Scientific Explanations

Measurement and Scientific Tools

Key Concepts
- What is the difference between accuracy and precision?
- Why should you use significant digits?
- What are some tools used by life scientists?

Mark the Text

Sticky Notes As you read, use sticky notes to mark information that you do not understand. Read the text carefully a second time. If you still need help, write a list of questions to ask your teacher.

Reading Check

1. Define What is the International System of Units?

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Read to Learn

Description and Explanation

How would you write a description of a squirrel's activity? *A* ***description*** *is a spoken or written summary of observations.*

Your description might include information such as the squirrel buried five acorns near a large tree or that the squirrel climbed the tree when a dog barked. A qualitative description uses your senses (sight, sound, smell, touch, taste) to describe an observation. *A large tree* is a qualitative description.

A quantitative observation uses numbers to describe the observation. *Five acorns* is a quantitative description. You can use measuring tools, such as a ruler, a balance, or a thermometer to make quantitative descriptions.

How would you explain the squirrel's activity? *An* ***explanation*** *is an interpretation of observations.* You might explain that the squirrel is storing acorns for food at a later time or that the squirrel was frightened by and ran away from the dog.

When you describe something, you report what you observe. But when you explain something, you try to interpret your observations. The can lead to a hypothesis.

The International System of Units

Suppose you observed a squirrel searching for buried food. You recorded that it traveled about 200 feet from its nest.

Someone who measures distances in meters might not understand how far the squirrel traveled. The scientific community solved this problem in 1960. It adopted *an internationally accepted system for measurement called the* ***International System of Units (SI).***

SI Base Units and Prefixes

Like scientists and many others around the world, you probably use the SI system in your classroom. All SI units are derived from the seven base units listed in the table on the left below. For example, the base unit for length, or the unit most commonly used to measure length, is the meter. You have probably made measurements in kilometers or millimeters before. Where do these units come from?

A prefix can be added to a base unit's name to indicate either a fraction or a multiple of that base unit. The prefixes are based on powers of ten, such as 0.01 and 100, as shown below on the right. One centimeter (cm) is one-hundredth of a meter and a kilometer (km) is 1,000 meters.

Reading Check

2. Name What is added to the name of a base unit to indicate a fraction or a multiple of the base unit?

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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)

Prefixes

Prefix	Meaning
Mega– (M)	1,000,000 (10^6)
Kilo– (k)	1,000 (10^3)
Hecto– (h)	100 (10^2)
Deka– (da)	10 (10^1)
Deci– (d)	0.1 (10^{-1})
Centi– (c)	0.01 (10^{-2})
Milli– (m)	0.001 (10^{-3})
Micro– (μ)	0.000 001 (10^{-6})

Conversion It is easy to convert from one SI unit to another. You multiply or divide by a power of ten. You also can use proportion calculations to make conversions. For example, a biologist measures an Emperor goose in the field. Her triple-beam balance shows that the goose has a mass of 2.8 kg. She could perform the calculation below to find the goose's mass in grams, x.

$$\frac{x}{2.8 \text{ kg}} = \frac{1{,}000 \text{ g}}{1 \text{ kg}}$$

$$(1 \text{ kg})x = (1{,}000 \text{ g})(2.8 \text{ kg})$$

$$x = \frac{(1{,}000 \text{ g})(2.8 \cancel{\text{kg}})}{1 \cancel{\text{kg}}}$$

$$x = 2{,}800 \text{ g}$$

Notice that the answer has the correct units.

Interpreting Tables

3. Identify What unit measures mass?

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Reading Check

4. State How do you convert one SI unit to another?

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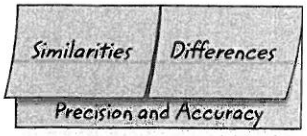
FOLDABLES®

Make a horizontal two-tab book with a top tab to compare precision and accuracy.

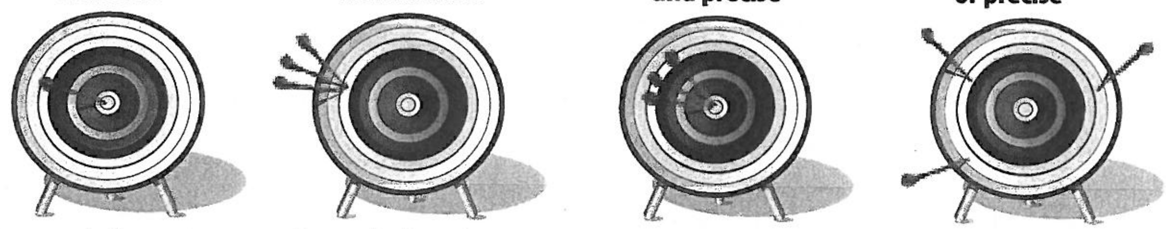


Precision and Accuracy

Suppose your friend Simon tells you that he will call you in one minute, but he calls you a minute and a half later. Sarah tells you that she will call you in one minute, and she calls exactly 60 seconds later. What is the difference? Sarah is accurate, and Simon is not. **Accuracy** *is a description of how close a measurement is to an accepted or true value.* However, if Simon always calls about 30 seconds later than he says he will, then Simon is precise. **Precision** *is a description of how similar or close measurements are to each other*, as shown in the figure below.

Accuracy and Precision

Accurate	Precise but not accurate	Accurate and precise	Not accurate or precise



An arrow in the center indicates high accuracy.	Arrows far from the center indicate low accuracy. Arrows close together indicate high precision.	Arrows in the center indicate high accuracy. Arrows close together indicate high precision.	Arrows far from the center indicate low accuracy. Arrows far apart indicate low precision.

Visual Check

5. Interpret What do arrows close together in the target indicate?

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The table at the top of the next page illustrates the difference between precise and accurate measurements.

Students were asked to find the melting point of sucrose, or table sugar. Each student took three temperature readings and calculated the mean, or average, of his or her data.

Refer to the table at the top of the next page. As the recorded data in the table shows, student A had the most accurate data. That student's melting point mean, 184.7°C, is closest to the scientifically accepted melting point, 185°C. Although not accurate, student C's measurements are the most precise because they are similar in value.

Key Concept Check

6. Contrast How do accuracy and precision differ?

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Student Melting Point Data			
	Student A	Student B	Student C
Trial 1	183.5°C	190.0°C	181.2°C
Trial 2	185.9°C	183.3°C	182.0°C
Trial 3	184.6°C	187.1°C	181.7°C
Average	184.7°C	186.8°C	181.6°C
Sucrose Melting Point (accepted value) 185°C			

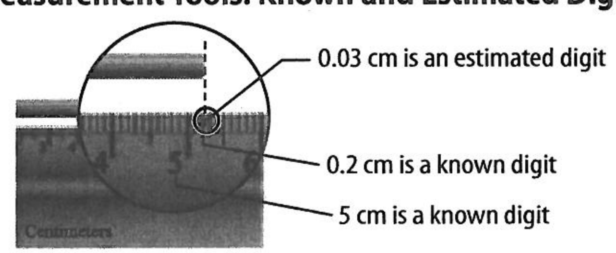
Measurement and Accuracy

The tools used to take measurements can limit the accuracy of the measurements. Suppose you are measuring the temperature at which sugar melts, and the thermometer's measurements are divided into whole numbers. If your sugar sample melts between 183°C and 184°C, you can estimate the temperature between these two numbers. But, if the thermometer's measurements are divided into tenths, and your sample melts between 183.2°C and 183.3°C, your estimate between these numbers would be more accurate.

Significant Digits

In the second example above, you know that the temperature is between 183.2°C and 183.3°C. You could estimate that the temperature is 183.25°C. When you take any measurement, you know some digits for certain and you estimate some digits. **Significant digits** *are the number of digits in a measurement that are known with a certain degree of reliability*. The significant digits in a measurement include all digits you know for certain, plus one estimated digit. Therefore your measurement of 83.25°C would contain five significant digits. The figure below shows how to round to three significant digits. Since the ruler is divided into tenths, you know the rod is between 5.2 cm and 5.3 cm. You can estimate that the rod is 5.25 cm.

Measurement Tools: Known and Estimated Digits



Visual Check

7. Analyze Why were student B's measurements imprecise compared to the measurements of student C?

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Visual Check

8. Interpret Is 4.5 in the figure a known or an estimated digit?

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Math Skills

The number 5,281 has four significant digits. Rule 1, in the table to the right, states that all nonzero numbers are significant.

9. Significant Digits Use the rules in the table to determine the number of significant digits in each of the following numbers: 2.02; 0.0057; 1,500; and 0.500.

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Key Concept Check

10. Explain Why should you use significant digits?

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Reading Check

11. Describe Why would you use a science journal?

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Significant Digits

Rules

1. All nonzero numbers are significant.
2. Zeros between nonzero digits are significant.
3. Final zeros used after the decimal are significant.
4. Zeros used solely for spacing the decimal are not significant. The zeros indicate only the position of the decimal.

* The bold numbers in the examples are the significant digits.

Example Number	Significant Digits	Applied Rules
1.234	4	1
1.2	2	1
0.0**23**	2	1, 4
0.**200**	3	1, 3
1,002	4	1, 2
3.07	3	1, 2
0.00**1**	1	1, 4
0.0**12**	2	1, 4
50,600	3	1, 2, 4

Using significant digits lets others know how certain your measurements are. The rules for using significant digits are shown in the table above.

Scientific Tools

Scientific inquiry often requires the use of tools. Scientists, including life scientists, might use the tools listed below and on the next page. You might use one or more of them during a scientific inquiry, too.

Science Journal

In a science journal, you can record descriptions, explanations, plans, and steps used in a scientific inquiry. A science journal can be a spiral-bound notebook or a loose-leaf binder. It is important to keep your science journal organized so you can find information when you need it. Make sure you keep thorough and accurate records.

Balances

You can use a triple-beam balance or an electric balance to measure mass. Mass usually is measured in kilograms (kg) or grams (g). When using a balance, do not let objects drop heavily onto the balance. Gently remove an object after you record its mass.

Thermometer

A thermometer measures the temperature of substances. The Kelvin (K) is the SI unit for temperature. However, in the science classroom, you measure temperature in degrees Celsius (°C). Use care when you place a thermometer into a hot substance so you do not burn yourself. Handle glass thermometers gently so they do not break. If a thermometer does break, tell your teacher immediately. Do not touch the broken glass or the thermometer's liquid. Never use a thermometer to stir anything. ✓

Glassware

Laboratory glassware is used to hold, pour, heat, and measure liquids. Most labs have many types of glassware. For example, flasks, beakers, petri dishes, test tubes, and specimen jars are used as containers. To measure the volume of a liquid, you use a graduated cylinder. The unit of measure for liquid volume is the liter (L) or milliliter (mL). ✓

Compound Microscope

Microscopes enable you to observe small objects that you cannot observe with just your eyes. Usually, two types of microscopes are in science classrooms—dissecting microscopes and compound light microscopes. Microscopes have either a single eyepiece or two eyepieces to observe a magnified image of a small object or an organism.

Microscopes can be damaged easily. It is important to follow your teacher's instructions when carrying and using a microscope.

Computers—Hardware and Software

Computers process information. In science, you can use computers to compile, retrieve, and analyze data for reports. You also can use them to create reports and other documents, to send information to others, and to research information.

The physical components of computers, such as monitors and keyboards, are called hardware. The programs that you run on computers are called software. These programs include word processing, spreadsheet, and presentation programs. When scientists write reports, they use word processing programs. They use spreadsheet programs for organizing and analyzing data. Presentation programs can be used to explain information to others. ✓

✓ **Reading Check**

12. State In a science classroom, what unit of measure do you use for temperature?

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✓ **Reading Check**

13. Identify Which unit of measure do you use for liquid volume?

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✓ **Reading Check**

14. Name What are the physical components of a computer called? What are computer programs called?

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Reading Check
15. Describe how you might use a magnifying lens.

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Key Concept Check
16. Name What are some tools used by life scientists?

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Tools Used by Life Scientists

Life scientists often use the tools described below.

Magnifying Lens

A magnifying lens is a hand-held lens that magnifies, or enlarges, the image of an object. It is not as powerful as a microscope and is useful when great magnification is not needed. Magnifying lenses also can be used outside the lab where microscopes might not be available.

Slide

To observe an item using a compound light microscope, you first must place it on a thin, rectangular piece of glass called a slide. You must handle slides gently to avoid breaking them.

Dissecting Tools

Scientists use dissecting tools, such as scalpels and scissors, to examine tissues, organs, or prepared organisms. Dissecting tools are sharp, so always use extreme caution when handling them.

Pipette

A pipette is similar to a eyedropper. It is a small glass or plastic tube used to draw up and transfer liquids.

After You Read

Mini Glossary

accuracy: a description of how close a measurement is to an accepted or true value

description: a spoken or written summary of observations

explanation: an interpretation of observations

International System of Units (SI): the internationally accepted system for measurement

precision: a description of how similar or close measurements are to each other

significant digits: the number of digits in a measurement that are known with a certain degree of reliability

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that explains the importance of accuracy in measurement.

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2. Complete the following table to identify and describe SI base units.

Unit (symbol)	Quantity Measured
ampere (A)	
	light intensity
meter (m)	
	temperature
mole (mol)	

3. Explain the difference between a description and an explanation.

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END OF LESSON