MS What is Earth Science?

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CHAPTER 1 MS What is Earth Science?

CHAPTER OUTLINE

Earth Science is all about the Earth: its land, its water, its atmosphere. It's about Earth's resources and about the impacts human activities are having on all of those things: the land, water, and atmosphere. Earth Science is even about the vastness that surrounds the planet: the solar system, galaxy, and universe. So can we say Earth Science is about everything? Well, not really, but it is a science that encompasses an awful lot.

Note the word science in that last sentence. Earth Science is a science, or maybe it's made up of a lot of sciences. But what is science? Most people think of science as a bunch of knowledge. And it is. But science is also a way of knowing things. It's different from other ways of knowing because it is based on a method that relies on observations and data. Science can't say how many angels can dance on the end of a pin because that question can't be tested. In fact, science can't even say if there are such things as angels for the same reason. For something to be science, it must be testable. And scientists are the people who do those tests.

1.1 The Nature of Science

Lesson Objectives

- Why is it important to ask questions?
- How can you use the steps of the scientific method to answer questions?
- How do scientists make models?
- What steps should you take to be safe while you are doing science?

Vocabulary

- control
- dependent variable
- hypothesis
- independent variable
- physical model
- theory

Introduction

Sometime in your life you've asked a question about the world around you. Probably you've asked a lot of questions over the years. The best way to answer questions about the natural world is by using science. Scientists ask questions every day, and then use a set of steps to answer those questions. The steps are known as the scientific method. By following the scientific method, scientists come up with the best information about the natural world. As a scientist, you need to do experiments to find out about the world. You also need to wonder, observe, talk, and think. Everything we learn helps us to ask new and better questions.

Scientific Method

The scientific method is a set of steps that help us to answer questions. When we use logical steps and control the number of things that can be changed, we get better answers. As we test our ideas, we may come up with more questions. The basic sequence of steps followed in the scientific method is illustrated in **Figure** 1.1.

Questions

Asking a question is one really good way to begin to learn about the natural world. You might have seen something that makes you curious. You might want to know what to change to produce a better result. Let's say a farmer is having an erosion problem. She wants to keep more soil on her farm. The farmer learns that a farming method

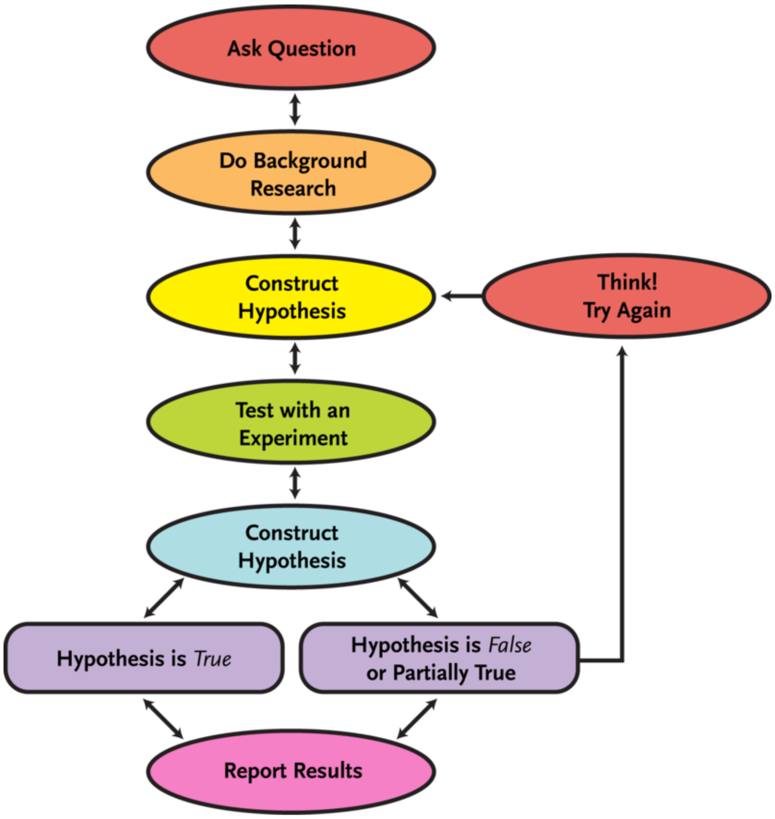

FIGURE 1.1
The Scientific Method.

called "no-till farming" allows farmers to plant seeds without plowing the land. She wonders if planting seeds without plowing will reduce the erosion problem and help keep more soil on her farmland. Her question is this: "Will using the no-till method of farming help me to lose less soil on my farm?" (**Figure** 1.2).

FIGURE 1.2
Soil is often lost from ground that has been plowed.

Research

Before she begins, the farmer needs to learn more about this farming method. She can look up information in books and magazines in the library. She may also search the Internet. A good way for her to learn is to talk to people who have tried this way of farming. She can use all of this information to figure out how she is going to test her question about no-till farming. Farming machines are shown in the **Figure** 1.3.

FIGURE 1.3
Rather than breaking up soil like in this picture, the farmer could try no-till farming methods.

Hypothesis

After doing the research, the farmer will try to answer the question. She might think, "If I don't plow my fields, I will lose less soil than if I do plow the fields. Plowing disrupts the soil and breaks up roots that help hold soil in place." This answer to her question is a **hypothesis**. A hypothesis is a reasonable explanation. A hypothesis can be tested. It may be the right answer, it may be a wrong answer, but it must be testable. Once she has a hypothesis, the next step is to do experiments to test the hypothesis. A hypothesis can be proved or disproved by testing. If a hypothesis is repeatedly tested and shown to be true, then scientists call it a **theory**.

Experiment

When we design experiments, we choose just one thing to change. The thing we change is called the **independent variable**. In the example, the farmer chooses two fields and then changes only one thing between them. She changes how she plows her fields. One field will be tilled and one will not. Everything else will be the same on both fields: the type of crop she grows, the amount of water and fertilizer that she uses, and the slope of the fields she plants on. The fields should be facing the same direction to get about the same amount of sunlight. These are the experimental **controls**. If the farmer only changes how she plows her fields, she can see the impact of the one change. After the experiment is complete, scientists then measure the result. The farmer measures how much soil is lost from each field. This is the **dependent variable**. How much soil is lost from each field "depends" on the plowing method.

Data and Experimental Error

During an experiment, a scientist collects data. The data might be measurements, like the farmer is taking in **Figure** 1.4. The scientist should record the data in a notebook or onto a computer. The data is kept in charts that are clearly labeled. Labeling helps the scientist to know what each number represents. A scientist may also write descriptions of what happened during the experiment. At the end of the experiment the scientist studies the data. The scientist may create a graph or drawing to show the data. If the scientist can picture the data the results may be easier to understand. Then it is easier to draw logical conclusions.

FIGURE 1.4
A pair of farmers take careful measurements in the field.

Even if the scientist is really careful it is possible to make a mistake. One kind of mistake is with the equipment. For example, an electronic balance may always measure one gram high. To fix this, the balance should be adjusted. If it can't be adjusted, each measurement should be corrected. A mistake can come if a measurement is hard to make. For example, the scientist may stop a stopwatch too soon or too late. To fix this, the scientist should run the experiment many times and make many measurements. The average of the measurements will be the accurate answer. Sometimes the result from one experiment is very different from the other results. If one data point is really different, it may be thrown out. It is likely a mistake was made in that experiment.

Conclusions

The scientist must next form a conclusion. The scientist must study all of the data. What statement best explains the data? Did the experiment prove the hypothesis? Sometimes an experiment shows that a hypothesis is correct. Other times the data disproves the hypothesis. Sometimes it's not possible to tell. If there is no conclusion, the scientist may test the hypothesis again. This time he will use some different experiments. No matter what the experiment shows the scientist has learned something. Even a disproved hypothesis can lead to new questions.

The farmer grows crops on the two fields for a season. She finds that 2.2 times as much soil was lost on the plowed field as compared to the unplowed field. She concludes that her hypothesis was correct. The farmer also notices some other differences in the two plots. The plants in the no-till plots are taller. The soil moisture seems higher. She decides to repeat the experiment. This time she will measure soil moisture, plant growth, and the total amount of water the plants consume. From now on she will use no-till methods of farming. She will also research other factors that may reduce soil erosion.

Theory

When scientists have the data and conclusions, they write a paper. They publish their paper in a scientific journal. A journal is a magazine for the scientists who are interested in a certain field. Before the paper is printed, other scientists look at it to try to find mistakes. They see if the conclusions follow from the data. This is called peer review. If the paper is sound it is printed in the journal.

Other papers are published on the same topic in the journal. The evidence for or against a hypothesis is discussed by many scientists. Sometimes a hypothesis is repeatedly shown to be true and never shown to be false. The hypothesis then becomes a theory. Sometimes people say they have a ”theory” when what they have is a hypothesis.

In science, a theory has been repeatedly shown to be true. A theory is supported by many observations. However, a theory may be disproved if conflicting data is discovered. Many important theories have been shown to be true by many observations and experiments and are extremely unlikely to be disproved. These include the theory of plate tectonics and the theory of evolution.

Scientific Models

Scientists use models to help them understand and explain ideas. Models explain objects or systems in a more simple way. Models often only show only a part of a system. The real situation is more complicated. Models help scientists to make predictions about complex systems. Some models are something that you can see or touch. Other types of models use an idea or numbers. Each type is useful in certain ways.

Scientists create models with computers. Computers can handle enormous amounts of data. This can more accurately represent the real situation. For example, Earth’s climate depends on an enormous number of factors. Climate models can predict how climate will change as certain gases are added to the atmosphere. To test how good a model is, scientists might start a test run at a time in the past. If the model can predict the present it is probably a good model. It is more likely to be accurate when predicting the future.

Physical Models

A **physical model** is a representation of something using objects. It can be three-dimensional, like a globe. It can also be a two-dimensional drawing or diagram. Models are usually smaller and simpler than the real object. They most likely leave out some parts, but contain the important parts. In a good model the parts are made or drawn to scale. Physical models allow us to see, feel and move their parts. This allows us to better understand the real system.

An example of a physical model is a drawing of the layers of Earth (**Figure** 1.5). A drawing helps us to understand the structure of the planet. Yet there are many differences between a drawing and the real thing. The size of a model is much smaller, for example. A drawing also doesn’t give good idea of how substances move. Arrows showing the direction the material moves can help. A physical model is very useful but it can’t explain the real Earth perfectly.

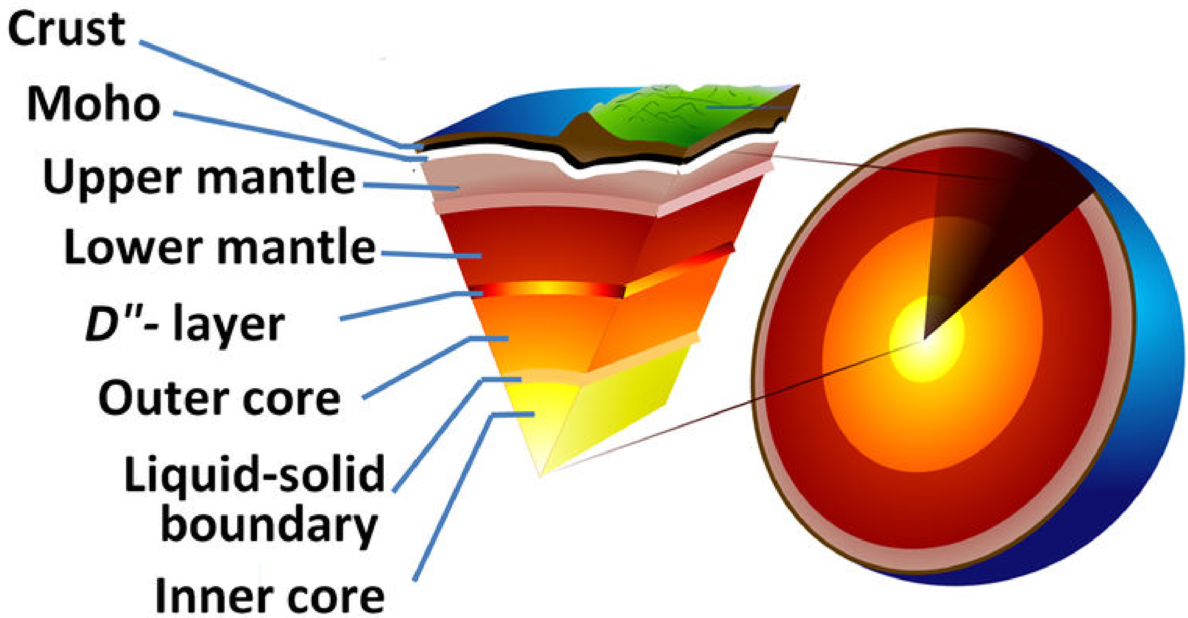

FIGURE 1.5
Earth's Center.

Ideas as Models

Some models are based on an idea that helps scientists explain something. A good idea explains all the known facts. An example is how Earth got its Moon. A Mars-sized planet hit Earth and rocky material broke off of both bodies (**Figure** 1.6). This material orbited Earth and then came together to form the Moon. This is a model of something that happened billions of years ago. It brings together many facts known from our studies of the Moon's surface. It accounts for the chemical makeup of rocks from the Moon, Earth, and meteorites. The physical properties of Earth and Moon figure in as well. Not all known data fits this model, but much does. There is also more information that we simply don't yet know.

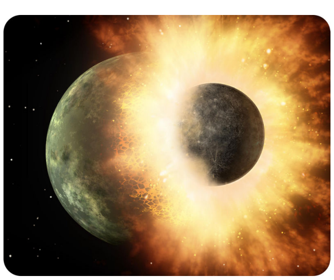

FIGURE 1.6
A collision showing a meteor striking Earth.

Models that Use Numbers

Models may use formulas or equations to describe something. Sometimes math may be the only way to describe it. For example, equations help scientists to explain what happened in the early days of the universe. The universe formed so long ago that math is the only way to describe it. A climate model includes lots of numbers, including temperature readings, ice density, snowfall levels, and humidity. These numbers are put into equations to make a model. The results are used to predict future climate. For example, if there are more clouds, does global temperature go up or down? Models are not perfect because they are simple versions of the real situation. Even so, these models are very useful to scientists. These days, models of complex things are made on computers.

Safety in Science

Accidents happen from time to time in everyday life. Since science involves an adventure into the unknown, it is natural that accidents can happen. Therefore, we must be careful and use proper equipment to prevent accidents (**Figure** 1.7). We must also be sure to treat any injury or accident appropriately.

FIGURE 1.7
Safety Symbols: A. Corrosive , B. Oxidizing Agent, C. Toxic, D. High Voltage.

Inside the Science Laboratory

If you work in the science lab, you may come across dangerous materials or situations. Sharp objects, chemicals, heat, and electricity are all used at times in science laboratories. With proper protection and precautions, almost all accidents can be prevented (**Figure** 1.8). If an accident happens, it can be dealt with appropriately. Below is a list of safety guidelines to follow when doing labs:

- Follow directions at all times.
- A science lab is not a play area.
- Be sure to obey all safety guidelines given in lab instructions or by the lab supervisor.
- Be sure to use the correct amount of each material.
- Tie back long hair.
- Wear closed shoes with flat heels.
- Shirts should have no hanging sleeves, hoods, or drawstrings.
- Use gloves, goggles, or safety aprons as instructed.
- Be very careful when you use sharp or pointed objects, such as knives.
- Clean up broken glass quickly with a dust pan and broom. Never touch broken glass with your bare hands.
- Never eat or drink in the science lab. Table tops and counters could have dangerous substances on them.
- Keep your work area neat and clean. A messy work area can lead to spills and breakage.
- Completely clean materials like test tubes and beakers. Leftover substances could interact with other substances in future experiments.
- If you are using flames or heat plates, be careful when you reach. Be sure your arms and hair are kept far away from heat sources.

- Use electrical appliances and burners as instructed.
- Know how to use an eye wash station, fire blanket, fire extinguisher, and first aid kit.
- Alert the lab supervisor if anything unusual occurs. Fill out an accident report if someone is hurt. The lab supervisor must know if any materials are damaged or discarded.

FIGURE 1.8
A medical researcher protects herself and her work with a net cap, safety goggles, a mask, and gloves.

Outside the Laboratory

Many Earth science investigations are conducted in the field (**Figure** 1.9). Field work needs some additional precautions:

- Be sure to wear appropriate clothing. Hiking requires boots, long pants, and protection from the Sun, for example.
- Bring sufficient supplies like food and water, even for a short trip. Dehydration can occur rapidly.
- Take along first aid supplies.
- Let others know where you are going, what you will be doing, and when you will be returning. Take a map with you if you don't know the area and leave a copy of the map with someone at home.
- Try to have access to emergency services and some way to communicate. Beware that cell phones may not have coverage in all locations.
- Be sure that you are accompanied by a person familiar with the area or is familiar with field work.

Lesson Summary

- Scientists ask questions about the natural world.
- Scientific method is a set of logical steps that can be used to answer these questions.
- A hypothesis is a reasonable explanation of something.
- A theory is a hypothesis that has been shown to be true many times over.
- Models represent real things but are simpler.
- If you are working in a lab, it is very important to be safe.

FIGURE 1.9
Outdoor Excursions.

Lesson Review Questions

Recall

1. Describe three types of scientific models. Under what circumstances would each be used?

2. If you have access to a science laboratory, look around to see what safety symbols there are. What does each mean?

Apply Concepts

3. Write five questions that would get a friend interested in exploring the natural world.

4. A scientist was studying the effects of oil contamination on ocean seaweed. He believed that oil runoff from storm drains would keep seaweed from growing normally. He had two large aquarium tanks of equal size. He kept the amount of dissolved oxygen and the water temperature the same in each tank. He added some motor oil to one tank but not to the other. He then measured the growth of seaweed plants in each tank. In the tank with no oil, the average growth was 2.57cm/day. The average growth of the seaweed in the tank with oil was 2.37cm/day. Based on this experiment, answer the following questions:

- What was the question that the scientist started with?
- What was his hypothesis?
- Identify the independent variable, the dependent variable, and the experimental control(s).
- What did the data show?

Think Critically

5. Design your own experiment based on one of your questions from question 3 above. Include the question, hypothesis, independent and dependent variables, and safety precautions.

Points to Consider

- What parts of Earth do you think are most important and should be better studied?
- Describe a model that you have had experience with. What type of model was it? What did you learn from it?
- What situations are both necessary and dangerous for scientists to study? What precautions do you think they should use when they study them?
- If you could go anywhere, where would it be? What safety equipment or precautions would you take?

1.2 Earth Science and Its Branches

Lesson Objectives

- Describe Earth Science and its branches.
- Identify the field of geology as a branch of Earth Science that deals with the rocks and minerals of Earth.
- Describe the field of oceanography as a branch of Earth Science that explores the ocean.
- Define the field of meteorology as a branch of Earth Science that deals with the atmosphere.
- Understand that astronomy is a branch of Earth Science that studies our solar system and universe.
- List some of the other branches of Earth Science, and how they relate to the study of Earth.

Vocabulary

- astronomy
- geology
- meteorology
- oceanography

Introduction

Earth Science is the study of all aspects of our planet Earth. Earth Science is not just about the molten lava, icy mountain peaks, steep canyons and towering waterfalls of the continents. Earth Science includes the atmosphere and oceans. The field also looks out into the solar system, galaxy, and universe. Earth scientists seek to understand the beautiful planet on which we depend (**Figure** 1.10).

FIGURE 1.10
Earth as seen from Apollo 17.

Different branches of Earth Science study one particular part of Earth. Since all of the branches are connected, specialists work together to answer complicated questions. Let's look at some important branches of Earth Science.

Geology

Geology is the study of the solid Earth. Geologists study how rocks and minerals form. The way mountains rise up is part of geology. The way mountains erode away is another part. Geologists also study fossils and Earth's history. There are many other branches of geology. There is so much to know about our home planet that most geologists become specialists in one area. For example, a mineralogist studies minerals, as seen in (**Figure** 1.11).

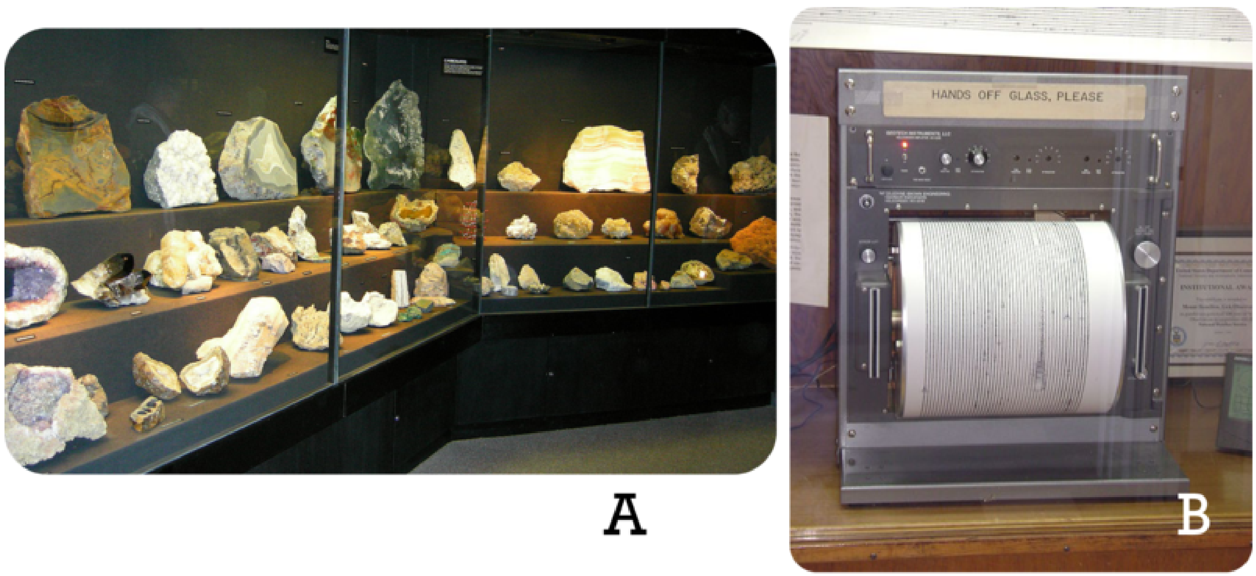

FIGURE 1.11
(A) Mineralogists focus on all kinds of minerals. (B) Seismographs are used to measure earthquakes and pinpoint their origins.

Some volcanologists brave molten lava to study volcanoes. Seismologists monitor earthquakes worldwide to help protect people and property from harm (**Figure** 1.11). Paleontologists are interested in fossils and how ancient organisms lived. Scientists who compare the geology of other planets to Earth are planetary geologists. Some geologists study the Moon. Others look for petroleum. Still others specialize in studying soil. Some geologists can tell how old rocks are and determine how different rock layers formed. There is probably an expert in almost anything you can think of related to Earth!

Geologists might study rivers and lakes, the underground water found between soil and rock particles, or even water that is frozen in glaciers. Earth scientists also need geographers who explore the features of Earth's surface and work with cartographers, who make maps. Studying the layers of rock beneath the surface helps us to understand the history of planet Earth (**Figure** 1.12).

Oceanography

Oceanography is the study of the oceans. The word oceanology might be more accurate, since "ology" is "the study of." "Graph" is "to write" and refers to map making. But mapping the oceans is how oceanography started.

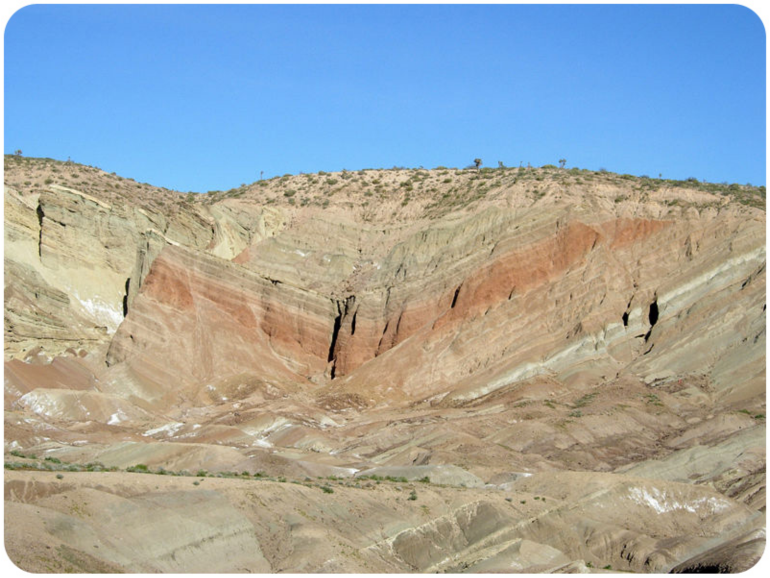

FIGURE 1.12
These folded rock layers have bent over time. Studying rock layers helps scientists to explain these layers and the geologic history of the area.

More than 70% of Earth's surface is covered with water. Almost all of that water is in the oceans. Scientists have visited the deepest parts of the ocean in submarines. Remote vehicles go where humans can't. Yet much of the ocean remains unexplored. Some people call the ocean "the last frontier."

Humans have had a big impact on the oceans. Populations of fish and other marine species have been overfished. Contaminants are polluting the waters. Global warming is melting the thick ice caps and warming the water. Warmer water expands and, along with water from the melting ice caps, causes sea levels to rise.

FIGURE 1.13
This research vessel is specially designed to explore the seas around Antarctica.

There are many branches of oceanography. Physical oceanography is the study of water movement, like waves and ocean currents (**Figure** 1.13). Marine geology looks at rocks and structures in the ocean basins. Chemical oceanography studies the natural elements in ocean water. Marine biology looks at marine life.

Climatology and Meteorology

Meteorologists don't study meteors —they study the atmosphere! The word "meteor" refers to things in the air. **Meteorology** includes the study of weather patterns, clouds, hurricanes, and tornadoes. Meteorology is very important. Using radars and satellites, meteorologists work to predict, or forecast, the weather (**Figure** 1.14).

FIGURE 1.14
Meteorologists can help us to prepare for major storms or know if today is a good day for a picnic.

The atmosphere is a thin layer of gas that surrounds Earth. Climatologists study the atmosphere. These scientists work to understand the climate as it is now. They also study how climate will change in response to global warming.

The atmosphere contains small amounts of carbon dioxide. Climatologists have found that humans are putting a lot of extra carbon dioxide into the atmosphere. This is mostly from burning fossil fuels. The extra carbon dioxide traps heat from the Sun. Trapped heat causes the atmosphere to heat up. We call this global warming (**Figure** 1.15).

FIGURE 1.15
Carbon dioxide released into the atmosphere is causing global warming.

Environmental Science

Environmental scientists study the ways that humans affect the planet we live on. We hope to find better ways of living that can also help the environment. Ecologists study lifeforms and the environments they live in (**Figure** 1.16). They try to predict the chain reactions that could occur when one part of the ecosystem is disrupted.

FIGURE 1.16
In a marine ecosystem, coral, fish, and other sea life depend on each other for survival.

Astronomy

Astronomy and astronomers have shown that the planets in our solar system are not the only planets in the universe. Over 530 planets were known outside our solar system in 2011. And there are billions of other planets! The universe also contains black holes, other galaxies, asteroids, comets, and nebula. As big as Earth seems, the entire universe is vastly more enormous. Earth is just a tiny part of our universe.

Astronomers use many tools to study things in space. Earth-orbiting telescopes view stars and galaxies from the darkness of space (**Figure** 1.17). They may have optical and radio telescopes to see things that the human eye can't see. Spacecraft travel great distances to send back information on faraway places.

Astronomers ask a wide variety of questions. How do strong bursts of energy from the Sun, called solar flares, affect communications? How might an impact from an asteroid affect life on Earth? What are the properties of black holes? Astronomers ask bigger questions too. How was the universe created? Is there life on other planets? Are there resources on other planets that people could use? Astronomers use what Earth scientists know to make comparisons with other planets.

Lesson Summary

- Earth science includes many fields of science related to our home planet.
- Geology is the study of Earth's material and structures and the processes that create them.

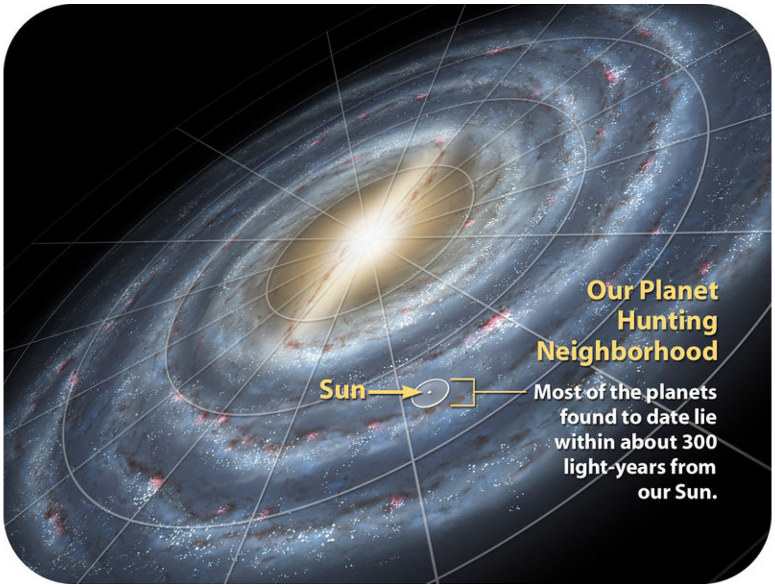

FIGURE 1.17
Scientists are using telescopes to search for other planets that may have conditions favorable for life. The places they can look are near our solar system in our galaxy.

- Oceanography is the study of the oceans: water movement, chemistry and the ocean basins among other things.
- Meteorologists study the atmosphere including climate and weather.
- Environmental science deals with the effects people have on the environment.
- Astronomers study Earth's larger environment: the solar system, galaxy, and universe that our planet resides in.

Lesson Review Questions

Recall

1. What are three major branches of Earth Science?
2. What branch of science deals with stars and galaxies beyond Earth?
3. List important functions of Earth scientists.
4. What does a meteorologist study?

Apply Concepts

5. A glacier is melting. What are all of the scientists you can think of who might be involved in studying this glacier? What would each of them do?

Think Critically

6. Design an experiment that you could conduct in any branch of Earth Science. Identify the independent variable and dependent variable.

Points to Consider

- Why is Earth Science so important?
- Which branch of Earth Science would you most like to explore?
- What is the biggest problem that we face today? Which Earth scientists may help us to solve the problem?
- What other branches of science or society are related to and necessary for Earth Science?

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