Chapter 1

The Practice of Science

Standards: SC.6.N.1.1, SC.6.N.1.3, SC.6.N.1.5

Chapter 1 • Lesson 1

Scientific Investigation

Key Words • observation • investigation • data • experiment • hypothesis

Getting the Idea

Have you ever asked a question about something in nature? Scientists ask questions all the time. But the questions they ask may be different from yours. In this lesson you will learn about the questions scientists ask. You will also learn how they find answers to those questions.

Observations and Questions

You notice things around you when you see, hear, feel, taste, smell, and touch. An **observation** is information gathered with your senses. Once you make an observation, you may get curious and start asking questions. So do scientists.

Suppose you wonder if playing music changes how plants grow. Every day after school, you play your favorite music for six plants growing on your bedroom windowsill. Six similar plants on your brother's windowsill get no music. You make sure all the plants get the same amount of sunlight and water. After a month, you measure the growth of each plant. Now you are ready to figure out what you learned. You have asked and answered a question. You have carried out a scientific investigation. An **investigation** is a close study of something to answer a question about it.

Kinds of Investigations

An investigation can simply be observing something or recording an event. For example, you might observe which trees lose their leaves first as fall approaches. Perhaps a construction crew is digging a basement or a foundation near you. You might observe the layers of rock that have been uncovered. If you are lucky, you might get to watch a solar or a lunar eclipse.

You might also collect samples as part of an investigation. For example, you might gather the falling leaves to make sure you have identified the trees correctly. You might chip off pieces of the rock layers and identify them.

All the pieces of information that you gather during an investigation are called **data** (singular, *datum*). Often data are measurements or other numbers.

Some investigations are experiments. An **experiment** is a carefully controlled test to answer a scientific question. Playing music for one group of plants and not for another is an experiment. You must control all the conditions in an experiment. Then you will know what causes changes.

Suppose no one waters the plants in your brother's room. The plants in your room grow about 10 centimeters during your study. Your brother's plants grow only 4 centimeters. You do not know why your plants grew faster. Was it because of the music? Or was it because of the water? In a good study, both groups must have the same conditions. In this study, both groups of plants must get the same amount of water. Only one thing can be different—the music. Then you can be more sure you are measuring the effects of the music.

Some investigations are not experiments. They may be surveys in which you ask questions and write down the answers. They may be studies in which you make observations in a laboratory. They may be field studies, in which you work outside instead of in a lab. They may be studies in which you use models instead of observing real objects or events. (You will learn more about using models in science in Lesson 6.) The type of investigation you should choose depends on the question you are trying to answer. For example, suppose you want to know how different amounts of light affect the growth of tomato plants. To answer that question, you should do a controlled experiment. But to find out about the feeding habits of mockingbirds, you should do a field study. You cannot control conditions outside in a natural setting.

Forming and Testing Hypotheses

Scientists learn about the world by asking and answering questions. Every investigation begins with a question. A **hypothesis** is a possible answer to a scientific question. Scientists use what they already know to form a hypothesis. Then they conduct an investigation to test the hypothesis.

Think again about your plant investigation. First, you asked the question, "Does playing music change how plants grow?" What hypothesis would you form about music and plant growth? Think about what you already know about plants. You know they need sunlight and water to grow. You might form the hypothesis that playing music has no effect on plant growth.

Did You Know?

Albert Einstein was one of the world's greatest scientists. He said, "The important thing is not to stop questioning."

The table below shows some scientific questions. The table gives one hypothesis for each question. The hypothesis is a possible answer to the question. To find out if the hypothesis is true, you could conduct an investigation or an experiment.

Scientific Questions and Hypotheses

Scientific Question	Hypothesis
Which fertilizer—X or Y—will cause tomato plants to produce more tomatoes?	Tomato plants given fertilizer Y will produce more tomatoes than plants given fertilizer X.
What effect does the size of a parachute have on how fast an object falls?	The larger the parachute, the more slowly the object falls.
How does salt affect water's boiling point?	If salt is added to water, then the boiling point will increase.

How Scientists Learn

Scientists use what they already know to form hypotheses and plan investigations. They use creativity, too. *Creativity* is the ability to think of new ideas and ways of doing things. Scientists use creativity all the time. They use it to think of good questions to ask. They use it to design experiments and other investigations. They also use it when they figure out what the results of their investigations mean. Creativity in science does not mean making things up. It means thinking about observations and data in a new way.

Scientists make observations and collect as much data as possible. Then, they study the information. They use logical reasoning to figure out what their data mean and decide if their hypothesis is correct. A scientist may find out that a hypothesis is not correct. But, he or she has still learned something important. The information gathered during any investigation adds to scientific knowledge. It can also lead to new investigations.

Discussion Question

What is the difference between a hypothesis and a guess?

Lesson Review

1. Which of these is an experiment?

   A. a controlled study of the effect of temperature on the growth of bean plants

   B. a survey to collect data on students' exercise habits

   C. observations of bacteria under a microscope

   D. a study of how blue jays build their nests

2. What do scientists collect during a scientific investigation?

   A. technology **C.** data

   B. hypotheses **D.** questions

3. What is the **best** definition of hypothesis?

   A. a question

   B. an observation

   C. a possible answer to a scientific question

   D. a question that can be answered

4. What do you do first in a scientific investigation?

   A. collect data

   B. gather materials

   C. form a hypothesis

   D. ask a question

5. When scientists come up with new ideas and ways of doing things, they use

   A. technology. **C.** data.

   B. creativity. **D.** questions.

Standards: SC.6.N.1.1, SC.6.N.1.2, SC.6.N.1.4

Designing and Conducting an Experiment

Key Words • hypothesis • data • experiment • variable • independent variable • dependent variable • procedure • conclusion • trial

Getting the Idea

A scientific experiment is one way to answer a question. The experiment can show if a hypothesis is correct. There are many kinds of experiments. But all of them have some things in common.

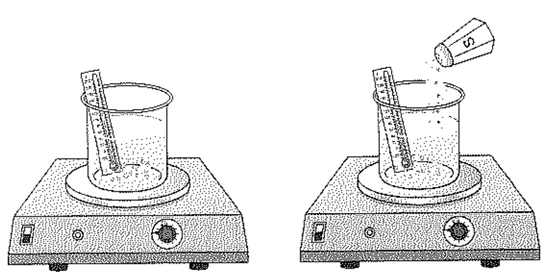
Before the Experiment

In the last lesson, you learned that scientists ask questions. Then they think of possible answers. They use what they already know to think of answers that make sense. A possible answer to a scientific question is called a **hypothesis**. A good hypothesis can be tested. Testing usually includes collecting **data**, or information. Data can be measurements or observations. One way to gather data is to do an experiment. An **experiment** is a carefully controlled study.

Parts of an Experiment

Experiments include variables. A **variable** is something that can change, or vary. In an experiment, scientists investigate how changing one thing causes something else to change. Scientists are careful to change just one variable at a time. Then they know that any effects they observe are caused by that variable.

Suppose that you want to find out how salt changes the boiling point of water. The boiling point is the temperature at which water boils. You decide to use two beakers that are exactly the same. You pour the same amount of water into each beaker. The water in each beaker starts at the same temperature. You will add salt to one of the beakers, as shown below. Your variables are the amount of salt, the amount of water, and the starting temperature of the water. You want to be sure that only the amount of salt is different. The other variables must stay the same.



Every experiment has two main variables. The **independent variable** is the variable that is changed in an experiment. In this experiment, the independent variable is the amount of salt added to the water. The **dependent variable** is the variable that changes as a result of changes in the independent variable. The dependent variable is the boiling point of the water. You will add salt to one of the beakers. Then you will find out if adding salt changes the boiling point.

Your scientific question might be: How does adding salt to water change its boiling point? You state a hypothesis, or a possible answer to your question. A good hypothesis tells how changing the independent variable may change the dependent variable. Your hypothesis might be: Adding salt to water will make the water boil at a higher temperature. Your experiment will tell you if your hypothesis is correct.

Doing an Experiment

When you design an experiment, you must decide what steps to follow. The written, step-by-step plan for an experiment is called a **procedure**. This plan helps you decide what materials you will need. It also lets other people review your work. They can repeat the experiment to check the results. For your experiment, your procedure might have these steps:

1. Use two beakers of the same size. Label one "no salt" and the other "salt."
2. Add 250 mL of water to each beaker.
3. Measure 10 mL of salt. Add the salt to the beaker labeled "salt." Stir the water.
4. Place each beaker on a hot plate. Heat each beaker until the water starts to boil. Use a thermometer to measure the boiling temperature in each beaker. Record each boiling temperature.

At the end of the experiment, you analyze the data. You study your data carefully to figure out what they mean. Suppose you find that the water with salt boils at a higher temperature. Then you know the results support your hypothesis. The water with salt has a higher boiling point.

Now you are ready to draw a conclusion. A **conclusion** is a statement about what you think data mean. It indicates whether or not the results support the hypothesis. In this experiment, your conclusion might be: Adding salt to water causes the water to boil at a higher temperature. In this case, the results support your hypothesis.

After the Experiment

Suppose the data did not support your hypothesis. That would *not* mean your experiment was a failure. You would still have learned something. You could do other experiments. For example, you could try adding different amounts of salt. All your experiments will give you new information.

Even when the data support your hypothesis, you should repeat the experiment. You should follow exactly the same procedure. Each repetition of an experiment is called a **trial.** Conducting several trials lets you check your results. If you do an experiment just once, you cannot be sure that the same results will occur again. Doing several trials helps make sure your data can be trusted.

Scientists repeat their experiments many times. Each time, they follow exactly the same procedure. They do this to test their results. If the results of several trials are different, then something may be wrong with the experiment. There may be extra variables. Or errors may have been made in measuring. If an experiment cannot be repeated, the conclusion may not be true.

Other scientists should be able to test the results, too. If they repeat the experiment, they should make the same observations. They should get the same results. Results that many scientists can find again and again are the basis for valid scientific conclusions. That is one reason why communicating, or sharing, results is an important part of science.

You and your classmates often conduct the same experiments. Sometimes different scientists, too, try to answer the same question. They may conduct experiments using similar procedures and tools. When the scientists share their results, they may find that their results are the same. If different scientists get the same results, they know their conclusions are most likely correct.

Now suppose the scientists get and share different results. If different scientists get different results, they know their conclusions may be incorrect. In this case, they probably need to go back and repeat the investigation. If they did not share their results, they might not know this. Sharing, discussing, and comparing results is an important part of any scientific investigation.

Discussion Question

Why is it important to change only one variable in an experiment?

Lesson Review

1. What is the main purpose of an experiment?

   A. to test a hypothesis
   B. to form a hypothesis
   C. to ask a question
   D. to prove that a hypothesis is correct

2. Which sentence is correct?

   A. An experiment should have only one variable.
   B. An experiment begins with drawing a conclusion and ends with asking a question.
   C. Doing an experiment includes recording data and drawing a conclusion.
   D. You can make up an experiment as you go along.

3. A student sets up an experiment to see how sunlight affects how tall a plant grows. She gives two identical plants the same amount of water every day, but she puts one plant in sunlight and the other plant in shade. Which of the following is the dependent variable?

   A. plant location
   B. amount of water given to each plant
   C. time of year
   D. plant height

4. A student is conducting an experiment to see how a watering schedule affects the growth of grass. He conducts the experiment two times. His data are different each time, and he comes to two different conclusions. What should he do next?

   A. forget about the entire investigation
   B. get different kinds of plants and start over
   C. repeat the experiment carefully one or more times
   D. change the results so that they match

Standard: SC.6.N.1.1

Organizing and Analyzing Data

Key Words • data table • line graph • *x*-axis • *y*-axis • interval • prediction • bar graph • circle graph

Getting the Idea

In the last lesson, you learned how to carry out a scientific investigation. Once you have collected data in your experiment or study, you are not done. You still need to organize and understand the data. When you share your results, you may want to describe your data with more than words. You can make tables and draw graphs to organize and display the data clearly. Tables and graphs can help the reader or listener understand data. These visual displays make it easier to see patterns in the data.

Using Data Tables

A **data table** is a chart made up of rows and columns in which scientists record data. Data tables are used to organize and display information such as measurements. Data tables can also show words that describe observations. An example is shown below.

Suppose your class has a pet guinea pig. It was two months old when you got it. You and the other students weigh the guinea pig and measure its length. You do this every week for six weeks. You record and organize the data in the table shown.

Guinea Pig's Weekly Growth

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Weight (N)	5	7	8	9	10	10
Length (cm)	20	24	28	30	30	30

Using Line Graphs

A **line graph** is a visual display that uses a line on a grid to relate two variables. For example, the graph may show how a variable changes over time. A line graph has two scales called *axes* (singular: *axis*). Each axis shows values for one variable. The ***x*-axis** is the horizontal or bottom edge of a graph. The ***y*-axis** is the vertical or left edge of a graph. Within a graph, a point is plotted at each place where the values of the two variables intersect. Then a line is drawn to connect all the points.

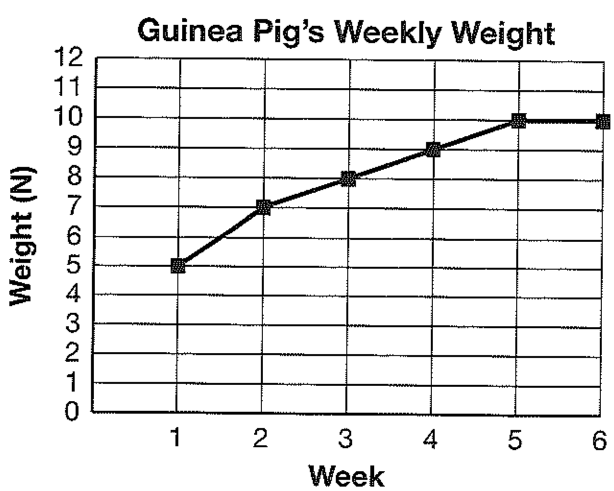
To start making a line graph, draw a horizontal line and a vertical line. The lines should meet at a right angle. The horizontal *x*-axis usually shows the independent variable. Recall that the independent variable is the variable that is changed in an experiment. Time is often shown on the *x*-axis. The vertical *y*-axis shows the dependent variable. The dependent variable is the variable that changes as a result of changes in the independent variable.

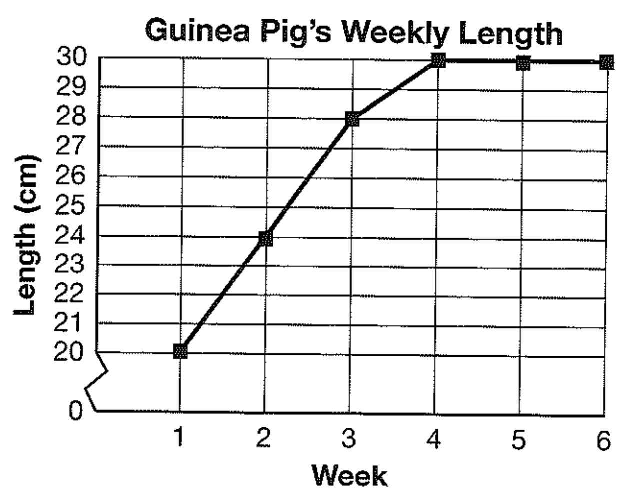
In your class investigation, the independent variable is time, measured in weeks. There are two dependent variables—weight and length. Since you have two dependent variables, you will need to make two graphs. You can follow the steps below to make a line graph.

Steps for Making a Line Graph

- Draw the horizontal and vertical axes.
- Put the independent variable on the *x*-axis. In your investigation, this is time, or the number of weeks. Decide on the **interval**, or equal division of the graph's axis. Your interval is 1 week.
- Put the dependent variable on the *y*-axis. For your first graph, this is weight. You can use an interval of 1 N. For the second graph, the dependent variable is length. You can use an interval of 1 cm.
- Plot the data. This means making a mark or point for each matched pair of numbers. For example, the first matched pair of numbers for the weight graph is (1, 5). It represents a time (week 1) and a weight (5 N). This pair of numbers gets plotted as a point on the graph.
- Connect the data points with a line.
- Write a title for the graph. Use both variables in your title.

The graphs below show the data from the table on page 20. They show how the guinea pig changed over the six weeks.





You can use the graphs on page 21 to help you analyze the data and see patterns. Then you can draw conclusions. You can see that the guinea pig got longer for three weeks. It also got heavier for four weeks. After week 5, the guinea pig did not get longer or heavier. By then, it was three months old. Based on this information, you draw a conclusion. You conclude that the guinea pig was full-grown when it was about three months old.

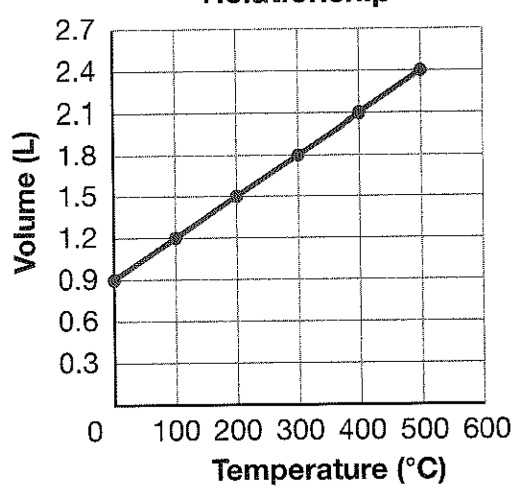
Showing Trends in Data

Data from an investigation can be organized and displayed in many ways. Writing, making tables, and drawing graphs are some ways scientists organize and show data. Sometimes one way makes it easier to analyze the data and spot trends than another way. Compare the table and graph below.

Volume–Temperature Relationship

Temperature (°C)	Volume (L)
0	0.9
100	1.2
200	1.5
300	1.8
400	2.1
500	2.4

Volume–Temperature Relationship



Line graphs can show trends in data more clearly than data tables do. Both the graph and the table show how the volume and temperature of a gas are related. As the temperature of the gas increases, its volume also increases. It is easier to see this trend on the graph than in the table.

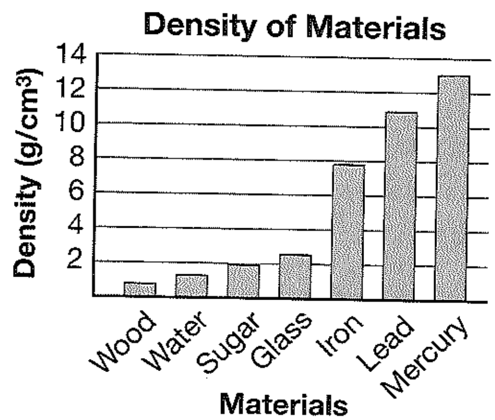
You can use graphs to make predictions. A **prediction** is a statement about what is likely to happen in the future. The volume-temperature graph is a straight line. This line shows a constant rate of change. Each 100°C increase in temperature causes a 0.3 L increase in volume. The data in the table stop at 500°C. But you can make the line on the graph longer. You can extend it to 600°C. Then you can predict that the volume of the gas at that temperature will be 2.7 L.

Did You Know?

Extending the line on a graph to make a prediction is called *extrapolation*. Looking between two points on a line and predicting a value is called *interpolation*.

Using Bar Graphs

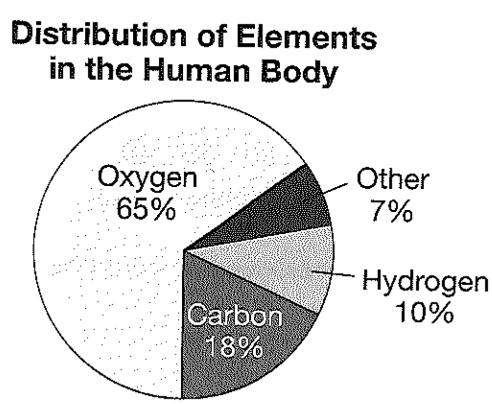
A **bar graph** is a display that shows data as bars of different lengths. Bar graphs are useful for comparing data for several items. You can use the bar graph below to compare the densities of several substances.



Most bar graphs have vertical bars. The items being compared—in this case, types of materials—appear on the horizontal axis. The property that was measured—in this case, density—appears on the vertical axis. The height of each bar shows the value.

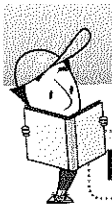
Using Circle Graphs

Sometimes data are presented in a circle graph, or pie chart. A **circle graph** is a display that shows data as parts of a whole. The circle is divided into wedges. The size of each wedge represents a fraction, or a percentage, of the whole (100%). The example below shows the elements that make up the human body.



Discussion Question

Find an example of each type of graph discussed in this lesson in a science textbook, newspaper, or magazine. Explain what each graph shows, and summarize the data.



Lesson Review

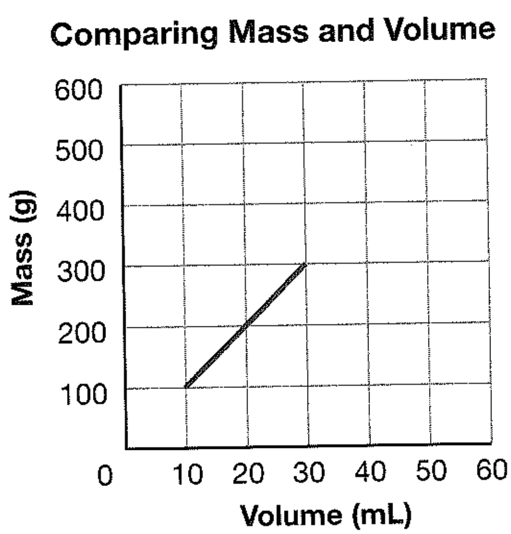
1. Which type of display is **most** useful for showing parts of a whole?

   A. line graph
   B. bar graph
   C. circle graph
   D. data table

2. A student grows a tomato plant. She measures its height every day for one month. At the end of the month, she wants to show her results on a line graph. What should she put along the vertical axis of her graph?

   A. time in days
   B. temperature of the soil
   C. number of tomatoes
   D. height of the plant

3. The graph below shows how the mass and volume of a certain substance are related.



   Based on the data provided, what do you predict would be the mass of 50 mL of this substance?

   A. 30 g
   B. 50 g
   C. 400 g
   D. 500 g

Standards: SC.6.N.2.1, SC.6.N.2.2, SC.6.N.2.3

Scientific Knowledge

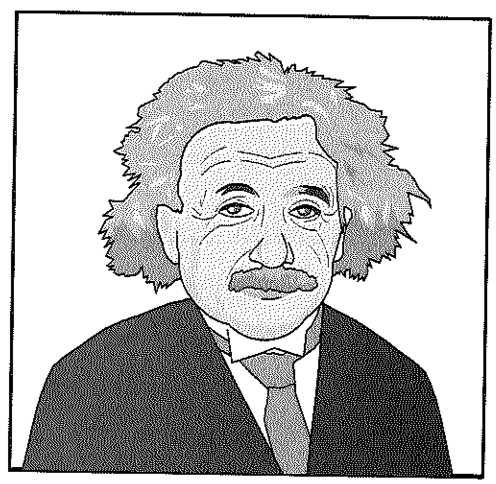
Key Words • fact • opinion

Getting the Idea

If you have ever asked a question about something in nature, you have taken the first step in learning to think like a scientist. Scientific reasoning is different from other ways of thinking. The goals of science are different from those in other fields of study. One goal of science is to gain knowledge to understand the natural world. Another goal is to gain knowledge to solve everyday problems.

Scientific Thought

Do you recognize the people in these pictures? The man on the left is Wolfgang Amadeus Mozart. He composed over 600 works of music. The man on the right is Albert Einstein. He is considered one of the most creative physicists of all time. Both men were great thinkers. Both were very creative. Both influenced many people, even to this day.

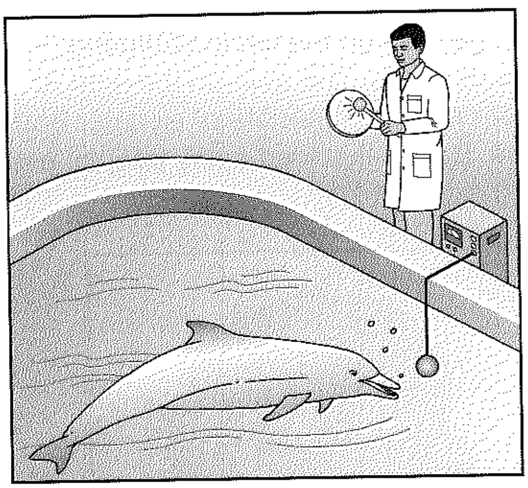


How were these men different? Mozart was not a scientist, but Einstein was. Einstein's work involved asking questions about the natural world. His ideas were based on observations and data. He thought like a scientist. He asked scientific questions. He conducted scientific investigations. He added to our knowledge of the natural world.

Scientific knowledge is based on *evidence*, which includes observations that you make yourself. Evidence also includes facts. A **fact** is information that is proved to be true. You can make an observation or repeat an investigation to prove that a fact is true. Unlike a fact, an **opinion** is an idea not proved by observations. An opinion may be a thought, belief, or judgment. It can vary from person to person or from place to place. The same person can change an opinion from one day to another. For example, you may think Mozart was the best composer ever. However, your friend may think Beethoven was the best composer. What you think or your friend thinks is an opinion, not a fact.

Who Are Scientists?

The work of scientists takes place everywhere. Scientists may work indoors or outdoors. A geologist may work near a volcano. A marine biologist may work with dolphins at an aquarium. A botanist may work on a farm and may look for ways to grow better crops. Scientists may work in laboratories. They may use microscopes to study living things. They may study how different building materials affect how well ships float. Some scientists are shown below.



Scientists come from all nations and speak many languages. But scientists are all alike in one way—they are curious.

In Bangladesh, Dr. Atik Rahman studies changes in climate. He wants to know how global warming will affect his country. In Bolivia, agronomist Emilio Chileno helps farmers learn to improve the soil. An agronomist is someone who studies crop production and soil management. In Kenya, Dr. Wangari Maathai has used her knowledge of biology to start the Green Belt Movement. She has helped women from poor villages in Kenya plant more than 30 million trees.

Scientists can be men or women. They can be people of any age. In 2003, 19-year-old Jana Ivanidze of Germany won a prize for her work on cells.

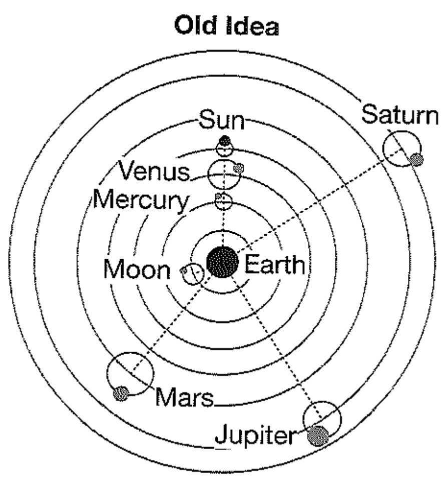
Changes in Scientific Thought

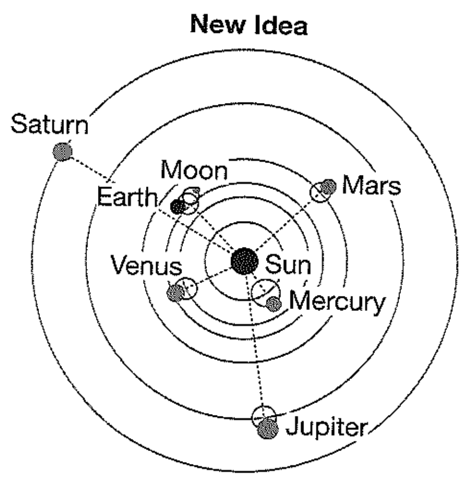
Recall that a hypothesis is a possible answer to a scientific question. Sometimes a hypothesis does not explain what is observed. It is not supported by evidence. The hypothesis is then changed or discarded. Scientific knowledge changes over time when new discoveries are made and new data collected. One example is our understanding of the movement of the planets and stars.

Just like scientists today, scientists long ago asked questions about the natural world. They formed hypotheses. They made observations and drew conclusions. They had fewer scientific tools than we do today. Still, some of their conclusions were correct. For example, they correctly measured the length of a year. However, many of their ideas have been proved wrong. Aristotle and other ancient Greek scientists thought Earth was the center of the universe. They believed that the sun and all the other stars circled Earth. They did not realize that some of those "stars" were planets.

Those scientists were trying to make sense of what they could see. They did not have telescopes to help them observe the sky. Their ideas, although incorrect, made sense to them. After all, they watched the sun move across the sky every day.

The development of the telescope in the 1600s led Galileo and other scientists to change this idea. They began to understand that Earth and the other planets in our solar system circle the sun. People learned to think about the universe in a completely new way.





Scientific knowledge is always growing and changing. New evidence may lead scientists to change their ideas. Or a new investigation may support an old conclusion. Often, scientists ask new questions that have never been asked before. New questions and investigations add to our knowledge of the natural world.

Discussion Question

How does scientific knowledge change?

Lesson Review

1. Which statement correctly describes scientific knowledge?

   A. It changes from place to place.

   B. It is based on opinions.

   C. It is based on facts.

   D. It varies from person to person.

2. Ancient scientific knowledge

   A. can be correct or incorrect.

   B. should always be accepted without question.

   C. is always incorrect because of new discoveries.

   D. is always correct because nature does not change.

3. Which statement is true about today's scientists?

   A. They all study living things.

   B. They study many different subjects.

   C. They are all men.

   D. They are all women.

4. Conclusions made by today's scientists should be

   A. accepted because these scientists are using the latest tools.

   B. accepted because these scientists are helping us learn about the world.

   C. supported by evidence, including facts and observations.

   D. compared with conclusions by ancient scientists.

Scientific Theories and Laws

Key Words • scientific law • law of gravity • law of conservation of energy • scientific theory

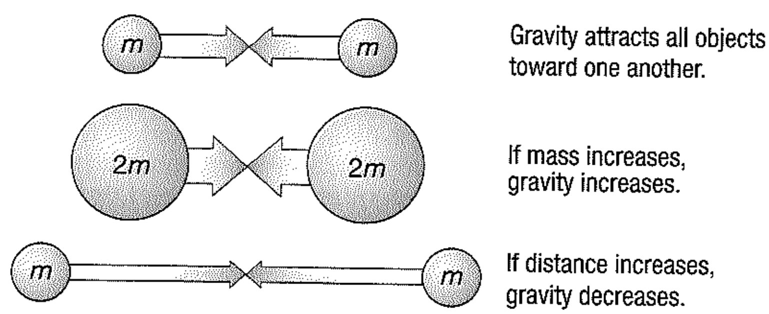
Getting the Idea

In Lesson 4, you learned that science does not stand still. As scientists gain new knowledge, their conclusions and ideas change. Sometimes, after conducting many experiments, scientists gather data that keep telling them the same thing. When many scientists agree on the same idea, it becomes a theory. An idea can also become a scientific law. In this lesson, you will learn what a theory and a law mean in science.

Scientific Laws

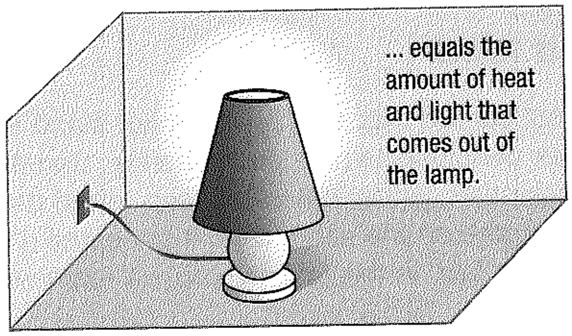
In many states, there is a law that states that people riding in cars must wear seat belts. The word *law* often refers to a rule passed by a government that people must follow. In science, the word *law* has a different meaning. A **scientific law** is a statement that describes how certain things relate to each other under given conditions in the natural world. It describes what always happens in a particular situation. A scientific law has been tested over and over again by many scientists. It has been found to always be true.

One example of a scientific law is the **law of gravity**. You will learn more about the law of gravity in Lesson 19. It states that gravity pulls, or attracts, all objects in the universe towards each other. This pull makes dropped objects fall toward Earth. Gravity, mass, and distance are always related in the ways shown in the diagram below.



Another example of a scientific law is the **law of conservation of energy**. It states that energy cannot be created or destroyed. Energy can only change from one form to another. Look at the picture below. The energy used when a lamp gets turned on is not destroyed. Instead, it is changed into different forms of energy. You will learn more about conservation of energy in Lesson 16.

Law of Conservation of Energy



Scientific Theories

Scientific laws have been proved to be true. Most people believe they will never change. A scientific theory is different. A **scientific theory** is an explanation of why something happens in the natural world. A hypothesis that is supported by data over and over again may become a scientific theory. Scientists accept a theory only if there is a great deal of evidence to support it. But, if new discoveries are made, a theory may prove to be untrue. Then the theory will likely be changed, or even replaced with a new theory.

Remember that a scientific law describes *what* happens. However, a scientific theory explains *why* something happens. Also, theories are usually more complicated than laws. A law describes an individual event. A theory explains an entire group of events.

In science, the word *law* has a different meaning from how it is used every day. So does the word *theory*. For example, you might have a theory that your teachers give more homework when the weather is colder. But your theory may be just a guess. It is not based on evidence. In science, a theory is an idea that has been tested. It is based on evidence, so most scientists believe it is true. It is a well-supported and widely accepted explanation.

Did You Know?

Albert Einstein introduced the basic ideas of the theory of relativity in the early part of the twentieth century. The theory changed the way scientists thought about space and time. Many parts of the theory continue to be studied today.

Discussion Question

How are scientific laws different from the laws made by governments?

Lesson Review

1. A certain scientific idea states that when a beam of light strikes a mirror at a certain angle, the light will be reflected back at that same angle. This idea is an example of

   A. an experiment.

   B. a hypothesis.

   C. a scientific law.

   D. a scientific theory.

2. A scientific theory is an idea that most scientists

   A. think is true.

   B. have proved to be always true.

   C. disagree about and discuss.

   D. have used to create new experiments.

3. Which is **not** a characteristic of a scientific law?

   A. It has been found to always be true.

   B. There is evidence to support it.

   C. It describes a particular situation.

   D. It is a rule that everyone must follow.

Standard: SC.6.N.3.4

Using Models in Science

Key Words • model • scale • computer simulation

Getting the Idea

In Lesson 3, you learned about graphs. These are ways to show data. They make data easier to study and understand. Graphs are one kind of model. Many different models are used in science. They help scientists explain and study the natural world.

What Models Are

A **model** is something used to represent an object, system, or process. A model shows how something works or how its parts are related to each other. Diagrams, equations, computer models, and three-dimensional models are all examples of models used in science. Each shows some properties of an actual object, system, or process.

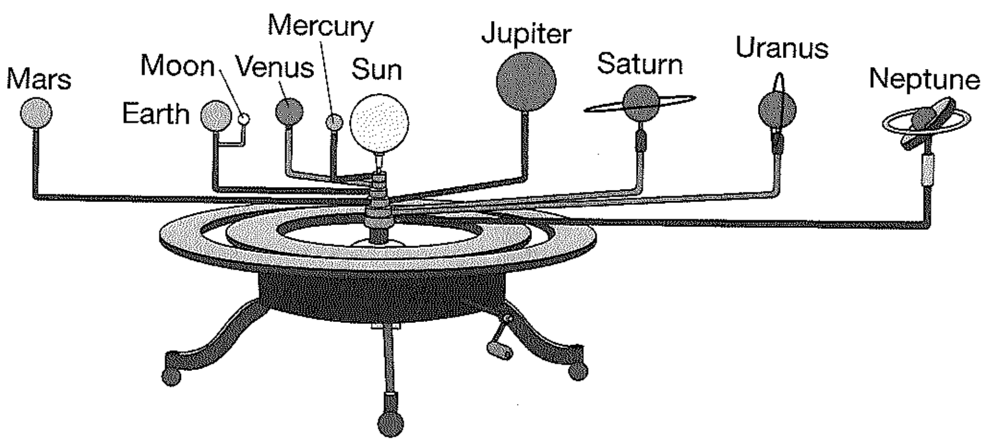
When Models Are Useful

Scientists make models to study many different objects and systems. Models are used to understand processes and predict change. Models can help scientists test hypotheses, analyze data, and make predictions. Here are some ways in which models are used:

- to shrink something very large to a practical size
- to enlarge something that is very small
- to show how the sizes of the parts of an object are related
- to show how objects affect each other
- to show how objects change over time

A model can be larger, smaller, or simpler than the actual object. But a model must correctly show the parts. The model must also show how the parts relate to each other.

For example, look at the model of the solar system below. This model shrinks something too large to study easily. A good model of the solar system shows more than the names of the planets. The model below shows the order of the planets and how they move around the sun. Someone who uses the model below will see that Neptune is much farther from the sun than Earth.



Making Models to Scale

Models can be smaller or bigger than the objects they represent. They can be flat, two-dimensional drawings, such as maps. Or they can be three-dimensional objects, such as globes or dioramas. A science museum might have a small model of the solar system. It might also have a giant model of an insect, so everyone can see the insect's parts clearly. Whatever its size, a model must show how the actual parts are related. To do that most accurately, all the parts of the model must have the same scale. **Scale** is the ratio between two sets of measurements. For example, a map might have a scale of 1 centimeter = 1 kilometer. If a model is to scale, its parts have the same proportions as those of the object it represents.

Suppose that the body of an insect is 2 cm long and its legs are each 1 cm long. A model of the insect should have a body that is twice as long as its legs. Whether the model has a 2-meter body with 1-meter legs or a 4-meter body with 2-meter legs does not matter. Either way, the model will be to scale. It will show the correct relationship of the real insect's parts.

When models are made to scale, scientists can use them to estimate and compare size, distance, or volume. But not all models are made to scale. The solar system model shown above is not a scale model. A scale model of the solar system requires a large, outdoor space. A smaller model cannot show distances to scale, but it can still be useful. It can show how the sun and the planets are arranged in space.

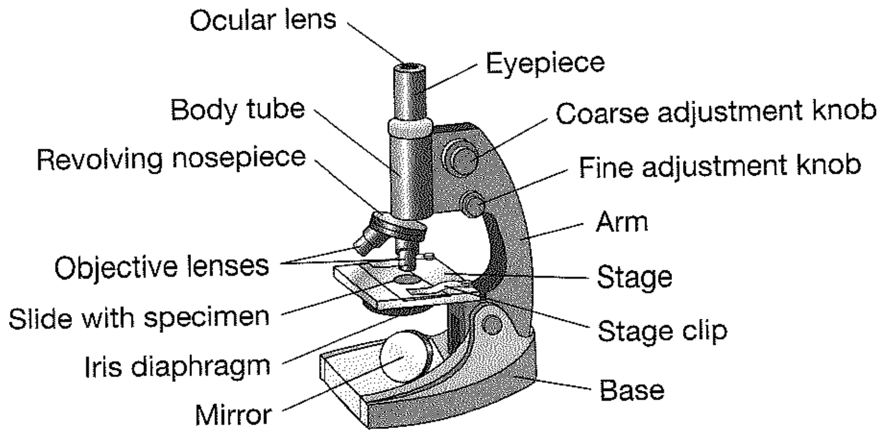
Did You Know?

One of the largest models of the solar system is located in Peoria, Illinois. In this model, the sun is 11 m wide. The dwarf planet Pluto is a sphere that is 2.5 cm wide and is located 64 km from the model sun.

Types of Models

Science textbooks have many diagrams. A diagram is a two-dimensional model. Diagrams often show the parts of an object or a system and their relative locations. For example, you can use the diagram below to learn the parts of a microscope. This book has many diagrams that are used as models. You can use the diagram in Lesson 14 to compare the parts of Earth's atmosphere. You can use the diagrams in Lesson 24 to find out where the parts of different systems in your body are located.

Parts of a Microscope



Three-dimensional models can be made of many different materials, such as metal, plastic, or wood. You may have seen a plastic model of a dinosaur skeleton or the human body. Such models show how the parts of something fit together.

Models can show things you cannot observe directly. You cannot visit the inside of Earth. But a diagram or a three-dimensional model can show Earth's different layers. Some models make ideas easier to understand. Such models do not always look like real objects. The diagram of gravity in Lesson 5 is an example.

Many models today are made using computers. Computer models can be *interactive*—you can move parts of the model and see what happens. **Computer simulations** are models displayed on a computer that can be used to show changes under different conditions. Computer simulations are used to predict the weather. They provide a safe way to study dangerous events such as earthquakes and storms such as hurricanes. Simulations are also used to test new products to make sure they are safe.

Discussion Question

What do all scientific models have in common? Give an example of a model and how it is used.

Lesson Review

1. Which kind of model would be **most** useful for predicting the path of a hurricane?

   A. diagram

   B. three-dimensional model

   C. computer model

   D. map

2. A model of the solar system shows

   A. something too dangerous to study.

   B. something too large to observe all at once.

   C. something that cannot be observed.

   D. an idea that is hard to understand.

3. Which statement is true?

   A. Models are always the same size as what they represent.

   B. Models are always made of the same materials as what they represent.

   C. Models look exactly like what they represent.

   D. Models make it easier to study an object, system, or process.

4. Which of these is **not** a model?

   A. a drawing of the parts of a flower

   B. a diagram of the muscles in the human body

   C. a list of materials for a science experiment

   D. a weather map