Scientific Explanations

Understanding Science

Read to Learn

What is science?

The last time that you watched squirrels play in a park or in your yard, did you realize that you were practicing science? Every time you observe the natural world, you are practicing science. **Science** *is the investigation and exploration of natural events and of the new information that results from those investigations.*

When you observe the natural world, you might form questions about what you see. While you are exploring those questions, you probably use reasoning, creativity, and skepticism to help you find answers to your questions. These behaviors are the same ones that scientists use in their work and that other people use in their daily lives to solve problems.

Scientists use a reliable set of skills and methods in different ways to find answers to questions. After reading this chapter, you will have a better understanding of how science works, the limitations of science, and scientific ways of thinking. In addition, you will recognize that when you practice science at home or in the classroom, you probably use scientific methods to answer questions just as scientists do.

Branches of Science

No one person can study all the natural world. Therefore, people tend to focus their efforts on one of the three fields or branches of science—life science, Earth science, or physical science. Then people or scientists can seek answers to specific problems within one field of science.

Life Science Biology, or life science, is the study of all living things. For example, a forest ecologist is a life scientist who studies interactions in forest ecosystems. Biologists ask questions such as the following: How do plants produce their own food? Why do some animals give birth to live young and others lay eggs? How are reptiles and birds related?

Key Concepts

- What is scientific inquiry?
- What are the results of scientific investigations?
- How can a scientist prevent bias in a scientific investigation?

Study Coach

Building Vocabulary Write each vocabulary term in this lesson on an index card. Shuffle the cards. After you have studied the lesson, take turns picking cards with a partner. Each of you should define the term using your own words.

Reading Check

1. Describe the behaviors scientists use in their work.

Earth Science The study of Earth, including Earth's landforms, rocks, soil, and forces that shape Earth's surface, is Earth science. Earth scientists ask questions such as the following: How do rocks form? What causes earthquakes? What substances are in soil?

Physical Science The study of chemistry and physics is physical science. Physical scientists study the interactions of matter and energy. They ask questions such as these: How do substances react and form new substances? Why does a liquid change to a solid? How are force and motion related?

Reading Check

2. Explain Why do scientists practice scientific inquiry?

Scientific Inquiry

As scientists study the natural world, they ask questions about what they observe. To find the answers to these questions, they use certain skills, or methods. The figure below and at the bottom of the next page shows a sequence of the skills that a scientist might use in an investigation. Sometimes, not all of these skills are performed in an investigation or are performed in this order. Scientists practice scientific inquiry—a process that uses a variety of skills and tools to answer questions or to test ideas about the natural world.

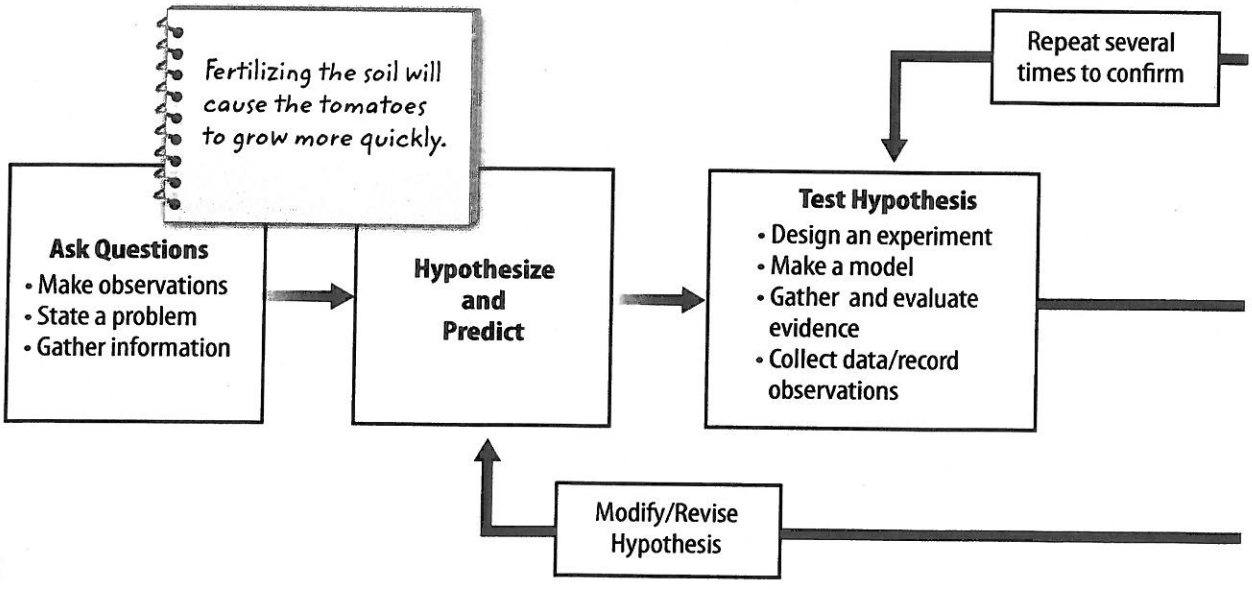
Visual Check

3. Recognize What happens if a hypothesis is not supported?

Ask Questions

Like a scientist, you use scientific inquiry in your life, too. Suppose you decide to plant a vegetable garden. As you plant, you water some seeds more than others. You weed part of the garden and mix fertilizer into some of the soil.

Steps in Scientific Investigation



Observation After a few weeks, you observe that some plants are growing better than others. An **observation** *is using one or more of your senses to gather information and take note of what occurs.* Observations often are the beginning of the process of inquiry and can lead to questions such as "Why are some plants growing better than others?"

Inferring As you are making observations and asking questions, you recall that plants need water and light to grow. You infer that perhaps some vegetables are receiving more water or sunlight than others and, therefore, are growing better. *An* **inference** *is a logical explanation of an observation that is drawn from prior knowledge or experience.*

Hypothesize

After making observations and inferences, you are ready to develop a hypothesis and investigate why some vegetable plants are growing better than others. *A possible explanation about an observation that can be tested by scientific investigations is a* **hypothesis.** Your hypothesis might be: Some plants are growing larger and more quickly than others because they are receiving more water and sunlight. Or, your hypothesis might be: The plants that are growing quickly have received fertilizer because fertilizer helps plants grow.

Predict

After you state a hypothesis, you might make a prediction to help you test your hypothesis. *A* **prediction** *is a statement of what will happen next in a sequence of events.* For instance, based on your hypotheses, you might predict that if some plants receive more water, sunlight, or fertilizer, then they will grow larger.

Reading Check

4. Consider How does the process of inquiry usually begin?

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Reading Check

5. Analyze What is the purpose of a hypothesis?

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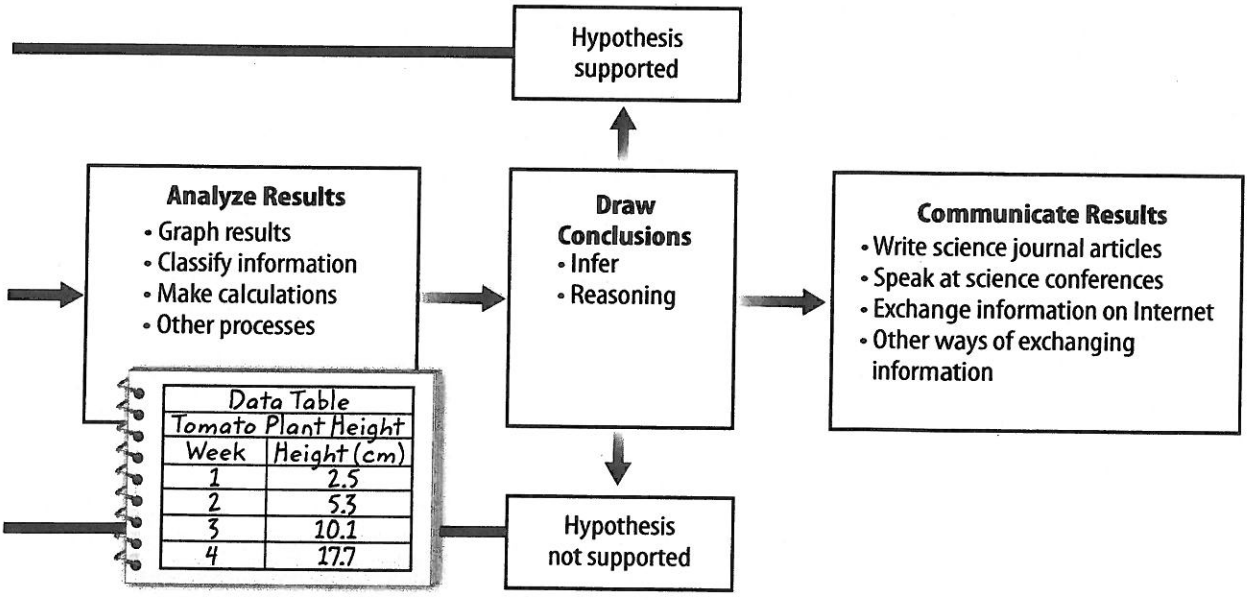

Test Your Hypothesis

When you test a hypothesis, you often are testing your predictions. For example, you might design an experiment to test you hypothesis on the fertilizer. You set up an experiment in which you plant seeds and add fertilizer to only some of them. Your prediction is that the plants that get the fertilizer will grow more quickly. If your prediction is confirmed, your hypothesis is supported. If your prediction is not confirmed, you hypothesis might need revision.

Analyze Results

As you are testing your hypothesis, you are probably collecting data about the plants' growth rates and how much fertilizer each plant receives. At first, it might be difficult to recognize patterns and relationships in data. Your next step might be to organize and analyze your data. You can create graphs, classify information, or make models and calculations. After the data are organized, you can more easily study the data and draw conclusions.

Reading Check

6. Relate What are three ways to organize data?

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Draw Conclusions

Now you must decide whether your data support your hypothesis and then draw conclusions. A conclusion is a summary of the information gained from testing a hypothesis. You might make more inferences when drawing conclusions. If your hypothesis is supported, you can repeat your experiment several times to confirm your results. If your hypothesis is not supported, you can modify it and repeat the scientific inquiry process.

Reading Check

7. Explain What should scientists do if their hypothesis is supported?

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Communicate Results

An important step in scientific inquiry is communicating results to others. Professional scientists write scientific articles, speak at conferences, or exchange information on the Internet.

Communication is an important part of scientific inquiry. Scientists use new information from other scientists in their research or perform other scientists' investigations to verify results.

Key Concept Check

8. Confirm What is scientific inquiry?

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Results of Scientific Inquiry

Scientists perform scientific inquiry to find answers to their questions. Scientific inquiry can have many possible outcomes, such as technology, materials, and explanations, as described in the following paragraphs.

Technology New technology is one possible outcome of scientific inquiry. **Technology** *is the practical use of scientific knowledge, especially for industrial or commercial use.* Televisions, MP3 players, and computers are examples of technology.

New Materials The creation of new materials is another possible outcome of an investigation. For example, scientists have developed a bone bioceramic. A bioceramic is a natural calcium-phosphate mineral complex that is part of bones and teeth. This synthetic bone mimics natural bone's structure. Its porous structure allows a type of cell to grow and develop into new bone tissue.

The bioceramic can be shaped into implants that are treated with certain cells from the patient's bone marrow. It then can be implanted into the patient's body to replace missing bone.

Possible Explanations Many times, scientific investigations answer the questions who, what, when, where, and how. For example, who left fingerprints at a crime scene? When should fertilizer be applied to plants? What organisms live in rain forests?

Scientific Theory and Scientific Laws

Scientists often repeat scientific investigations many times to verify, or confirm, that the results for a hypothesis or a group of hypotheses are correct. This can lead to a scientific theory.

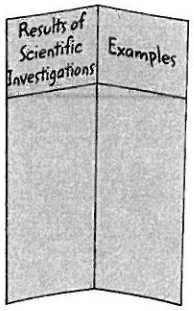
Scientific Theory The everyday meaning of the word *theory* is "an untested idea or an opinion." However, in science, *theory* has a different meaning. *A* **scientific theory** *is an explanation of observations or events based on knowledge gained from many observations and investigations.*

For example, about 300 years ago, scientists began looking at samples of trees, water, and blood through the first microscopes. They noticed that all these organisms were made of tinier units, or cells. As more scientists observed cells in other organisms, their observations became known as the cell theory.

The cell theory explains that all living things are made of cells. A scientific theory is assumed to be the best explanation of observations unless it is disproved. The cell theory will continue to explain the makeup of all organisms until an organism is discovered that is not made of cells.

FOLDABLES

Make a two-column chart book to organize your notes on scientific investigations.



Key Concept Check

9. Define What are the results of scientific investigations?

Reading Check

10. Point Out What can change a scientific theory?

Scientific Laws Scientific laws are different from societal laws, which are an agreement on a set of behaviors. *A* **scientific law** *describes a pattern or an event in nature that is always true.* A scientific theory might explain how and why an event occurs. But a scientific law states only that an event in nature will occur under specific conditions.

Example of Scientific Law The law of conservation of mass states that the mass of materials will be the same before and after a chemical reaction. This scientific law does not explain why this occurs—only that it will occur. The table below compares a scientific theory and a scientific law.

Comparing Scientific Theory and Scientific Law

Scientific Theory	Scientific Law
A scientific theory is based on repeated observations and scientific investigations.	Scientific laws are observations of similar events that have been observed repeatedly.
If new information does not support a scientific theory, the theory will be modified or rejected.	If new observations do not follow the law, the law is rejected.
A scientific theory attempts to explain why something happens.	A scientific law states that something will happen.
A scientific theory usually is more complex than a scientific law and might contain many well-supported hypotheses.	A scientific law usually contains one well-supported hypothesis that states that an event will occur.

Interpreting Tables

11. Consider How do scientific theories and laws compare?

Skepticism in Media

When you see scientific issues in the media, such as newspapers, radio, television, and magazines, it is important to be skeptical. When you are skeptical, you question information that you read or hear, or events you observe. Is the information truthful? Is it accurate? It also is important that you question statements made by people outside their area of expertise and claims that are based on vague statements.

Reading Check

12. Summarize Why is it important to question information in the media?

Evaluating Scientific Evidence

Critical thinking is an important skill in scientific inquiry. **Critical thinking** *is comparing what you already know with the information you are given in order to decide whether you agree with it.* Identifying and preventing bias also is important when conducting scientific inquiry. To prevent bias in an investigation, sampling, repetition, and blind studies can be helpful, as shown in the figure on the next page.

Key Concept Check

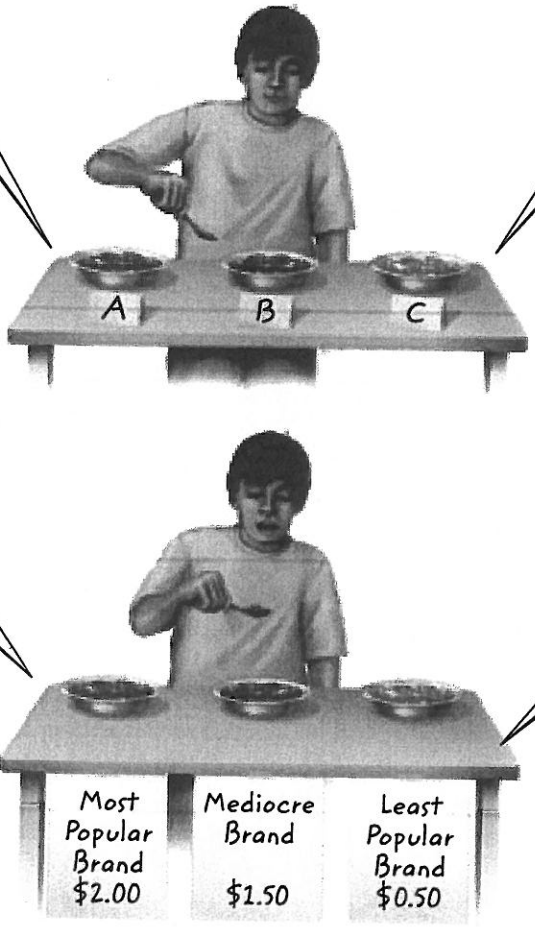
13. State How can a scientist prevent bias in a scientific investigation?

Identifying and Preventing Bias

1 Sampling
A method of data collection that involves studying small amounts of something in order to learn about the larger whole is sampling. A sample should be a random representation of the whole.

2 Bias
It is important to remain unbiased during scientific investigations. Bias is intentional or unintentional prejudice toward a specific outcome. Sources of bias in an investigation can include equipment choices, hypothesis formation, and prior knowledge.

Suppose you were part of a taste test for a new cereal. If you knew the price of each cereal, you might think that the most expensive one tastes the best. This is a bias.



3 Blind Study
A procedure that can reduce bias is a blind study. The investigator, subject, or both do not know which item they are testing. Personal biases cannot affect an investigation if participants do not know what they are testing.

4 Repetition
If you get different results when you repeat an investigation, then the original investigation probably was flawed. Repetition of an experiment helps reduce bias.

Science cannot answer all questions.

You might think that any question can be answered through a scientific investigation. But some questions cannot be answered using science.

For example, science cannot answer a question such as, Which paint color is the prettiest? Questions about personal opinions, values, beliefs, and feelings cannot be answered scientifically. However, some people use scientific evidence to try to strengthen their claims about these topics.

Visual Check

14. Identify What are some sources of bias?

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Safety in Science

Scientists follow safety procedures when they conduct investigations. You also should follow safety procedures when you do any experiments. You should wear appropriate safety equipment and listen to your teacher's instructions. Also, you should learn to recognize potential hazards and know the meaning of safety symbols.

Ethics are especially important when using living things during investigations. Animals should be treated properly. Scientists also should tell research participants about the potential risks and benefits of the research. Anyone can refuse to participate in scientific research.

ACADEMIC VOCABULARY

ethics
(noun) rules of conduct or moral principles

After You Read

Mini Glossary

critical thinking: comparing what you already know with the information you are given in order to decide whether you agree with it

hypothesis: a possible explanation about an observation that can be tested by scientific investigations

inference: a logical explanation of an observation that is drawn from prior knowledge or experience

observation: using one or more of your senses to gather information and take note of what occurs

prediction: a statement about what will happen next in a sequence of events

science: the investigation and exploration of natural events and of the new information that results from those investigations

scientific law: a pattern or an event in nature that is always true

scientific theory: an explanation of observations or events based on knowledge gained from many observations and investigations

technology: the practical use of scientific knowledge, especially for industrial or commercial use

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes the importance of critical thinking.

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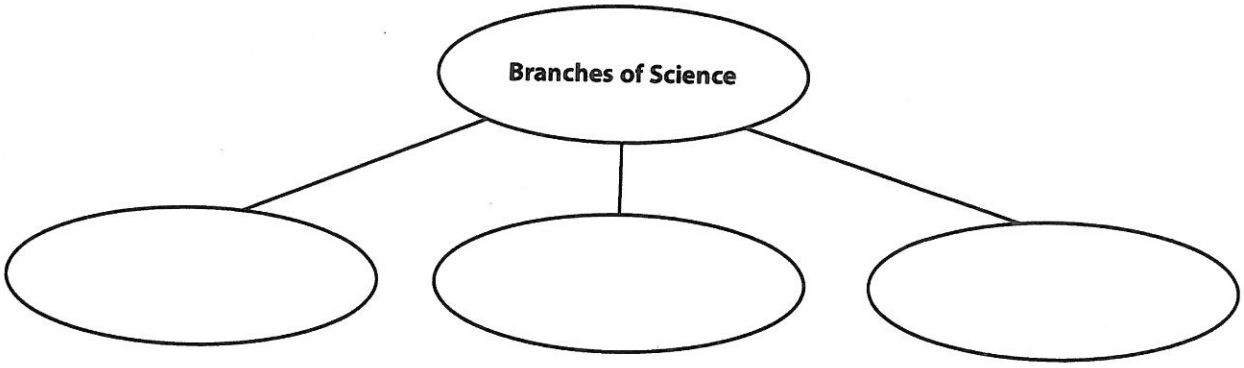
2. Use the graphic organizer below to list the three branches of science.



3. Discuss what types of questions cannot be answered scientifically and why.

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ConnectED

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END OF LESSON