Chapter Menu

What is scientific inquiry?

Lesson 1

Scientific Inquiry

Key Concepts

- What are some steps used during scientific inquiry?
- What are the results of scientific inquiry?
- What is critical thinking?

Lesson 1

Scientific Inquiry

Vocabulary

- science
- observation
- inference
- hypothesis
- prediction
- scientific theory
- scientific law
- technology
- critical thinking

Understanding Science

Science is the investigation and exploration of natural events and of the new information that results from those investigations.

WORD ORIGIN

science

from Latin *scientia*, means "knowledge" or "to know"

Understanding Science (cont.)

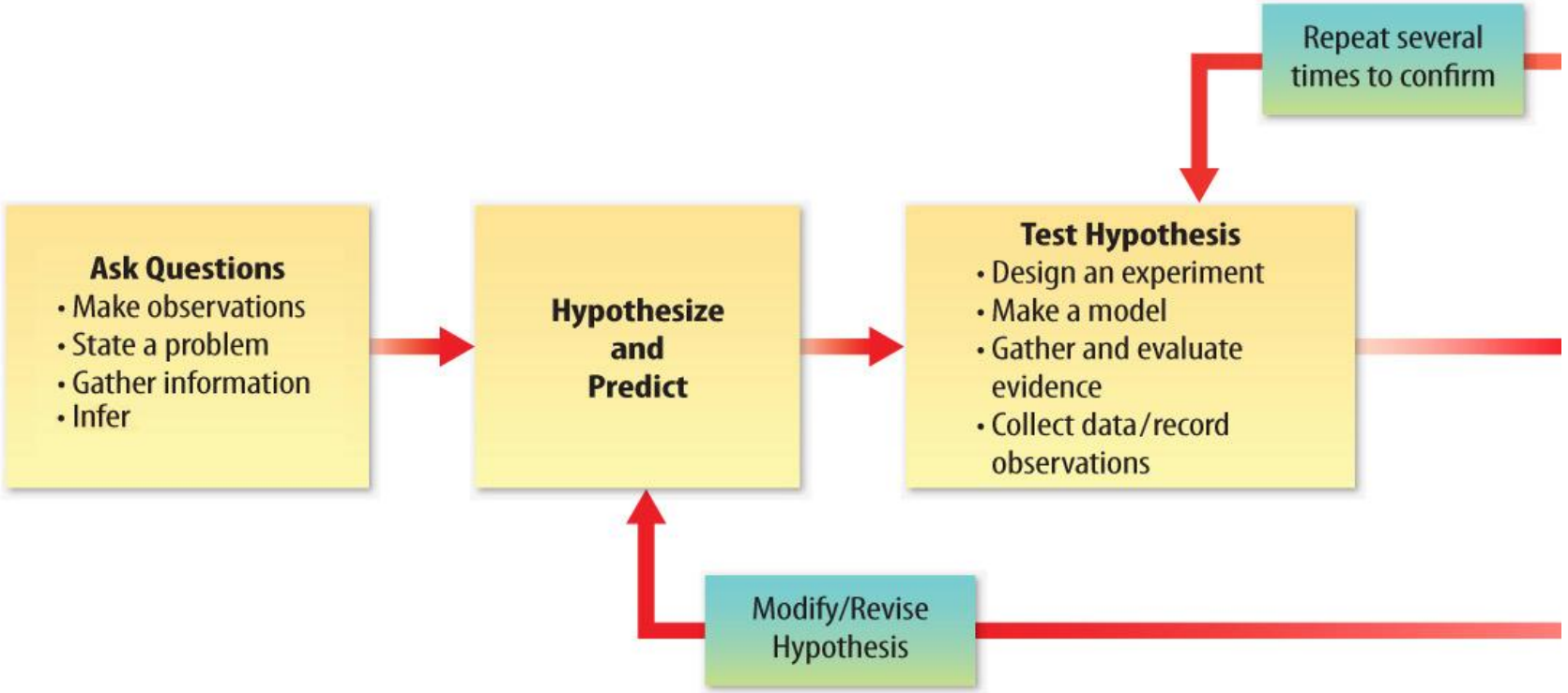
- Throughout history, people of many different backgrounds, interests, and talents have made scientific contributions.
- Scientific study is organized into several branches, each of which focuses on a different part of the natural world.

Branches of Science

- Physical science, or physics and chemistry, is the study of matter and energy.
- Earth scientists study the many processes that occur on Earth and deep within Earth.
- Life scientists study all organisms and the many processes that occur in them.

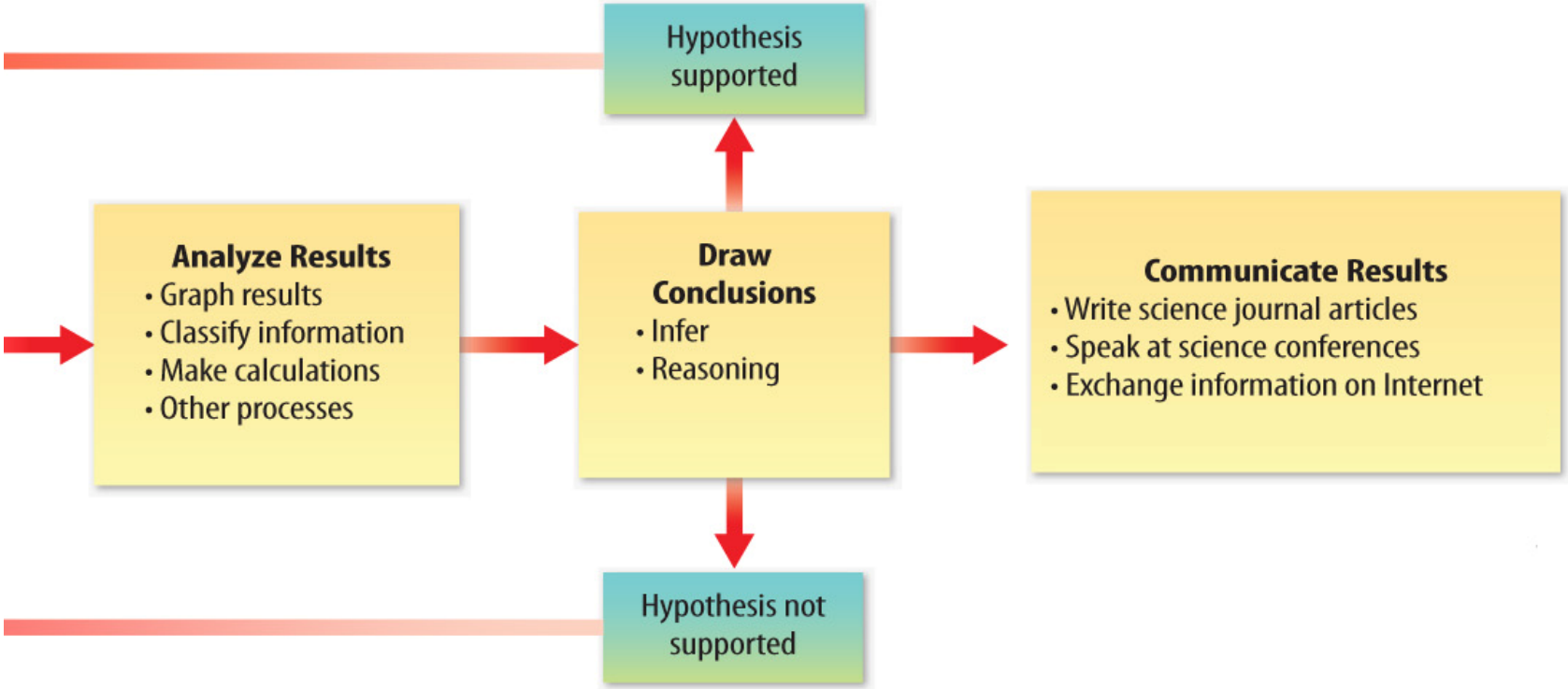
What is Scientific Inquiry?

When scientists conduct investigations, they often want to answer questions about the natural world.



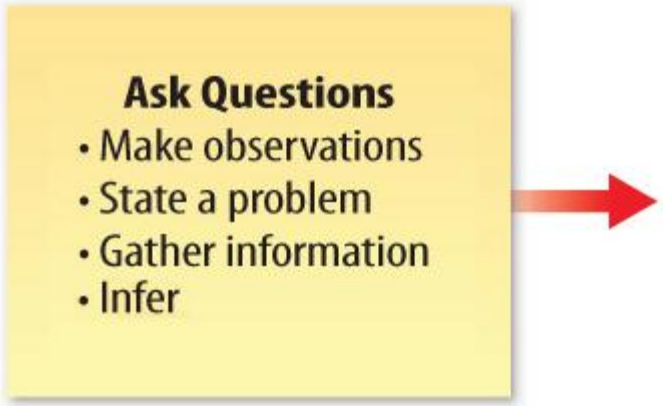
What is Scientific Inquiry? (cont.)

When scientists conduct investigations, they often want to answer questions about the natural world.



What is Scientific Inquiry? (cont.)

Observations are the results of using one or more of your senses to gather information and taking note of what occurs.

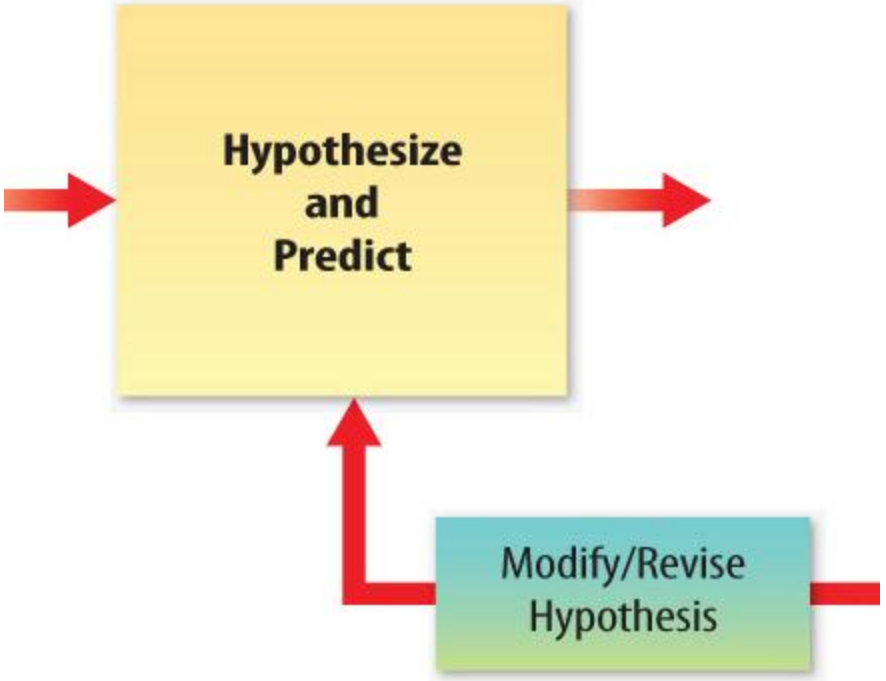


What is Scientific Inquiry? (cont.)

- An **inference** is a logical explanation of an observation that is drawn from prior knowledge or experience.
- A **hypothesis** is a possible explanation for an observation that can be tested by scientific investigations.

What is Scientific Inquiry? (cont.)

A **prediction** is a statement of what will happen next in a sequence of events.

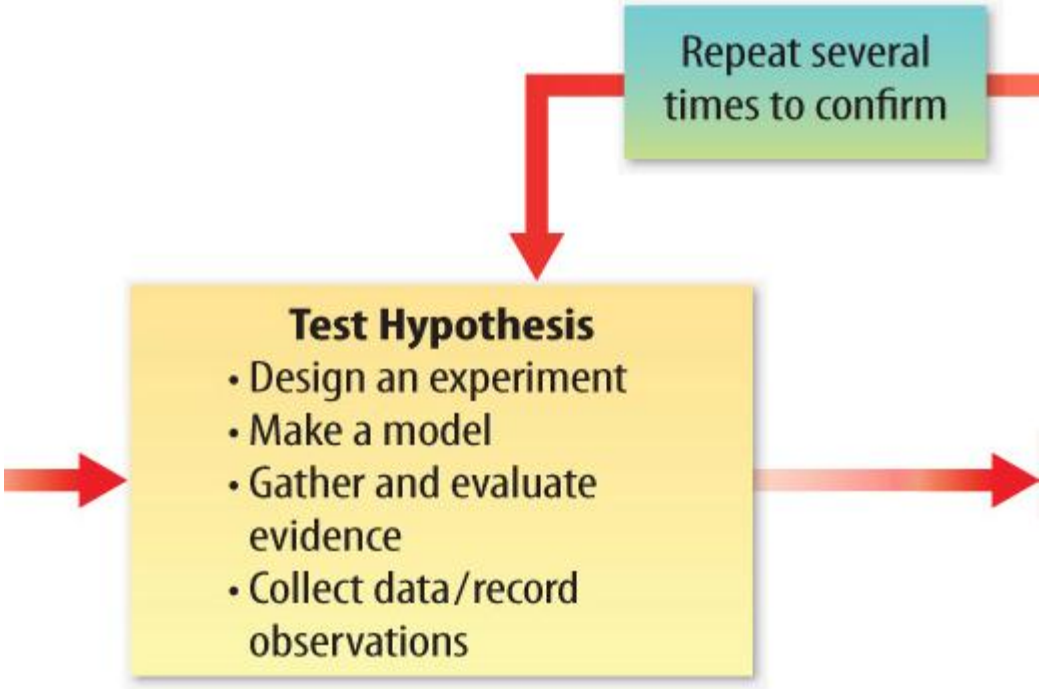


What is Scientific Inquiry? (cont.)

- Scientists make predictions based on what information they think they will find when testing their hypothesis.
- If a prediction is confirmed, then it supports your hypothesis.
- If your prediction is not confirmed, you might modify your hypothesis and retest it.

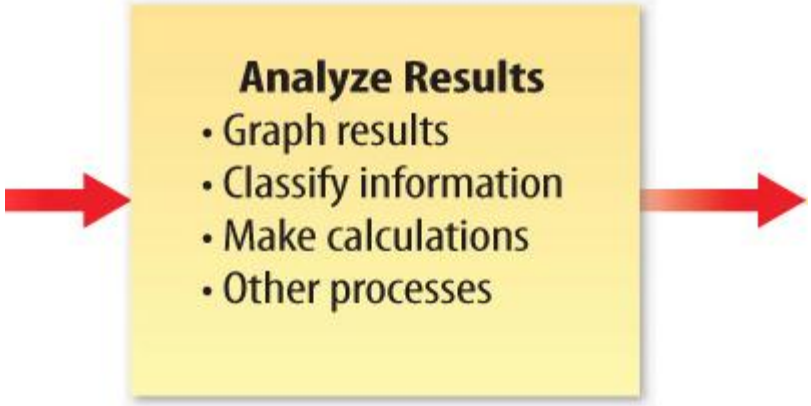
What is Scientific Inquiry? (cont.)

To test your predictions and hypothesis, you design an experiment.



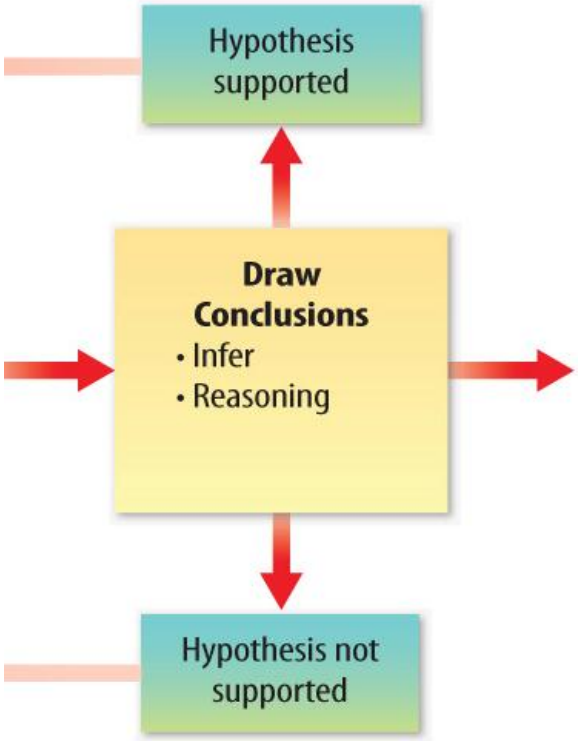
What is Scientific Inquiry? (cont.)

After doing an experiment or research, you analyze your results and findings.



What is Scientific Inquiry? (cont.)

A conclusion is a summary of the information gained from testing a hypothesis.



What is Scientific Inquiry? (cont.)

By exchanging information, scientists can evaluate and test others' work and make faster progress in their own research.

Communicate Results
- Write science journal articles
- Speak at science conferences
- Exchange information on Internet

What is Scientific Inquiry? (cont.)

- Each time you test a hypothesis, you learn more about the topic you are studying.
- Even when a hypothesis is not supported, you gain valuable information.

What is Scientific Inquiry? (cont.)

KEY CONCEPT CHECK

What are some steps used during scientific inquiry?

Scientific Theory

- A **scientific theory** is an explanation of observations or events that is based on knowledge gained from many observations and investigations.
- A scientific theory does not develop from just one hypothesis, but from many hypotheses that are connected by a common idea.

Scientific Law

- A **scientific law** is a rule that describes a repeatable pattern in nature.
- A scientific law does not explain why or how the pattern happens, it only states that it will happen.

Kinetic Molecular Theory

The kinetic molecular theory explains that particles that make up a gas move in constant, random motions. A particle moves in a straight line until it collides with another particle or with the wall of its container.

The kinetic molecular theory also assumes that the collisions of particles in a gas are elastic collisions. An elastic collision is a collision in which no kinetic energy is lost. Therefore, kinetic energy among gas particles is conserved.

Law of Conservation of Energy

The law of conservation of energy states that in any chemical reaction or physical change, energy is neither created nor destroyed. The total energy of particles before and after collisions is the same.

However, this scientific law, like all scientific laws, does not explain *why* energy is conserved. It simply states that energy *is* conserved.

Scientific Law v. Scientific Theory

Both are based on repeated observations and can be rejected or modified.

A scientific law states that an event *will* occur. For example, energy will be conserved when particles collide. It does not explain why an event will occur or how it will occur. Scientific laws work under specific conditions in nature. A law stands true until an observation is made that does not follow the law.

A scientific theory is an explanation of *why* or *how* an event occurred. For example, collisions of particles of a gas are elastic collisions. Therefore, no kinetic energy is lost. A theory can be rejected or modified if someone observes an event that disproves the theory. A theory will never become a law.

Results of Scientific Inquiry

- Most often, the purpose of a scientific investigation is to develop new materials and technology, discover new objects, or find answers to questions.
- **Technology** is the practical use of scientific knowledge, especially for industrial or commercial use.

Results of Scientific Inquiry (cont.)

KEY CONCEPT CHECK

What are the results of scientific inquiry?

Evaluating Scientific Information

- Whether you are reading printed media or watching commercials on TV, it is important that you are skeptical, identify facts and opinions, and think critically about the information.
- **Critical thinking** is comparing what you already know with the information you are given in order to decide whether you agree with it.

Evaluating Scientific Information (cont.)

KEY CONCEPT CHECK

What is critical thinking?

Science cannot answer all questions.

- There are some questions that science cannot answer.
- Questions that deal with beliefs, values, personal opinions, and feelings cannot be answered scientifically.

Safety in Science

- When you begin scientific inquiry, you should always wear protective equipment.
- You also should learn the meaning of safety symbols, listen to your teacher's instructions, and learn to recognize potential hazards.

Lesson Review

Which describes an explanation that is based on knowledge gained from many observations and investigation?

A. inference

B. prediction

C. scientific law

D. scientific theory

Lesson Review

Which term refers to a possible explanation for an observation that can be tested by scientific investigations?

A. hypothesis

B. prediction

C. scientific law

D. scientific theory

Lesson Review

Which term refers to the practical use of scientific knowledge, especially for industrial or commercial use?

A. technology

B. scientific law

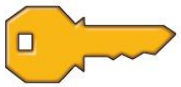
C. inference

D. critical thinking

Lesson 2

Measurement and Scientific Tools

Key Concepts



- Why did scientists create the International System of Units (SI)?
- Why is scientific notation a useful tool for scientists?
- How can tools, such as graduated cylinders and triple-beam balances, assist physical scientists?

Lesson 2

Measurement and Scientific Tools

Vocabulary

- description
- explanation
- International System of Units (SI)
- scientific notation
- percent error

Description and Explanation

- A **description** is a spoken or written summary of observations.
- An **explanation** is an interpretation of observations.
- When you describe something, you report your observations. When you explain something, you interpret your observations.

The International System of Units

- Different systems of measurements used in different parts of the world can cause confusion when people who use them try to communicate their measurements.
- The **International System of Units (SI)** is the internationally accepted system of measurement.

The International System of Units (cont.)

Key Concept Check

Why did scientists create the International System of Units?

A rock has a mass of 17.5 grams. How many kilograms is that?

1. Determine the correct relationship between grams and kilograms. There are 1,000 g in 1 kg.

$$\frac{1\text{ kg}}{1{,}000\text{ g}}$$

$$\frac{x}{17.5\text{ g}} = \frac{1\text{ kg}}{1{,}000\text{ g}}$$

$$x = \frac{(17.5\ \cancel{\text{g}})(1\text{ kg})}{1{,}000\ \cancel{\text{g}}};\ x = 0.0175\text{ kg}$$

2. Check your units. The unit *grams* divides in the equation, so the answer is 0.0175 kg.

- The SI system uses standards of measurement, called base units.
- Other units used in the SI system that are not base units are derived from the base units.

SI Base Units

Quantity Measured	Unit (symbol)
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Electric current	ampere (A)
Temperature	kelvin (K)
Substance amount	mole (mol)
Light intensity	candela (cd)

- The SI system is based on multiples of ten.
- Factors of ten are represented by prefixes.
- You either multiply or divide by a factor of ten to convert from one SI unit to another.

Prefixes

Prefix	Meaning
Mega- (M)	1,000,000 or (10^6)
Kilo- (k)	1,000 or (10^3)
Hecto- (h)	100 or (10^2)
Deka- (da)	10 or (10^1)
Deci- (d)	0.1 or $\left(\frac{1}{10}\right)$ or (10^{-1})
Centi- (c)	0.01 or $\left(\frac{1}{100}\right)$ or (10^{-2})
Milli- (m)	0.001 or $\left(\frac{1}{1{,}000}\right)$ or (10^{-3})
Micro- (μ)	0.000001 or $\left(\frac{1}{1{,}000{,}000}\right)$ or (10^{-6})

Measurement and Uncertainty

- Precision is a description of how similar or close repeated measurements are to each other.
- Accuracy is a description of how close a measurement is to an accepted value.

Student A's measurements are the most precise because they are closest to each other.

Student Density and Error Data
(Accepted value: Density of sodium chloride, 21.7 g/cm^3)

	Student A	Student B	Student C
	Density	Density	Density
Trial 1	23.4 g/cm^3	18.9 g/cm^3	21.9 g/cm^3
Trial 2	23.5 g/cm^3	27.2 g/cm^3	21.4 g/cm^3
Trial 3	23.4 g/cm^3	29.1 g/cm^3	21.3 g/cm^3
Mean	23.4 g/cm^3	25.1 g/cm^3	21.5 g/cm^3

Student C's measurements are the most accurate because they are closest to the scientifically accepted value.

Student Density and Error Data
(Accepted value: Density of sodium chloride, 21.7 g/cm^3)

	Student A	Student B	Student C
	Density	Density	Density
Trial 1	23.4 g/cm^3	18.9 g/cm^3	21.9 g/cm^3
Trial 2	23.5 g/cm^3	27.2 g/cm^3	21.4 g/cm^3
Trial 3	23.4 g/cm^3	29.1 g/cm^3	21.3 g/cm^3
Mean	23.4 g/cm^3	25.1 g/cm^3	21.5 g/cm^3

Student B's measurements are neither precise nor accurate. They are not close to each other or to the accepted value.

Student Density and Error Data
(Accepted value: Density of sodium chloride, 21.7 g/cm^3)

	Student A	Student B	Student C
	Density	Density	Density
Trial 1	23.4 g/cm^3	18.9 g/cm^3	21.9 g/cm^3
Trial 2	23.5 g/cm^3	27.2 g/cm^3	21.4 g/cm^3
Trial 3	23.4 g/cm^3	29.1 g/cm^3	21.3 g/cm^3
Mean	23.4 g/cm^3	25.1 g/cm^3	21.5 g/cm^3

Measurement and Uncertainty (cont.)

- No measuring tool provides a perfect measurement.
- All measurements have some degree of uncertainty.

Measurement and Uncertainty (cont.)

- **Scientific notation** is a method of writing or displaying very small or very large numbers in a short form.
- You would use scientific notation to report Earth's distance from the Sun—149,600,000 km—and the density of the Sun's lower atmosphere—0.000000028 g/cm^3.

How to Write in Scientific Notation

1. Write the original number.
   - A. 149,600,000
   - B. 0.000000028
2. Move the decimal point to the right or the left to make the numbers between 1 and 10. Count the number of decimal places moved and note the direction.
   - A. 1.49600000 = 8 places to the left
   - B. 00000002.8 = 8 places to the right
3. Rewrite the number deleting all extra zeros to the right or to the left of the decimal point.
   - A. 1.496
   - B. 2.8
4. Write a multiplication symbol and the number *10* with an exponent. The exponent should equal the number of places that you moved the decimal point in step 2. If you moved the decimal point to the left, the exponent is positive. If you moved the decimal point to the right, the exponent is negative.
   - A. 1.496×10^{8}
   - B. 2.8×10^{-8}

Measurement and Uncertainty (cont.)

Key Concept Check

Why is scientific notation a useful tool for scientists?

Measurement and Uncertainty (cont.)

- Percent error can help you determine the size of your experimental error.
- **Percent error** is the expression of error as a percentage of the accepted value.

Measurement and Uncertainty (cont.)

Math Skills — Percent Error

Solve for Percent Error A student in the laboratory measures the boiling point of water at 97.5°C. If the accepted value for the boiling point of water is 100.0°C, what is the percent error?

1. This is what you know: **experimental value = 97.5°C**, **accepted value = 100.0°C**
2. This is what you need to find: percent error
3. Use this formula:

$$\text{percent error} = \frac{|\text{experimental value} - \text{accepted value}|}{\text{accepted value}} \times 100\%$$

4. Substitute the known values into the equation and perform the calculations

$$\text{percent error} = \frac{|97.5° - 100.0°|}{100.0°} \times 100\% = 2.50\%$$

Scientific Tools

- A science journal is used to record observations, write questions and hypotheses, collect data, and analyze the results of scientific inquiry.
- A balance is used to measure the mass of an object.
- Laboratory glassware, such as flasks, beakers, test tubes, and graduated cylinders, are used to hold or measure the volume of liquids.

Scientific Tools (cont.)

- A thermometer is used to measure the temperature of substances.
- A hand-held calculator is a scientific tool that can be used in the lab and in the field to make quick calculations using your data.
- Scientists can collect, compile, and analyze data more quickly using a computer.

Scientific Tools (cont.)

KEY CONCEPT CHECK

How can scientific tools, such as graduated cylinders and triple-beam balances, assist scientists?

Additional Tools Used by Physical Scientists

- pH paper is used to quickly estimate the acidity of a liquid substance.
- Hot plates are used to heat substances in the laboratory.

Additional Tools Used by Physical Scientists (cont.)

- Scientists use stopwatches to measure the time it takes for an event to occur.
- A spring scale is used to measure the weight or the amount of force applied to an object.

Lesson Review

Which describes an interpretation of observations?

A. description

B. explanation

C. prefix

D. proportion calculation

Lesson Review

What term refers to the standards of measurement used by the International System of Units?

A. base units

B. percent error

C. prefixes

D. scientific notation

Lesson Review

Which is used to quickly estimate the acidity of a liquid substance?

A. hot plate

B. pH paper

C. spring scale

D. thermometer

Lesson 3

Case Study

Key Concepts

- Why are evaluation and testing important in the design process?
- How is scientific inquiry used in a real-life scientific investigation?

Lesson 3

Case Study

Vocabulary

- variable
- constant
- independent variable
- dependent variable
- experimental group
- control group
- qualitative data
- quantitative data

The Minneapolis Bridge Failure

- On August 1, 2007, the center section of the Interstate-35W bridge in Minneapolis, Minnesota, suddenly collapsed.
- The design and engineering processes that bridges undergo are supposed to ensure that bridge failures do not happen.

Controlled Experiments

- After the 2007 bridge collapse, investigators needed to use scientific inquiry to determine why the bridge failed.
- The investigators designed controlled experiments to help them answer questions and test their hypotheses.
- A controlled experiment is a scientific investigation that tests how one factor affects another.

Controlled Experiments (cont.)

- A **variable** is any factor that can have more than one value.
- The **independent variable** is the factor that you want to test. It is changed by the investigator to observe how it affects a dependent variable.

Controlled Experiments (cont.)

- The **dependent variable** is the factor you observe or measure during an experiment.
- **Constants** are the factors in an experiment that do not change.

Controlled Experiments (cont.)

- A controlled experiment usually has at least two groups: the experimental group and the control group.
- The **experimental group** is used to study how a change in the independent variable changes the dependent variable.
- The **control group** contains the same factors as the experimental group, but the independent variable is not changed.

Simple Beam Bridges

- The simplest type of bridge is a beam bridge, which has one horizontal beam across two supports.
- A disadvantage of beam bridges is that they tend to sag in the middle if they are too long.

Truss Bridges

- A truss bridge often spans long distances.
- This type of bridge is supported only at its two ends, but an assembly of interconnected triangles, or trusses, strengthens it.
- The I-35W bridge was a truss bridge designed in the early 1960s.

Bridge Failure Observations

- After recovering all the pieces of the collapsed bridge, investigators found physical evidence they needed to determine where the breaks in each section of the bridge occurred.
- Investigators also used video footage of the bridge collapse to help pinpoint where the collapse began.

Asking Questions

- Investigators reviewed the modifications made to the bridge since it opened.
- Investigators recorded qualitative and quantitative data.

Asking Questions (cont.)

- Qualitative data use words to describe what is observed.
- Quantitative data use numbers to describe what is observed.

Asking Questions (cont.)

- The analysis of the bridge was conducted using computer-modeling software.
- After evaluating the evidence, the accident investigators formulated a hypothesis and then tested their hypothesis and analyzed the results.

A demand-to-capacity value greater than 1 means the structure is unsafe. Notice how high the ratios are for the U10 gusset plate compared to the other plates.

Node-Gusset Plate Analysis

Gusset Plate	Thick-ness (cm)	Demand-to-Capacity Ratios for the Upper-Node Gusset Plates					
		Horizontal loads			Vertical loads		
U8	3.5	0.05	0.03	0.07	0.31	0.46	0.20
U10	1.3	1.81	1.54	1.83	1.70	1.46	1.69
U12	2.5	0.11	0.11	0.10	0.71	0.37	1.15

Asking Questions (cont.)

KEY CONCEPT CHECK

Why are evaluation and testing important in the design process?

Asking Questions (cont.)

- Investigators concluded that if the gusset plates were properly designed, they would have supported the added load, which led to the bridge collapse.
- Reports published by the Federal Highway Administration and the National Transportation Safety Board now provide scientists and engineers with valuable information they can use in future bridge designs.

Asking Questions (cont.)

Key Concept Check

Give three examples of the scientific inquiry process that was used in this investigation.

Lesson Review

Which is changed to observe how it affects a dependent variable?

A. constant

B. control group

C. experimental group

D. independent variable

Lesson Review

Which refers to data that use words to describe what is observed?

A. control group

B. dependent variable

C. qualitative data

D. quantitative data

Lesson Review

Which term refers to any factor that can have more than one value?

A. constants

B. control group

C. experimental group

D. variable

Menu

Scientific inquiry is a collection of methods that scientists use in different combinations to perform scientific investigations.

Lesson 1: Scientific Inquiry

- Some steps used during scientific inquiry are making observations and inferences, developing a hypothesis, analyzing results, and drawing conclusions. These steps, among others, can be performed in any order.
- There are many results of scientific inquiry, and a few possible outcomes are the development of new materials and new technology, the discovery of new objects and events, and answers to basic questions.
- Critical thinking is comparing what you already know about something to new information and deciding whether or not you agree with the new information.

Lesson 2: Measurement and Scientific Tools

- Scientists developed one universal system of units, the international System of Units (SI), to improve communication among scientists.
- Scientific notation is a useful tool for writing large and small numbers in a shorter form.
- Tools such as graduated cylinders and triple-beam balances make scientific investigation easier, more accurate, and repeatable.

Lesson 3: Case Study

- Evaluation and testing are important in the design process for the safety of the consumer and to keep costs of building or manufacturing the product at a reasonable level.
- Scientific inquiry was used throughout the process of determining why the bridge collapsed, including hypothesizing potential reasons for the bridge failure and testing those hypotheses.

Chapter Review

Which is a logical explanation of an observation that is drawn from prior knowledge or experience?

A. hypothesis

B. inference

C. prediction

D. scientific theory

Chapter Review

Which refers to a rule that describes a repeatable pattern in nature?

A. hypothesis

B. observation

C. scientific law

D. scientific theory

Chapter Review

Which refers to the internationally accepted system of measurement?

A. base unit

B. International System of Units

C. proportion calculation

D. scientific notation

Chapter Review

Which is the expression of error as a percentage of the accepted value?

A. scientific theory

B. scientific notation

C. quantitative data

D. percent error

Chapter Review

Which refers to the factors in an experiment that do not change?

A. constant

B. control group

C. dependent variable

D. variable

Standardized Test Practice

Which is the result of using one or more of your senses to gather information and taking note of what occurs?

A. hypothesis

B. inference

C. observation

D. prediction

Standardized Test Practice

Which describes the investigation and exploration of events and of the information that results from those investigations?

A. inference

B. science

C. scientific law

D. technology

Standardized Test Practice

Which refers to a spoken or written summary of observations?

A. hypothesis

B. explanation

C. description

D. base unit

Standardized Test Practice

Which is used to measure the mass of an object?

A. balance

B. beaker

C. spring scale

D. thermometer

Standardized Test Practice

Which is used to study how a change in the independent variable changes the dependent variable?

A. control group

B. controlled experiment

C. experimental group

D. quantitative data