed so that it explains the new information. Sometimes, scientists have to develop a totally new theory to explain the new and old information.
Section 3 Review

SECTION VOCABULARY

<table>
<thead>
<tr>
<th><strong>model</strong></th>
<th>a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>theory</strong></td>
<td>a system of ideas that explains many related observations and is supported by a large body of evidence acquired through scientific investigation</td>
</tr>
</tbody>
</table>

1. Identify  How are scientific theories related to observations and evidence?

2. Explain  Why do scientists use models?

3. Describe  What effect can new observations have on a scientific theory?

4. List  Give one example of a physical model and one example of a mathematical model.

5. Explain  Why do scientists use computers to process climate models?

6. Infer  A globe is a model of the Earth. Give two ways a globe is like the Earth and two ways a globe is not like the Earth.
How Do Scientists Measure Objects?

Scientists make many measurements as they collect data. It is important for scientists to be able to share their data with other scientists. Therefore, scientists use units of measurement that are known to all other scientists. One system of measurement that most scientists use is called the International System of Units.

THE INTERNATIONAL SYSTEM OF UNITS

The International System of Units, or SI, is a system of measurement that scientists use when they collect data. This system of measurement has two benefits. First, scientists around the world can easily share and compare their data because all measurements are made in the same units. Second, SI units are based on the number 10. This makes it easy to change from one unit to another.

It is important to learn the SI units that are used for different types of measurements. You will use SI units when you make measurements in the science lab.

LENGTH

Length is a measure of how long an object is. The SI unit for length is the meter (m). Centimeters (cm) and millimeters (mm) are used to measure small distances. There are 100 cm in 1 m. There are 1,000 mm in 1 m. Kilometers (km) are used to measure long distances. There are 1,000 m in 1 km.

<table>
<thead>
<tr>
<th>Length</th>
<th>SI Unit: meter (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilometer (km)</td>
<td>1 km = 1,000 m</td>
</tr>
<tr>
<td>centimeter (cm)</td>
<td>1 cm = 0.01 m</td>
</tr>
<tr>
<td>millimeter (mm)</td>
<td>1 mm = 0.001 m</td>
</tr>
</tbody>
</table>

STUDY TIP

Compare As you read this section, make a table comparing how scientists measure length, area, mass, volume, and temperature. Include the units of measurement that scientists use.

Critical Thinking

1. Predict Consequences
What could happen if all scientists used different systems of measurement to record their data?

TAKE A LOOK

2. Identify What is the SI unit for length?
**AREA**

*Area* is the measure of how much surface an object has. For most objects, area is calculated by multiplying two lengths together. For example, you can find the area of a rectangle by multiplying its length by its width. Area is measured in square units, like square meters (m²) or square centimeters (cm²). There are 10,000 cm² in 1 m².

<table>
<thead>
<tr>
<th>Area</th>
<th>square meter (m²)</th>
<th>square centimeter (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 cm² = 0.0001 m²</td>
</tr>
</tbody>
</table>

**VOLUME**

*Volume* is the amount of space an object takes up. There are two main ways to find the volume of an object. You can find the volume of a box-shaped object by multiplying its length, width, and height together. To find the volume of other objects, measure the volume of water that they push out of a container.

The volume of a solid object is often measured in cubic units. For example, very large objects can be measured in cubic meters (m³). Smaller objects can be measured in cubic centimeters (cm³). There are 1 million cm³ in 1 m³.

The volume of a liquid is usually given in units of liters (L) or milliliters (mL). One mL has the same volume as one cm³. There are 1,000 mL in 1 L. There are 1,000 L in one m³.

<table>
<thead>
<tr>
<th>Volume</th>
<th>cubic meter (m³)</th>
<th>cubic centimeter (cm³)</th>
<th>liter (L)</th>
<th>milliliter (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 cm³ = 0.000001 m³</td>
<td>1 L = 0.001 m³</td>
<td>1 mL = 1 cm³</td>
</tr>
</tbody>
</table>

**MASS**

*Mass* is a measure of the amount of matter in an object. The SI unit for mass is the kilogram (kg). The masses of large objects, such as people, are measured using kilograms. The masses of smaller objects, such as apples, are measured in grams (g) or milligrams (mg). There are 1,000 g in 1 kg. There are 1 million mg in 1 kg.

<table>
<thead>
<tr>
<th>Mass</th>
<th>SI Unit: kilogram (kg)</th>
<th>gram (g)</th>
<th>milligram (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 g = 0.001 kg</td>
<td>1 mg = 0.000001 kg</td>
<td></td>
</tr>
</tbody>
</table>
TEMPERATURE

Temperature is a measure of how hot or cold an object is. The SI unit for temperature is the Kelvin (K). However, most people are more familiar with other units of temperature. For example, most people in the United States measure temperatures using degrees Fahrenheit (°F). Scientists often measure temperatures using degrees Celsius (°C).

<table>
<thead>
<tr>
<th>Temperature</th>
<th>SI Unit: Kelvin (K)</th>
<th>0°C = 273 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>degrees Celsius (°C)</td>
<td>100°C = 373 K</td>
<td></td>
</tr>
</tbody>
</table>

DENSITY

Density is a measure of how closely packed the particles in a substance are. You can calculate an object’s density by dividing the object’s mass by its volume. There is no SI unit for density. Scientists usually use the units grams per milliliter (g/mL) or grams per cubic centimeter (g/cm³) to measure density.

<table>
<thead>
<tr>
<th>Density</th>
<th>grams per milliliter (g/mL)</th>
<th>grams per cubic centimeter (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 g/mL</td>
<td>1 g/cm³</td>
</tr>
</tbody>
</table>

How Can You Stay Safe in Science Class?

Science can be exciting, but it can also be dangerous. In order to stay safe while you are doing a science activity, you should always follow your teacher’s directions. Read and follow the lab directions carefully, and do not take “shortcuts.” Pay attention to safety symbols, such as the ones in the figure below. If you do not understand something that you see in a science activity, ask your teacher for help.

Safety Symbols

Eye protection
Clothing protection
Hand safety
Heating safety
Electrical safety
Chemical safety
Animal safety
Sharp object
Plant safety

READING CHECK

7. Define What is temperature?

8. Investigate Look around your classroom for safety symbols like the ones in the figure. Give two examples of places where safety symbols are found in your classroom.
**Section 4 Review**

**SECTION VOCABULARY**

<table>
<thead>
<tr>
<th>area</th>
<th>a measure of the size of a surface or a region</th>
</tr>
</thead>
<tbody>
<tr>
<td>density</td>
<td>the ratio of the mass of a substance to the volume of the substance</td>
</tr>
<tr>
<td>mass</td>
<td>a measure of the amount of matter in an object</td>
</tr>
<tr>
<td>meter</td>
<td>the basic unit of length in the SI (symbol, m)</td>
</tr>
<tr>
<td>temperature</td>
<td>a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particles in an object</td>
</tr>
<tr>
<td>volume</td>
<td>a measure of the size of a body or region in three-dimensional space</td>
</tr>
</tbody>
</table>

1. **Identify**  What are two units that scientists use to measure temperature?

2. **List**  What are two benefits of using the SI?

3. **Describe**  How can you find the volume of a shoebox?

4. **Identify**  Fill in the blank spaces in the table below. Give at least two examples for each measurement.

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Examples of units used for this measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>length</td>
<td></td>
</tr>
<tr>
<td>area</td>
<td></td>
</tr>
<tr>
<td>mass</td>
<td></td>
</tr>
<tr>
<td>volume</td>
<td></td>
</tr>
</tbody>
</table>

5. **Apply Ideas**  An object has a mass of 10 g and a volume of 5 cm³. What is its density?

4. **Explain**  Give three ways that you can stay safe while doing a science activity.