How Are Electricity & DNA Connected?

CONTENTS

NATIONAL GEOGRAPHIC

In 1831, a scientist produced electricity by passing a magnet through a coil of wire. This confirmed what hundreds of previous scientific investigations had attempted. That simple experiment began a new era—the electrical age. By 1892, it was realized that electricity could be used for heating. Two years later, electricity was first used for cooking. In 1918, electric washing machines became available, and the next year, the refrigerator appeared on the electrical scene. By this time, electricity had been accepted as the energy of the future. Gas lighting and steam engines were losing ground to the new electric lights and motors. With electricity came radios, televisions, power tools, and automated appliances. In the 1970s, a new use was discovered for electricity. Scientists discovered that an electrical current passed through a gel containing fragments of DNA could separate larger ones from smaller ones. This process, called electrophoresis (ih lek truh fuh REE sus), is now used in DNA fingerprinting.

unit projects

Visit **blue.msscience.com/unit_project** to find project ideas and resources. Projects include:

- **History** Become a genealogist looking for patterns of hereditary traits in your family tree.
- **Career** Research the process of DNA fingerprinting and how it has helped police find and prosecute criminals in a court of law.
- **Model** Using DNA codes, investigate a mock crime scene, and then present mock evidence to a judge and jury of your peers.

WebQuest *Human Clone: Ethical Consideration* provides an opportunity to explore cloning, to discover the ethical debate, and what laws govern cloning.

CONTENTS

chapter 1

The Nature of Science

chapter preview

sections

Science at Work

Science is going on all the time. You probably use science skills to investigate the world around you. In labs, such as the one shown, scientists use skills and tools to answer questions and solve problems.

Science Journal Describe the most interesting science activity you've done. Identify as many parts of the scientific process used in the activity as you can.

TEK Image/Science Photo Library/Photo Researchers

CONTENTS

Start-Up Activities

Measure Using Tools

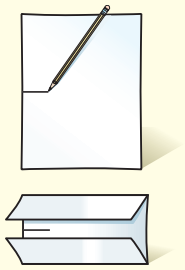
Ouch! That soup is hot. Your senses tell you a great deal of information about the world around you, but they can't answer every question. Scientists use tools, such as thermometers, to measure accurately. Learn more about the importance of using tools in the following lab.

1. Use three bowls. Fill one with cold water, one with lukewarm water, and the third with hot water. **WARNING:** *Make sure the hot water will not burn you.*
2. Use a thermometer to measure the temperature of the lukewarm water. Record the temperature.
3. Submerse one hand in the cold water and the other in the hot water for 2 min.
4. Put both hands into the bowl of lukewarm water. What do you sense with each hand? Record your response in your Science Journal.
5. **Think Critically** In your Science Journal, write a paragraph that explains why it is important to use tools to measure information.

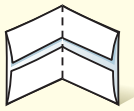
FOLDABLES™ Study Organizer

Make the following foldable to help you stay focused and better understand scientists when you are reading the chapter.

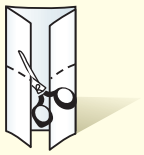
STEP 1 **Draw** a mark at the midpoint of a sheet of paper along the side edge. Then **fold** the top and bottom edges in to touch the midpoint.



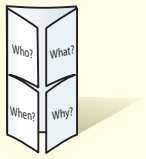
STEP 2 **Fold** in half from side to side.



STEP 3 **Turn** the paper vertically. **Open and cut** along the inside fold lines to form four tabs.



STEP 4 **Label** each tab.



Classify As you read the chapter, list the characteristics of the four major divisions of scientists under each tab.

ScienceOnline | Preview this chapter's content and activities at blue.msscience.com

section 1

What is science?

as you read

What You'll Learn

- **Identify** how science is a part of your everyday life.
- **Describe** what skills and tools are used in science.

Why It's Important

What and how you learn in science class can be applied to other areas of your life.

Review Vocabulary

observation: gathering information through the use of one or more senses

New Vocabulary

- science
- technology

Science in Society

When you hear the word *science,* do you think only of your science class, your teacher, and certain terms and facts? Is there any connection between what happens in science class and the rest of your life? You might have problems to solve or questions that need answers, as illustrated in **Figure 1.** Science is a way or a process used to investigate what is happening around you. It can provide possible answers to your questions.

Science Is Not New Throughout history, people have tried to find answers to questions about what was happening around them. Early scientists tried to explain things based on their observations. They used their senses of sight, touch, smell, taste, and hearing to make these observations. From the Launch Lab, you know that using only your senses can be misleading. What is cold or hot? How heavy is heavy? How much is a little? How close is nearby? Numbers can be used to describe observations. Tools, such as thermometers and metersticks, are used to give numbers to descriptions. Scientists observe, investigate, and experiment to find answers, and so can you.

Figure 1 You use scientific thinking every day to make decisions.

CONTENTS

Science as a Tool

As Luis and Midori walked into science class, they still were talking about their new history assignment. Mr. Johnson overheard them and asked what they were excited about.

"We have a special assignment—celebrating the founding of our town 200 years ago," answered Luis. "We need to do a project that demonstrates the similarities of and differences between a past event and something that is happening in our community now."

Mr. Johnson responded. "That sounds like a big undertaking. Have you chosen the two events yet?"

"We read some old newspaper articles and found several stories about a cholera epidemic here that killed ten people and made more than 50 others ill. It happened in 1871—soon after the Civil War. Midori and I think that it's like the *E. coli* outbreak going on now in our town," replied Luis.

"What do you know about an outbreak of cholera and problems caused by *E. coli*, Luis?"

"Well, Mr. Johnson, cholera is a disease caused by a bacterium that is found in contaminated water," Luis replied. "People who eat food from this water or drink this water have bad cases of diarrhea and can become dehydrated quickly. They might even die. *E. coli* is another type of bacterium. Some types of *E. coli* are harmless, but others cause intestinal problems when contaminated food and water are consumed."

"In fact," added Midori, "one of the workers at my dad's store is just getting over being sick from *E. coli*. Anyway, Mr. Johnson, we want to know if you can help us with the project. We want to compare how people tracked down the source of the cholera in 1871 with how they are tracking down the source of the *E. coli* now."

Figure 2 Newspapers, magazines, books, and the Internet are all good sources of information.

Using Science Every Day

"I'll be glad to help. This sounds like a great way to show how science is a part of everyone's life. In fact, you are acting like scientists right now," Mr. Johnson said proudly.

Luis had a puzzled look on his face, then he asked, "What do you mean? How can we be doing science? This is supposed to be a history project."

INTEGRATE Social Studies

Science in Advertising
You can't prevent all illnesses. You can, however, take steps to reduce your chances of coming in contact with disease-causing organisms. Antibacterial soaps and cleansers claim to kill such organisms, but how do you know if they work? Read ads for or labels on such products. Do they include data to support their claims? Communicate what you learn to your class.

Topic: Disease Control

Visit blue.msscience.com for Web links to information about disease control and the Centers for Disease Control and Prevention (CDC).

Activity Research two different diseases that the CDC have tracked down and identified in the past five years. Prepare a poster that includes the following information: symptoms, cause, cures or treatments, and locations.

Scientists Use Clues "Well, you're acting like a detective right now. You have a problem to solve. You and Midori are looking for clues that show how the two events are similar and different. As you complete the project, you will use several skills and tools to find the clues." Mr. Johnson continued, "In many ways, scientists do the same thing. People in 1871 followed clues to track the source of the cholera epidemic and solve their problem. Today, scientists are doing the same thing by finding and following clues to track the source of the *E. coli*."

Using Prior Knowledge

Mr. Johnson asked, "Luis, how do you know what is needed to complete your project?"

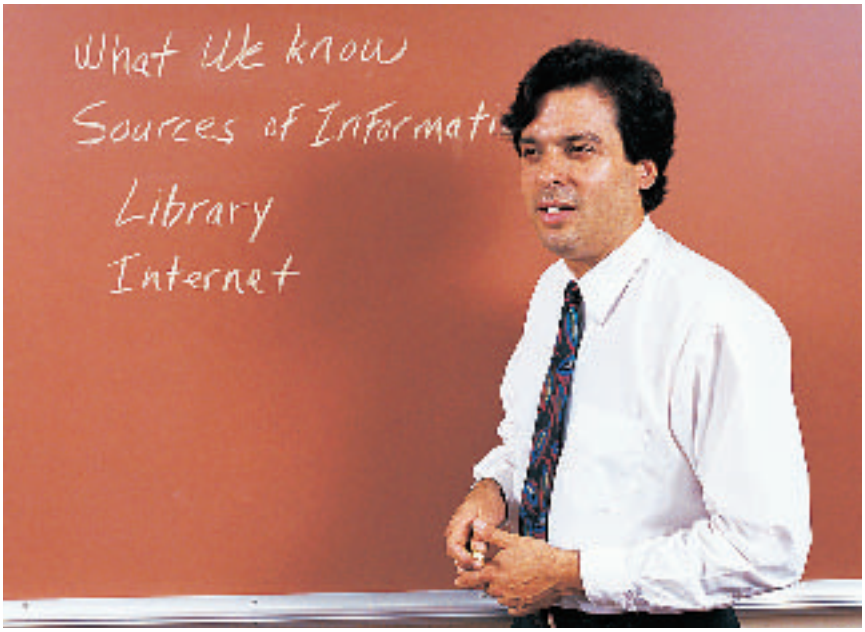
Luis thought, then responded, "Our history teacher, Ms. Hernandez, said the report must be at least three pages long and have maps, pictures, or charts and graphs. We have to use information from different sources such as written articles, letters, videotapes, or the Internet. I also know that it must be handed in on time and that correct spelling and grammar count."

"Did Ms. Hernandez actually talk about correct spelling and grammar?" asked Mr. Johnson.

Midori quickly responded, "No, she didn't have to. Everyone knows that Ms. Hernandez takes points away for incorrect spelling or grammar. I forgot to check my spelling in my last report and she took off two points."

"Ah-ha! That's where your project is like science," exclaimed Mr. Johnson. "You know from experience what will happen. When you don't follow her rule, you lose points. You can predict, or make an educated guess, that Ms. Hernandez will react the same way with this report as she has with others."

Mr. Johnson continued, "Scientists also use prior experience to predict what will occur in investigations. Scientists form theories when their predictions have been well tested. A theory is an explanation that is supported by facts. Scientists also form laws, which are rules that describe a pattern in nature, like gravity."



Aaron Haupt

Figure 3 When solving a problem, it is important to discover all background information. Different sources can provide such information.
Explain *how you would find information on a specific topic. What sources of information would you use?*

Using Science and Technology

"Midori, you said that you want to compare how the two diseases were tracked. Like scientists, you will use skills and tools to find the similarities and differences." Mr. Johnson then pointed to Luis. "You need a variety of resource materials to find information. How will you know which materials will be useful?"

"We can use a computer to find books, magazines, newspapers, videos, and web pages that have information we need," said Luis.

"Exactly," said Mr. Johnson. "That's another way that you are thinking like scientists. The computer is one tool that modern scientists use to find and analyze data. The computer is an example of technology. **Technology** is the application of science to make products or tools that people can use. One of the big differences you will find between the way diseases were tracked in 1871 and how they are tracked now is the result of new technology."

Figure 4 Computers are one example of technology. Schools and libraries often provide computers for students to do research and word processing.

Science Skills

"Perhaps some of the skills used to track the two diseases will be one of the similarities between the two time periods," continued Mr. Johnson. "Today's doctors and scientists, like those in the late 1800s, use skills such as observing, classifying, and interpreting data. In fact, you might want to review the science skills we've talked about in class. That way, you'll be able to identify how they were used during the cholera outbreak and how they still are used today."

Luis and Midori began reviewing the science skills that Mr. Johnson had mentioned. Some of these skills used by scientists are described in the Science Skill Handbook at the back of this book. The more you practice these skills, the better you will become at using them.

Mini LAB

Inferring from Pictures

Procedure

1. Study the two pictures to the left. Write your observations in your **Science Journal.**
2. Make and record inferences based on your observations.
3. Share your inferences with others in your class.

Analysis

1. Analyze your inferences. Are there other explanations for what you observed?
2. Why must you be careful when making inferences?

Observation and Measurement Think about the Launch Lab at the beginning of this chapter. Observing, measuring, and comparing and contrasting are three skills you used to complete the activity. Scientists probably use these skills more than other people do. You will learn that sometimes observation alone does not provide a complete picture of what is happening. To ensure that your data are useful, accurate measurements must be taken, in addition to making careful observations.

Reading Check ***What are three skills commonly used in science?***

Luis and Midori want to find the similarities and differences between the disease-tracking techniques used in the late 1800s and today. They will use the comparing and contrasting skill. When they look for similarities among available techniques, they compare them. Contrasting the available techniques is looking for differences.

Communication in Science

What do scientists do with their findings? The results of their observations, experiments, and investigations will not be of use to the rest of the world unless they are shared. Scientists use several methods to communicate their observations.

Results and conclusions of experiments often are reported in one of the thousands of scientific journals or magazines that are published each year. Some of these publications are shown in **Figure 5.** Scientists spend a large part of their time reading journal articles. Sometimes, scientists discover information in articles that might lead to new experiments.

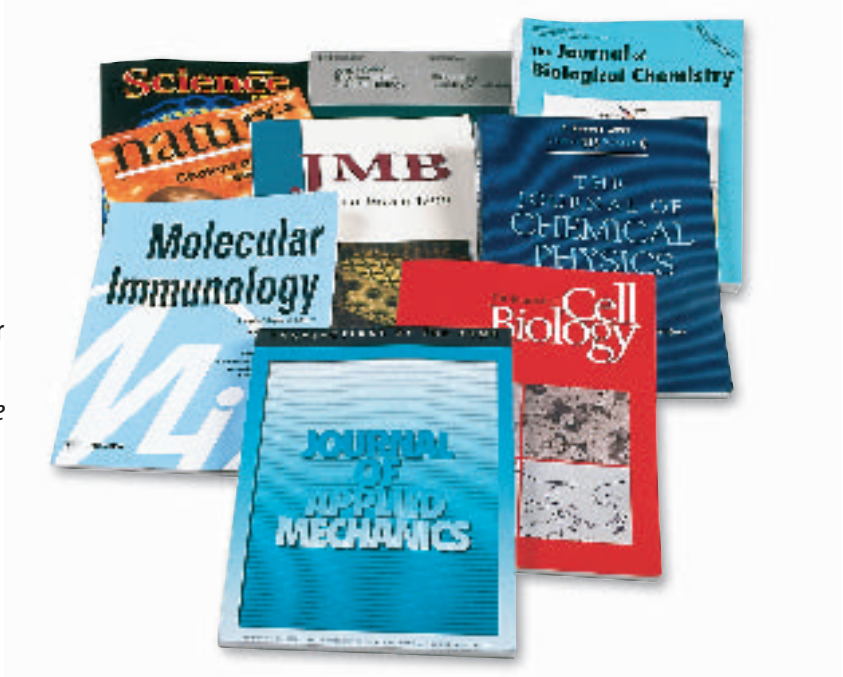


Figure 5 Scientific publications enable scientists around the world to learn about the latest research. Papers are submitted to journals. Other scientists review them before they are published. **Explain** *why other scientists review papers before they are published.*

Science Journal Another method to communicate scientific data and results is to keep a Science Journal. Observations and plans for investigations can be recorded, along with the step-by-step procedures that were followed. Listings of materials and drawings of how equipment was set up should be in a journal, along with the specific results of an investigation. You should record mathematical measurements or formulas that were used to analyze the data. Problems that occurred and questions that came up during the investigation should be noted, as well as any possible solutions. Your data might be summarized in the form of tables, charts, or graphs, or they might be recorded in a paragraph. Remember that it's always important to use correct spelling and grammar in your Science Journal.

Reading Check ***What are some ways to summarize data from an investigation?***

You will be able to use your Science Journal, as illustrated in **Figure 6,** to communicate your observations, questions, thoughts, and ideas as you work in science class. You will practice many of the science skills and become better at identifying problems. You will learn to plan investigations and experiments that might solve these problems.

Figure 6 Your Science Journal is used to record and communicate your findings. It might include graphs, tables, and illustrations.

section 1 review

Summary

Science in Society

- People use their senses to observe their surroundings.
- Scientific process is used to solve problems and answer questions.

Using Prior Knowledge

- Scientists use prior knowledge to predict the outcome of investigations.
- After hypotheses have been tested many times, theories are formed.

Using Science and Technology

- Journals, newspapers, books, and the Internet can be useful sources of information.
- Observation, classification, and interpretation are important scientific skills.

Communication in Science

- Scientists communicate their observations, experiments, and results with others.

Self Check

1. **Infer** why scientists use tools, such as thermometers and metersticks, when they make observations.
2. **Determine** what some skills used in science are. Name one science skill that you have used today.
3. **Evaluate** one example of technology. How is technology different from science?
4. **Think Critically** Why is a Science Journal used to record data? What are three different ways you could record or summarize data in your Science Journal?

Applying Skills

5. **Compare and Contrast** Sometimes you use your senses to make observations to find the answer to a question. Other times you use tools and measurements to provide answers. Compare and contrast these two methods of answering scientific questions.
6. **Communicate** In your Science Journal, record five things you observe in or about your classroom.

Geoff Butler

LAB

Battle of the Beverage Mixes

You can use science skills to answer everyday questions or to solve problems. For example, you might know that the cheapest brand of a product is not always the best value. In this lab, you will test one aspect, or quality, of a product.

Real-World Question

Which brand of powdered beverage mix dissolves best?

Goals

- **Determine** which brand of powdered beverage mix dissolves best using science skills.

Materials

weighing paper
50-mL graduated cylinder
powdered beverage mixes (3 or 4)
triple-beam balance
**electronic balance*
250-mL beaker
water
spoon

**Alternate materials*

Safety Precautions

WARNING: *Never eat or drink anything during science experiments.*

Procedure

1. Copy the following data table in your Science Journal.

Beverage-Mix Data	
Beverage Mix	Mass of Dissolved Powder (g)

2. Using the graduated cylinder, measure 50 mL of water and pour the water into the beaker.
3. **Measure** 20 g of powder from one of the brands of beverage powder.
4. Gradually add the powder to the water. Stir the mixture after each time that you add more powder. Stop adding powder when undissolved powder begins to accumulate at the bottom of the beaker.
5. **Measure** the mass of the remaining powder. Subtract this number from 20 g to find the amount of powder that was dissolved. Record your answer in your data table.
6. Empty the beverage mix into the sink, rinse out your beaker, and repeat steps 2 through 5 for the other brands of beverage mix.

Conclude and Apply

1. **Identify** the beverage-mix powder that dissolved best in the water.
2. **Infer** which beverage-mix brand would taste the best, based on the data you collected.
3. **List** the science skills you used during this experiment to help you determine the best beverage mix. Which beverage-mix brand would you buy?
4. **Review** promotional pamphlets. Make a list of inferences about the claims presented.

Communicating Your Data

Write and perfom a 15-s advertisement about why people should buy the best-dissolving beverage-mix brand. **For more help, refer to the Science Skill Handbook.**

section 2

Doing Science

Solving Problems

When Luis and Midori did their project, they were answering a question. However, there is more than one way to answer a question or solve a scientific problem. Every day, scientists work to solve scientific problems. Although the investigation of each problem is different, scientists use some steps in all investigations.

Identify the Problem Scientists first make sure that everyone working to solve the problem has a clear understanding of the problem. Sometimes, scientists find that the problem is easy to identify or that several problems need to be solved. For example, before a scientist can find the source of a disease, the disease must be identified correctly.

How can the problem be solved? Scientists know that scientific problems can be solved in different ways. Two of the methods used to answer questions are descriptive research and experimental research design. **Descriptive research** answers scientific questions through observation. When Luis and Midori gathered information to learn about cholera and *E. coli*, they performed descriptive research. **Experimental research design** is used to answer scientific questions by testing a hypothesis through the use of a series of carefully controlled steps. **Scientific methods,** like the one shown in **Figure 7,** are ways, or steps to follow, to try to solve problems. Different problems will require different scientific methods to solve them.

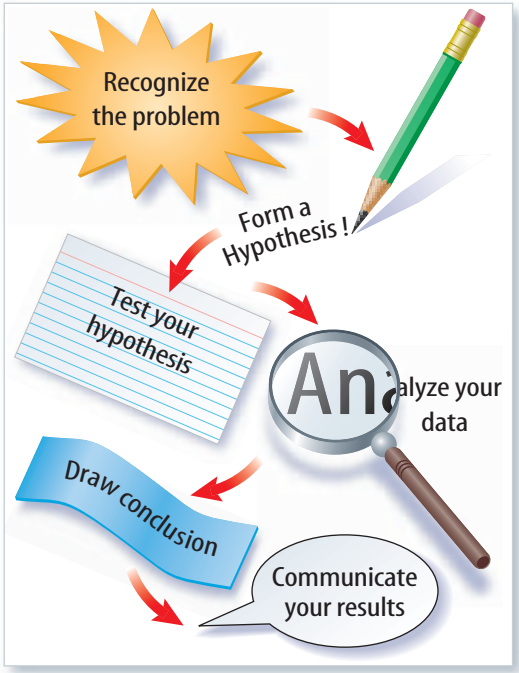


Figure 7 This poster shows one way to solve problems using scientific methods.

as you read

What You'll Learn

- **Examine** the steps used to solve a problem in a scientific way.
- **Explain** how a well-designed investigation is developed.

Why It's Important

Using scientific methods and carefully thought-out experiments can help you solve problems.

Review Vocabulary

experiment: a set of controlled steps carried out to discover, test, or demonstrate something

New Vocabulary

- descriptive research
- experimental research design
- scientific methods
- model
- hypothesis
- independent variable
- dependent variable
- constant
- control

Figure 8 Items can be described by using words and numbers. **Describe** *these objects using both words and numbers.*

Descriptive Research

Some scientific problems can be solved, or questions answered, by using descriptive research. Descriptive research is based mostly on observations. What observations can you make about the objects in **Figure 8?** Descriptive research can be used in investigations when experiments would be impossible to perform. For example, a London doctor, Dr. John Snow, tracked the source of a cholera epidemic in the 1800s by using descriptive research. Descriptive research usually involves the following steps.

State the Research Objective This is the first step in solving a problem using descriptive research. A research objective is what you want to find out, or what question you would like to answer. Luis and Midori might have said that their research objective was "to find out how the sources of the cholera epidemic and *E. coli* epidemic were tracked." Dr. John Snow might have stated his research objective as "finding the source of the cholera epidemic in London."

Applying Science

Problem-Solving Skills

Drawing Conclusions from a Data Table

During an investigation, data tables often are used to record information. The data can be evaluated to decide whether or not the prediction was supported and then conclusions can be drawn.

A group of students conducted an investigation of the human populations of some states in the United States. They predicted that the states with the highest human population also would have the largest area of land. Do you have a different prediction? Record your prediction in your Science Journal before continuing.

Identifying the Problem

The results of the students' research are shown in this chart. Listed are several states in the United States, their human population, and land area.

State Population and Size

State	Human Population	Area (km^2)
New York	18,976,457	122,284
New Jersey	8,414,350	19,210
Massachusetts	6,349,097	20,306
Maine	1,274,923	79,932
Montana	902,195	376,978
North Dakota	642,200	178,647
Alaska	626,902	1,481,350

Source: United States Census Bureau, United States Census 2000

1. What can you conclude about your prediction? If your prediction is not supported by the data, can you come up with a new prediction? Explain.
2. What other research could be conducted to support your prediction?

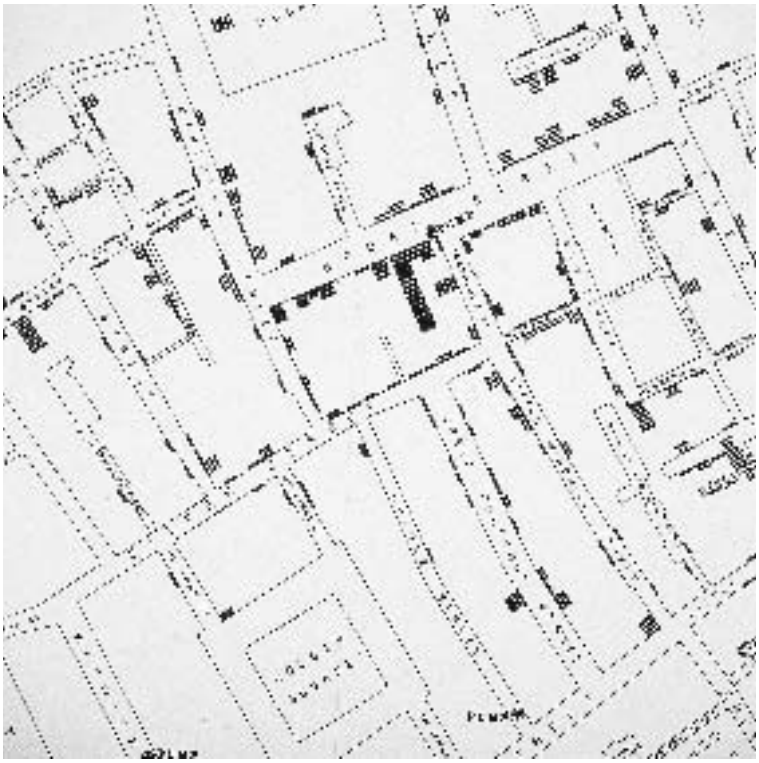


Figure 9 Each mark on Dr. Snow's map shows where a cholera victim lived. Dr. Snow had the water-pump handle removed, and the cholera epidemic ended.

Describe the Research Design How will you carry out your investigation? What steps will you use? How will the data be recorded and analyzed? How will your research design answer your question? These are a few of the things scientists think about when they design an investigation using descriptive research. An important part of any research design is safety. Check with your teacher several times before beginning any investigation.

Reading Check ***What are some questions to think about when planning an investigation?***

Dr. John Snow's research design included the map shown above. The map shows where people with cholera had lived, and where they obtained their water. He used these data to predict that the water from the Broad Street pump, shown in **Figure 9,** was the source of the contamination.

Eliminate Bias It's a Saturday afternoon. You want to see a certain movie, but your friends do not. To persuade them, you tell them about a part of the show that they will find interesting. You give only partial information so they will make the choice you want. Similarly, scientists might expect certain results. This is known as bias. Good investigations avoid bias. One way to avoid bias is to use careful numerical measurements for all data. Another type of bias can occur in surveys or groups that are chosen for investigations. To get an accurate result, you need to use a random sample.

INTEGRATE Environment

The Clean Water Act The U.S. Congress has passed several laws to reduce water pollution. The 1986 Safe Drinking Water Act is a law to ensure that drinking water in the United States is safe. The 1987 Clean Water Act gives money to the states for building sewage- and wastewater-treatment facilities. Find information about a state or local water quality law and share your findings with the class.

Figure 10 This presentation neatly and clearly shows experimental design and data.
List *the aspects of this display that make it easy to follow.*

Equipment, Materials, and Models

When a scientific problem is solved by descriptive research, the equipment and materials used to carry out the investigation and analyze the data are important.

Selecting Your Materials Scientists try to use the most up-to-date materials available to them. If possible, you should use scientific equipment such as balances, spring scales, microscopes, and metric measurements when performing investigations and gathering data. Calculators and computers can be helpful in evaluating or displaying data. However, you don't have to have the latest or most expensive materials and tools to conduct good scientific investigations. Your investigations can be completed successfully and the data displayed with materials found in your home or classroom, like paper, colored pencils, or markers. An organized presentation of data, like the one shown in **Figure 10,** is as effective as a computer graphic or an extravagant display.

Using Models One part of carrying out the investigative plan might include making or using scientific models. In science, a **model** represents things that happen too slowly, too quickly, or are too big or too small to observe directly. Models also are useful in situations in which direct observation would be too dangerous or expensive.

Dr. John Snow's map of the cholera epidemic was a model that allowed him to predict possible sources of the epidemic. Today, people in many professions use models. Many kinds of models are made on computers. Graphs, tables, and spreadsheets are models that display information. Computers can produce three-dimensional models of a microscopic bacterium, a huge asteroid, or an erupting volcano. They are used to design safer airplanes and office buildings. Models save time and money by testing ideas that otherwise are too small, too large, or take too long to build.

Aaron Haupt

Table 1 Common SI Measurements

Measurement	Unit	Symbol	Equal to
Length	1 millimeter	mm	0.001 (1/1,000) m
	1 centimeter	cm	0.01 (1/100) m
	1 meter	m	100 cm
	1 kilometer	km	1,000 m
Liquid volume	1 milliliter	mL	0.001 L
	1 liter	L	1,000 mL
Mass	1 milligram	mg	0.001 g
	1 gram	g	1,000 mg
	1 kilogram	kg	1,000 g
	1 tonne	t	1,000 kg = 1 metric ton

Scientific Measurement Scientists around the world use a system of measurements called the International System of Units, or SI, to make observations. This allows them to understand each other's research and compare results. Most of the units you will use in science are shown in **Table 1.** Because SI uses certain metric units that are based on units of ten, multiplication and division are easy to do. Prefixes are used with units to change their names to larger or smaller units. See the Reference Handbook to help you convert English units to SI. **Figure 11** shows equipment you can use to measure in SI.

Figure 11 Some of the equipment used by scientists is shown here. A graduated cylinder is used to measure liquid volume. Mass is measured with a balance. A scientist would use a thermometer with the Celsius scale to measure temperature.

Matt Meadows

CONTENTS

Mini LAB

Comparing Paper Towels

Procedure

1. Make a data table similar to the one in **Figure 12.**
2. Cut a 5-cm by 5-cm square from each of **three brands of paper towel.** Lay each piece on a level, smooth, waterproof surface.
3. Add one drop of water to each square.
4. Continue to add drops until the piece of paper towel no longer can absorb the water.
5. Tally your observations in your data table and graph your results.
6. Repeat steps 2 through 5 three more times.

Analysis

1. Did all the squares of paper towels absorb equal amounts of water?
2. If one brand of paper towel absorbs more water than the others, can you conclude that it is the towel you should buy? Explain.
3. Which scientific methods did you use to compare paper towel absorbency?

Try at Home

Figure 12 Data tables help you organize your observations and results.

Paper Towel Absorbency (Drops of Water Per Sheet)			
Trial	Brand A	Brand B	Brand C
1			
2			
3			
4			

Data

In every type of scientific research, data must be collected and organized carefully. When data are well organized, they are easier to interpret and analyze.

Designing Your Data Tables A well-planned investigation includes ways to record results and observations accurately. Data tables, like the one shown in **Figure 12,** are one way to do this. Most tables have a title that tells you at a glance what the table is about. The table is divided into columns and rows. These are usually trials or characteristics to be compared. The first row contains the titles of the columns. The first column identifies what each row represents.

As you complete a data table, you will know that you have the information you need to analyze the results of the investigation accurately. It is wise to make all of your data tables before beginning the experiment. That way, you will have a place for all of your data as soon as they are available.

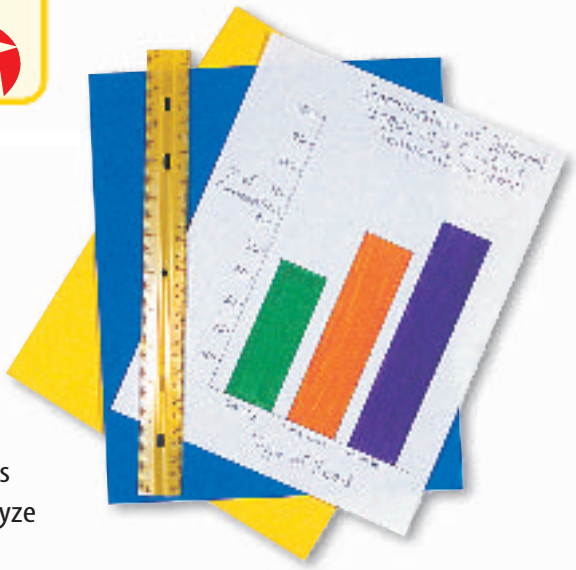


Figure 13 Charts and graphs can help you organize and analyze your data.

Analyze Your Data Your investigation is over. You breathe a sigh of relief. Now you have to figure out what your results mean. To do this, you must review all of the recorded observations and measurements. Your data must be organized to analyze them. Charts and graphs are excellent ways to organize data. You can draw the charts and graphs, like the ones in **Figure 13,** or use a computer to make them.

Doug Martin

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Draw Conclusions

After you have organized your data, you are ready to draw a conclusion. Do the data answer your question? Was your prediction supported? You might be concerned if your data are not what you expected, but remember, scientists understand that it is important to know when something doesn't work. When looking for an antibiotic to kill a specific bacteria, scientists spend years finding out which antibiotics will work and which won't. Each time scientists find that a particular antibiotic doesn't work, they learn some new information. They use this information to help make other antibiotics that have a better chance of working. A successful investigation is not always the one that comes out the way you originally predicted.

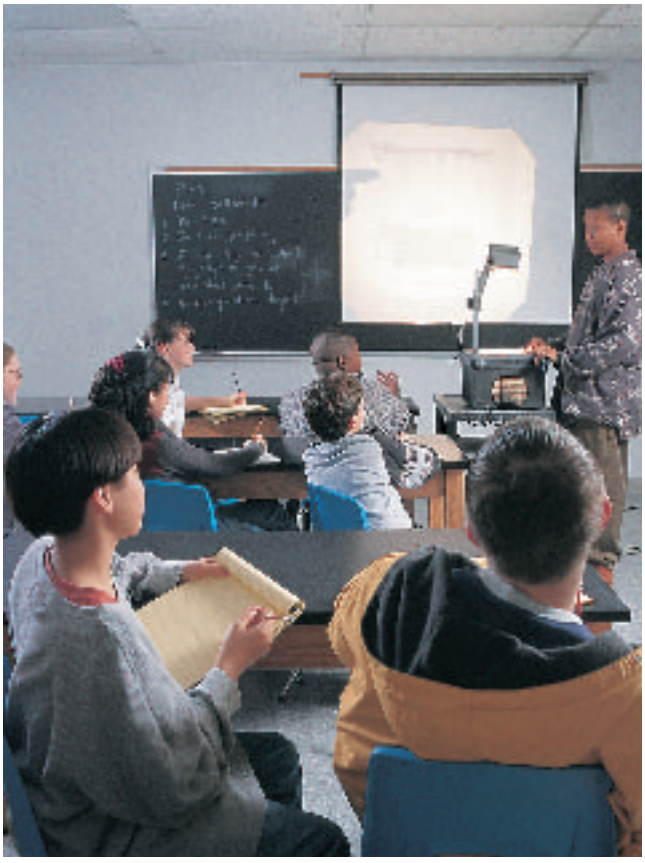

Figure 14 Communicating experimental results is an important part of the laboratory experience.

Communicating Your Results Every investigation begins because a problem needs to be solved. Analyzing data and drawing conclusions are the end of the investigation. However, they are not the end of the work a scientist does. Usually, scientists communicate their results to other scientists, government agencies, private industries, or the public. They write reports and presentations that provide details on how experiments were carried out, summaries of the data, and final conclusions. They can include recommendations for further research. Scientists usually publish their most important findings.

Reading Check ***Why is it important for scientists to communicate their data?***

Just as scientists communicate their findings, you will have the chance to communicate your data and conclusions to other members of your science class, as shown in **Figure 14.** You can give an oral presentation, create a poster, display your results on a bulletin board, prepare computer graphics, give a multimedia presentation, or talk with other students or your teacher. You will share with other groups the charts, tables, and graphs that show your data. Your teacher, or other students, might have questions about your investigation or your conclusions. Organized data and careful analysis will enable you to answer most questions and to discuss your work confidently. Analyzing and sharing data are important parts of descriptive and experimental research, as shown in **Figure 15.**

NATIONAL GEOGRAPHIC

VISUALIZING DESCRIPTIVE AND EXPERIMENTAL RESEARCH

Figure 15

Scientists use a series of steps to solve scientific problems. Depending on the type of problem, they may use descriptive research or experimental research with controlled conditions. Several of the research steps involved in determining water quality at a wastewater treatment plant are shown here.

A Gathering background information is an important first step in descriptive and experimental research.

B Some questions can be answered by descriptive research. Here, the scientists make and record observations about the appearance of a water sample.

C Some questions can be answered by experimentation. These scientists collect a wastewater sample for testing under controlled conditions in the laboratory.

D Careful analysis of data is essential after completing experiments and observations. The technician at right uses computers and other instruments to analyze data.

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Experimental Research Design

Another way to solve scientific problems is through experimentation. Experimental research design answers scientific questions by observation of a controlled situation. Experimental research design includes several steps.

Form a Hypothesis A **hypothesis** (hi PAH thuh sus) is a prediction, or statement, that can be tested. You use your prior knowledge, new information, and any previous observations to form a hypothesis.

Variables In well-planned experiments, one factor, or variable, is changed at a time. This means that the variable is controlled. The variable that is changed is called the **independent variable.** In the experiment shown below, the independent variable is the amount or type of antibiotic applied to the bacteria. A **dependent variable** is the factor being measured. The dependent variable in this experiment is the growth of the bacteria, as shown in **Figure 16.**

To test which of two antibiotics will kill a type of bacterium, you must make sure that every variable remains the same but the type of antibiotic. The variables that stay the same are called **constants.** For example, you cannot run the experiments at two different room temperatures, for different lengths of time, or with different amounts of antibiotics.

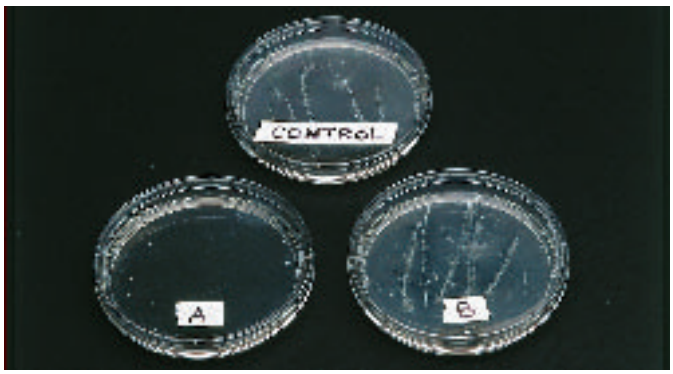


Figure 16 In this experiment, the effect of two different antibiotics on bacterial growth was tested. The type of antibiotic is the independent variable.

At the beginning of the experiment, dishes A and B of bacteria were treated with different antibiotics. The control dish did not receive any antibiotic.

The results of the experiment are shown. All factors were constant except the type of antibiotic applied.
Draw a conclusion *about the effects of these antibiotics on bacteria based on these photographs.*

CONTENTS

Figure 17 Check with your teacher several times as you plan your experiment. **Determine** *why you should check with your teacher several times.*

Identify Controls Your experiment will not be valid unless a control is used. A **control** is a sample that is treated like the other experimental groups except that the independent variable is not applied to it. In the experiment with antibiotics, your control is a sample of bacteria that is not treated with either antibiotic. The control shows how the bacteria grow when left untreated by either antibiotic.

Reading Check ***What is an experimental control?***

You have formed your hypothesis and planned your experiment. Before you begin, you must give a copy of it to your teacher, who must approve your materials and plans before you begin, as shown in **Figure 17.** This is also a good way to find out whether any problems exist in how you proposed to set up the experiment. Potential problems might include health and safety issues, length of time required to complete the experiment, and the cost and availability of materials.

Once you begin the experiment, make sure to carry it out as planned. Don't skip or change steps in the middle of the process. If you do, you will have to begin the experiment again. Also, you should record your observations and complete your data tables in a timely manner. Incomplete observations and reports result in data that are difficult to analyze and threaten the accuracy of your conclusions.

Number of Trials Experiments done the same way do not always have the same results. To make sure that your results are valid, you need to conduct several trials of your experiment. Multiple trials mean that an unusual outcome of the experiment won't be considered the true result. For example, if another substance is spilled accidentally on one of the containers with an antibiotic, that substance might kill the bacteria. Without results from other trials to use as comparisons, you might think that the antibiotic killed the bacteria. The more trials you do using the same methods, the more likely it is that your results will be reliable and repeatable. The number of trials you choose to do will be based on how much time, space, and material you have to complete the experiment.

Analyze Your Results After completing your experiment and obtaining all of your data, it is time to analyze your results. Now you can see if your data support your hypothesis. If the data do not support your original hypothesis, you can still learn from the experiment. Experiments that don't work out as you had planned can still provide valuable information. Perhaps your original hypothesis needs to be revised, or your experiment needs to be carried out in a different way. Maybe more background information is available that would help. In any case, remember that professional scientists, like those shown in **Figure 18,** rarely have results that support their hypothesis without completing numerous trials first.

After your results are analyzed, you can communicate them to your teacher and your class. Sharing the results of experiments allows you to hear new ideas from other students that might improve your research. Your results might contain information that will be helpful to other students.

In this section you learned the importance of scientific methods—steps used to solve a problem. Remember that some problems are solved using descriptive research, and others are solved through experimental research.

Figure 18 These scientists might work for months or years to find the best experimental design to test a hypothesis.

section 2 review

Summary

Solving Problems

- Scientific methods are the steps followed to solve a problem.
- Descriptive research is used when experiments are impossible to use.

Equipment, Materials, and Models

- Models are important tools in science.
- The International System of Units (SI) is used to take measurements.
- Data is collected, recorded, and organized.

Draw Conclusions

- Scientists look for trends in their data, then communicate their findings.

Experimental Research Design

- Experiments start with a hypothesis.
- Variables are factors that are changed. Controls are samples that are not changed.
- Conclusions are drawn. Research is communicated to other scientists.

Self Check

1. **Explain** why scientists use models. Give three examples of models.
2. **Define** the term *hypothesis*.
3. **List** the three steps scientists might use when designing an investigation to solve a problem.
4. **Determine** why it is important to identify carefully the problem to be solved.
5. **Measure** Use a meterstick to measure the length of your desktop in meters, centimeters, and millimeters.
6. **Think Critically** The data that you gathered and recorded during an experiment do not support your original hypothesis. Explain why your experiment is not a failure.

Applying Math

7. **Use Percentages** A town of 1,000 people is divided into five areas, each with the same number of people. Use the data below to make a bar graph showing the number of people ill with cholera in each area.
Area: A—50%; B—5%; C—10%; D—16%; E—35%.

CONTENTS

section 3

Science and Technology

as you read

What You'll Learn

- **Determine** how science and technology influence your life.
- **Analyze** how modern technology allows scientific discoveries to be communicated worldwide.

Why It's Important

Modern communication systems enable scientific discoveries and information to be shared with people all over the world.

Review Vocabulary

computer: an electrical device that can be programmed to store, retrieve, and process data

New Vocabulary

- information technology

Science in Your Daily Life

You have learned how science is useful in your daily life. Doing science means more than just completing a science activity, reading a science chapter, memorizing vocabulary words, or following a scientific method to find answers.

Scientific Discoveries

Science is meaningful in other ways in your everyday life. New discoveries constantly lead to new products that influence your lifestyle or standard of living, such as those shown in **Figure 19.** For example, in the last 100 years, technological advances have enabled entertainment to move from live stage shows to large movie screens. Now DVDs enable users to choose a variety of options while viewing a movie. Do you want to hear English dialogue with French subtitles or Spanish dialogue with English subtitles? Do you want to change the ending? You can do it all from your chair by using the remote control.

Figure 19 New technology has changed the way people work and relax.
Identify *which of the technologies in the photo you have used.*

KS Studios

CONTENTS

Figure 20 Modern medical technology helps people have better health. The physician is studying a series of X rays. New, more complete ways of seeing internal problems helps to solve them.

Technological Advances Technology also makes your life more convenient. Hand-held computers can be carried in a pocket. Foods can be prepared quickly in microwave ovens, and hydraulic tools make construction work easier and faster. A satellite tracking system in your car can give you verbal and visual directions to a destination in an unfamiliar city.

New discoveries influence other areas of your life as well, including your health. Technological advances, like the ones shown in **Figure 20,** help many people lead healthier lives. A disease might be controlled by a skin patch that releases a constant dose of medicine into your body. Miniature instruments enable doctors to operate on unborn children and save their lives. Bacteria also have been engineered to make important drugs such as insulin for people with diabetes.

Reading Check *What new scientific discoveries have you used?*

Science—The Product of Many

New scientific knowledge can mean that old ways of thinking or doing things are challenged. Aristotle, an ancient Greek philosopher, classified living organisms into plants and animals. This system worked until new tools, such as the microscope, enabled scientists to study organisms in greater detail. The new information changed how scientists viewed the living world. The current classification system will be used only as long as it continues to answer questions scientists have or until a new discovery enables them to look at information in a different way.

ScienceOnline

Topic: Student Scientists

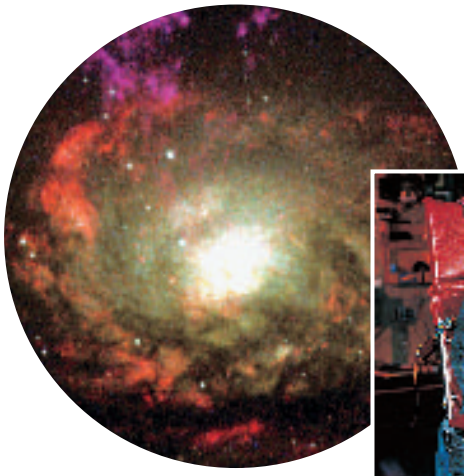
Visit blue.msscience.com for Web links to information about students who have made scientific discoveries or invented new technologies.

Activity Select one of the student scientists you read about. Work with a partner and prepare an interview where one of you is the interviewer and the other is the student scientist.

Figure 21 Science and technology are the results of many people's efforts.

Who practices science? Scientific discoveries have never been limited to people of one race, sex, culture, or time period, or to professional scientists, as shown in **Figure 21.** In fact, students your age have made some important discoveries.

Sarita M. James was a teenager when she developed a system that enables computers to recognize human speech easily.



Stephen Hawking, a physicist, studies the universe and black holes.

Grace Murray Hopper, a mathematician and software developer, helped pioneer the computer field.

Fred Begay is a physicist who studies ways to produce heat energy without harming the environment.

Ellen Ochoa is an inventor and an astronaut in NASA's space shuttle program.

Daniel Hale Williams performed the first open-heart surgery and founded a hospital.

Use of Scientific Information Science provides new information every day that people use to make decisions. A new drug can be found or a new way to produce electricity can be developed. However, science cannot decide whether the new information is good or bad, moral or immoral. People decide whether the new information is used to help or harm the world and its inhabitants. The Internet quickly spreads word of new discoveries. New knowledge and technology brought about by these discoveries are shared by people in all countries. Any information gathered from the Internet must be checked carefully for accuracy.

Looking to the Future

Midori and Luis discovered that technology has changed how modern scientists track the source of a disease. New information about bacteria and modern tools, such as those shown in **Figure 22,** help identify specific types of these organisms. Computers are used to model how the bacteria kill healthy cells or which part of a population the bacteria will infect. Today's scientists use cellular phones and computers to communicate with each other. This **information technology** has led to the globalization, or worldwide distribution, of information.

Figure 22 Modern laboratories enable scientists to track the source of a disease or solve many other scientific problems.

section 3 review

Summary

Science in Your Daily Life

- New discoveries lead to new technologies that make your life more convenient.
- Technological advances help many people lead healthier lives.

Science—The Product of Many

- New information and discoveries change how scientists view the world.
- Discoveries aren't limited to one gender, race, culture, or time period.
- The Internet enables information to spread quickly but it must be checked carefully for accuracy.
- Computers are used to model different situations in science.
- Information technology has led to the worldwide distribution of information.

Self Check

1. **Identify** one way that science or technology has improved your health.
2. **Infer** what might cause scientists to change a 100-year-old theory.
3. **List** five ways that scientists are able to communicate their discoveries.
4. **Describe** an advance in technology that makes your life more enjoyable. What discoveries contributed to this technology?
5. **Think Critically** Explain why modern communications systems are important to scientists worldwide.

Applying Skills

6. **Use a Word Processor** Research the life of a famous scientist. Find at least two sources for your information. Take notes on ten facts about the scientist and use a word processing program to write a short biography.

LAB

Use the Internet

When is the Internet the busiest?

Goals

- **Observe** when you, your friends, or your family use the Internet.
- **Research** how to measure the speed of the Internet.
- **Identify** the times of day when the Internet is the busiest in different areas of the country.
- **Graph** your findings and communicate them to other students.

Data Source

ScienceOnline

Visit blue.msscience.com/internet_lab for more information on how to measure the speed of the Internet, when the Internet is busiest, and data from other students.

Real-World Question

Using the Internet, you can get information any time from practically anywhere in the world. It has been called the "information superhighway." But does the Internet ever get traffic jams like real highways? Is the Internet busier at certain times? How long does it take data to travel across the Internet at different times of the day?

Make a Plan

1. **Observe** when you, your family, and your friends use the Internet. Do you think that everyone in the world uses the Internet during the same times?
2. How are you going to measure the speed of the Internet? Research different factors that might affect the speed of the Internet. What are your variables?
3. How many times are you going to measure the speed of the Internet? What times of day are you going to gather your data?

CONTENTS

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Visit the link shown below. Click on the Web Links button to view links that will help you do this activity.
3. Complete your investigation as planned.
4. **Record** all of your data in your Science Journal.
5. **Share** your data by posting it at the link shown below.

Analyze Your Data

1. **Record** in your Science Journal what time of day you found it took the most time to send data over the Internet.
2. **Compare** your results with those of other students around the country. In which areas did data travel the most quickly?

Conclude and Apply

1. **Compare** your findings to those of your classmates and other data that were posted at the link shown below. When is the Internet the busiest in your area? How does that compare to different areas of the country?
2. **Infer** what factors could cause different results in your class.
3. **Predict** how you think your data would be affected if you had performed this experiment during a different time of the year, like the winter holidays.

Communicating Your Data

Find this lab using the link below. **Post** your data in the table provided. Combine your data with those of other students and plot the combined data on a map to recognize patterns in internet traffic.

ScienceOnline

blue.msscience.com/internet_lab

The Everglades: River of Grass

by Marjory Stoneman Douglas

In this passage, Douglas writes about Lake Okeechobee, the large freshwater lake that lies in the southern part of Florida, north of the Everglades. A dike is an earthen wall usually built to protect against floods.

Something had to be done about the control of Okeechobee waters in storms. . . . A vast dike was constructed from east to south to west of the lake, within its average rim.[1] Canal gates were opened in it. It rises now between the lake itself and all those busy towns. . . .

To see the vast pale water you climb the levee[2] and look out upon its emptiness, hear the limpkins[3] crying among the islands of reeds in the foreground, and watch the wheeling creaking sea gulls flying about a man cutting bait in a boat. . . .

From the lake the control project extended west, cutting a long ugly canal straight through the green curving jungle and the grove-covered banks of Caloosahatchee [River].

Gary Retherford/Photo Researchers

1 "Average rim" refers to the average location of the southern bank of the lake. Before the dike was built, heavy rains routinely caused Lake Okeechobee to overflow, emptying water over its southern banks into the Everglades. The overflowing water would carry silt and soil toward the southern banks of the lake, causing the southern banks to vary in size and location.

2 dike

3 waterbirds

Understanding Literature

Nonfiction Nonfiction stories are about real people, places, and events. Nonfiction includes autobiographies, biographies, and essays, as well as encyclopedias, history and science books, and newspaper and magazine articles. How can you judge the accuracy of the information?

Respond to the Reading

1. How would you verify facts contained in this passage such as the construction of the dike and its location?
2. What hints does the author give you about her opinion of the dike-building project?
3. **Linking Science and Writing** Write a one-page nonfiction account of your favorite outdoor place.

INTEGRATE Life Science

Because nonfiction is based upon real life, nonfiction writers must research their subjects thoroughly. Author Marjory Stoneman Douglas relied upon her own observations as a long-time resident of Florida. She also conducted scientific investigation when she thoroughly researched the history of the Florida Everglades. *The Everglades: River of Grass* brought the world's attention to the need to preserve the Everglades because of its unique ecosystems.

Reviewing Main Ideas

Section 1 What is science?

1. Science is a process that can be used to solve problems or answer questions. Communication is an important part of all aspects of science.
2. Scientists use tools to measure.
3. Technology is the application of science to make tools and products you use each day. Computers are a valuable technological tool.
4. A hypothesis is an idea that can be tested. Sometimes experiments don't support the original hypothesis, and a new hypothesis must be formed.
5. In a well-planned experiment, there is a control and only one variable is changed at a time. All other factors are kept constant.

Section 2 Doing Science

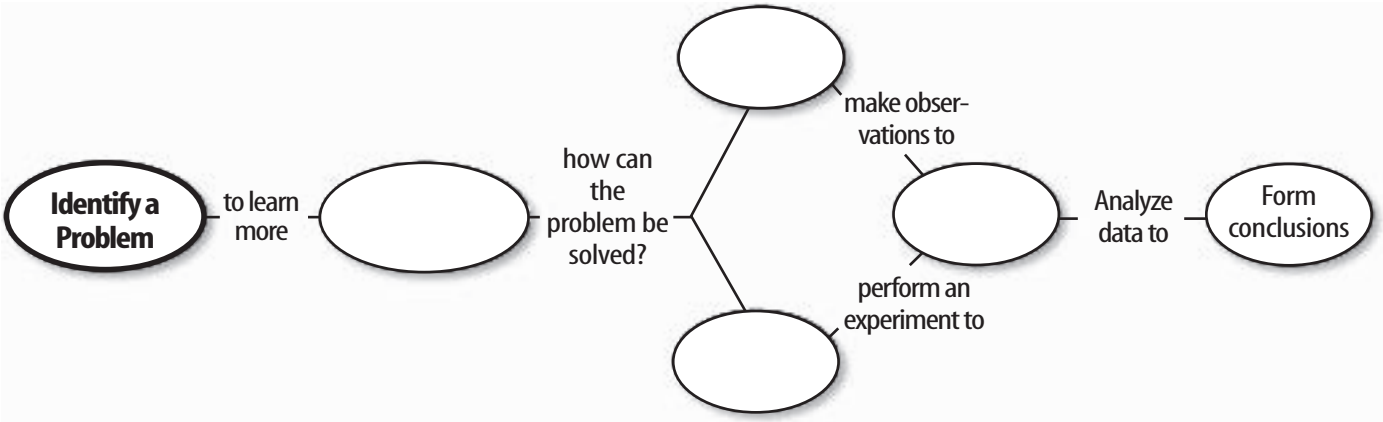
1. No one scientific method is used to solve all problems. Organization and careful planning are important when trying to solve any problem.
2. Scientific questions can be answered by descriptive research or experimental research.
3. Models save time and money by testing ideas that are too difficult to build or carry out. Models cannot completely replace experimentation.

Section 3 Science and Technology

1. Science is part of everyone's life. New discoveries lead to new technology and products.
2. Science continues to challenge old knowledge and ways of doing things. Old ideas are kept until new discoveries prove them wrong.
3. People of all races, ages, sexes, cultures, and professions practice science.
4. Modern communication assures that scientific information is spread around the world.

Visualizing Main Ideas

Copy and complete the following concept map with steps to solving a problem.



chapter 1 Review

Using Vocabulary

constant p. 21
control p. 22
dependent variable p. 21
descriptive research p. 13
experimental research design p. 13
hypothesis p. 21
independent variable p. 21
Information technology p. 27
model p. 16
science p. 6
scientific methods p. 13
technology p. 9

Match each phrase with the correct vocabulary word from the list.

1. the factor being measured in an experiment
2. a statement that can be tested
3. use of knowledge to make products
4. sample treated like other experimental groups except variable is not applied
5. steps to follow to solve a problem
6. a variable that stays the same during every trial of an experiment
7. the variable that is changed in an experiment

Checking Concepts

Choose the word or phrase that best answers the question.

8. To make sure experimental results are valid, which of these procedures must be followed?
   A) conduct multiple trials
   B) pick two hypotheses
   C) add bias
   D) communicate uncertain results

9. Predictions about what will happen can be based on which of the following?
   A) controls **C)** prior knowledge
   B) technology **D)** number of trials

10. Which of the following is the greatest concern for scientists using the Internet?
    A) speed **C)** language
    B) availability **D)** accuracy

11. In an experiment on bacteria, using different amounts of antibiotics is an example of which of the following?
    A) control **C)** bias
    B) hypothesis **D)** variable

12. Computers are used in science to do which of the following processes?
    A) analyze data
    B) make models
    C) communicate with other scientists
    D) all of the above

13. If you use a computer to make a three-dimensional picture of a building, it is an example of which of the following?
    A) model **C)** control
    B) hypothesis **D)** variable

14. When scientists make a prediction that can be tested, what skill is being used?
    A) hypothesizing
    B) inferring
    C) taking measurements
    D) making models

15. Which of the following is the first step toward finding a solution?
    A) analyze data
    B) draw a conclusion
    C) identify the problem
    D) test the hypothesis

16. Which of the following terms describes a variable that does not change in an experiment?
    A) hypothesis **C)** constant
    B) dependent **D)** independent

17. Carmen did an experiment to learn whether fish grew larger in cooler water. Once a week she weighed the fish and recorded the data. What could have improved her experiment?
    A) setting up a control tank
    B) weighing fish daily
    C) using a larger tank
    D) measuring the water temperature

Thinking Critically

18. Infer why it is important to record data as they are collected.

19. Compare and contrast analyzing data and drawing conclusions.

20. Explain the advantage of eliminating bias in experiments.

21. Determine why scientists collect information about what is already known when trying to solve a problem.

22. Recognize Cause and Effect If three variables were changed at one time, what would happen to the accuracy of the conclusions made for an experiment?

Use the photo below to answer question 23.

23. Interpret You applied two different antibiotics to two bacteria samples. The control bacteria sample did not receive any antibiotics. Two of the bacteria samples grew at the same rate. How could you interpret your results?

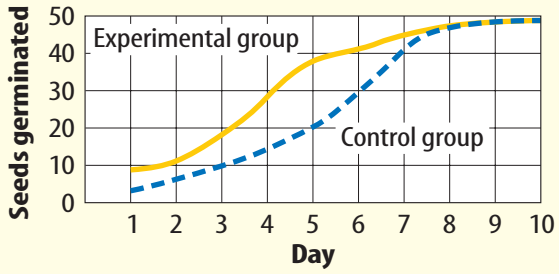
Performance Activities

24. Poster Create a poster showing steps in a scientific method. Use creative images to show the steps to solving a scientific problem.

Applying Math

Use the table below to answer question 25.

The Effect of Temperature on Germination



25. Seed Germination A team of student scientists measured the number of radish seeds that germinated over a 10-day period. The control group germinated at 20°C and the experimental group germinated at 25°C. According to the graph below, how many more experimental seeds than control seeds had germinated by day 5?

26. SI Measurements You have collected a sample of pond water to study in the lab. Your 1-L container is about half full. About how many milliliters of water have you collected? Refer to **Table 1** in this chapter for help.

Use the table below to answer question 27.

Disease Victims

Age Group (years)	Number of People
0–5	37
6–10	20
11–15	2
16–20	1
over 20	0

27. Disease Data Prepare a bar graph of the data in this table. Which age group seems most likely to get the disease? Which age group seems unaffected by the disease?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following is not a tool used to give numbers to descriptions of observations?
A. thermometers **C.** pencils
B. metersticks **D.** scales

Use the photo below to answer question 2.

2. These students are doing an important step before beginning an investigation. They are
A. drawing conclusions.
B. analyzing data.
C. controlling variables.
D. collecting information.

3. What would be a good source of information when doing a science report on a bacterial epidemic that happened over a hundred years ago locally?
A. pictures **C.** television
B. Internet **D.** newspapers

Test-Taking Tip

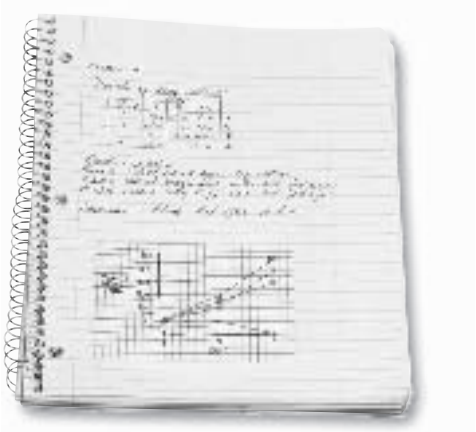
Sleep Instead of Cramming Get plenty of sleep—at least eight hours every night—during test week and the week before the test.

4. Giving partial information to get the results you want is known as
A. using a random sampling.
B. having a bias.
C. stating a theory.
D. conducting a survey.

5. The application of science to make products or tools that people use is
A. engineering. **C.** industry.
B. technology. **D.** mechanics.

6. What name is given to scientific research that answers questions by observation?
A. descriptive research
B. experimental research
C. technical research
D. analytical research

Use the photo below to answer question 7.



7. Which of the following would not go in this notebook?
A. listings of materials
B. drawings of equipment setups
C. specific results of an investigation
D. English assignments

8. What type of research answers scientific questions by testing a hypothesis?
A. experimental **C.** technical
B. descriptive **D.** analytical

CONTENTS

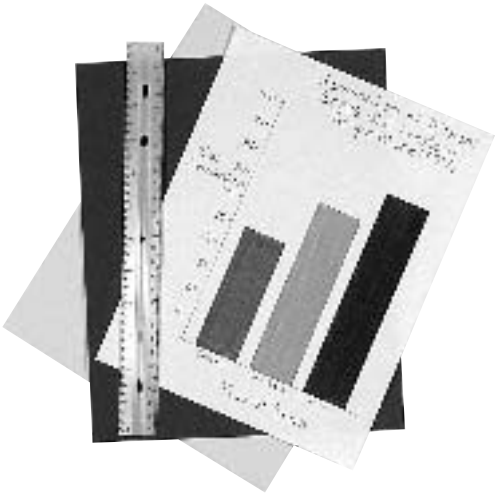
Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. Explain the basic steps to follow when solving a scientific problem.

10. Why do scientists around the world use the International System of Units (SI)?

Use the illustration below to answer question 11.



11. Why might you use this type of graphic in your scientific notebook?

12. Why is it important that you do multiple trials in an experiment?

13. Why is it important for scientists to search for new discoveries?

14. What is an experimental control?

15. Experiments are often conducted in secret. Why would you want to share your experiments and results with others?

16. Why are computers important to science? Describe three ways a scientist might use a computer.

17. Early scientists just used observation to explain things. What are some possible problems with just using observation in science?

Part 3 Open Ended

Record your answers on a sheet of paper.

18. Some people, such as farmers, produce food, while others consume what is produced. What would be your hypothesis as to what would happen if all farmers suddenly decided not to produce vegetables anymore? Is there a way to check your hypothesis?

Use the figure below to answer questions 19 and 20.

19. Describe how you would present the data in question 11 using the picture above.

20. The picture shows headlines labeled Data Tables, Effects, Conclusions, etc. What headlines would you put on your presentation board and what would go under each headline?

21. The black plague killed thousands of people in the Middle Ages. Explain how you would go about finding information about this disease. How was is spread? Is the disease still around today? If so, how is it treated?

22. How would you go about telling the world about observations you made in countries with drought and famine?