Name ______________________ Class ______________ Date ____________

CHAPTER 2 | Data in Science

SECTION 1

Tools and Models in Science

California Science Standards

8.9.b, 8.9.f

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do scientists take measurements?
- What is the International System of Units?
- How do scientists use models to explain theories and scientific laws?

What Is a Tool?

STUDY TIP

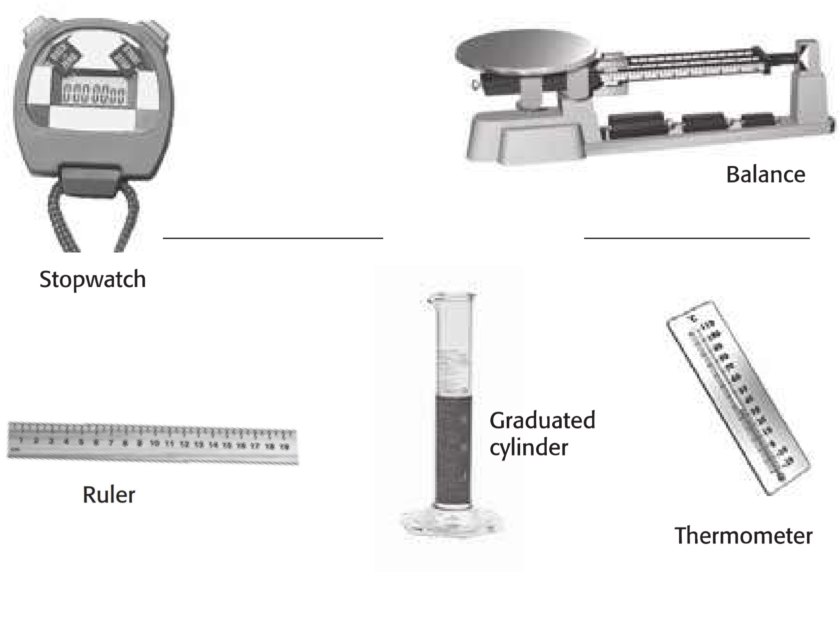
Map In your notebook, create a Concept Map about the SI units of measurement.

Think about a tool that you have used. Whether it was a hammer, a drill, or a pair of scissors, the tool was something that helped you do a task. Scientists use tools when they do experiments, too. Most scientific data are collected by taking measurements. You can use a ruler or meter stick to measure length. The tool for measuring temperature is a thermometer. The figure below shows some of the tools that can be used in an experiment.

After you collect data, you need other tools to evaluate and analyze your results. Can you think of any tools for that? Calculators and computers are modern tools for analyzing data. You can also use the tools that came before calculators, such as graph paper. ☑

READING CHECK

1. Identify In the text, circle three tools for handling data.



These are some of the tools that you can use to make measurements.

TAKE A LOOK

2. Identify Fill in each blank with the type of measurement each tool makes.

INTERNATIONAL SYSTEM OF UNITS

Scientists use a metric system of measurement, in which all units are multiples of 10. It is called the International System of Units (SI). The abbreviation SI comes from its French name Système Internationale.

Each type of measurement has a base unit. For example, the meter is the base unit of length. SI uses prefixes for units that are larger or smaller than the base unit. When a prefix is put in front of a base unit, it changes how big the unit is. The table below shows some common prefixes and an example of how it changes the size of the base unit. ☑

READING CHECK

3. Describe When a prefix is put in front of a base unit, what does it do to the base unit?

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Common International System of Units (SI) Prefixes

SI prefix	Symbol	Size	Example
mega	M	one million	1 Mg = 1,000,000 g
kilo	k	one thousand	1 km = 1,000 m
deci	d	one-tenth	1 dg = 0.1 g
centi	c	one-hundredth	1 cm = 0.01 m
milli	m	one-thousandth	1 mg = 0.001 g
micro	µ	one-millionth	1 µm = 0.000001 m
nano	n	one-billionth	1 ng = 0.000000001 g

TAKE A LOOK

4. Identify What does the prefix "d" mean? How many grams are in 1 dg?

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LENGTH

The meter (m) is the SI base unit for length. Most people are between 1 m and 2 m tall. To measure shorter distances, you can use centimeters or millimeters. Scientists who work with atoms and molecules measure nanometers, which are billionths of a meter. A molecule that is 1 nm long is too small to see with the best light microscope. In the lab, you will usually use a meter stick or ruler to measure length.

MASS

Mass is the amount of matter in an object. The SI base unit for mass is the kilogram (kg). A medium-sized textbook has a mass of about 1 kg. You may measure the masses of small objects in grams, which are thousandths of a kilogram. The mass of a very large object, such as a ship or airplane, is often stated in units of metric tons. A metric ton is 1,000 kilograms. In the lab, you will use a balance to measure mass.

Critical Thinking

5. Identify Relationships How many times bigger is a metric ton than a kilogram?

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Common International System of Units (SI) Units		
Length	meter (m)	
	kilometer (km)	1 km = 1,000 m
	decimeter (dm)	1 dm = 0.1 m
	centimeter (cm)	1 cm = 0.01 m
	millimeter (mm)	1 mm = 0.001 m
	micrometer (μm)	1 μm = 0.000001 m
	nanometer (nm)	1 nm = 0.000000001 m
Volume	cubic meter (m^3)	
	cubic centimeter (cm^3)	1cm^3 = 0.000001 m^3
	liter (L)	1 L = 1 dm^3 = 0.001 m^3
	milliliter (mL)	1 mL = 0.001 L = 1 cm^3
Mass	kilogram (kg)	
	gram (g)	1 g = 0.001 kg
	milligram (mg)	1 mg = 0.000001 kg
Temperature	kelvin (K)	0°C = 273 K
		100°C = 373 K

Math Focus

6. Make Comparisons How many mm long is a line that measures 15 cm?

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READING CHECK

7. Define What is the SI unit for temperature and its symbol?

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TAKE A LOOK

8. Compare Determine the difference in temperature between the freezing point and boiling point of water on the Celsius scale and then on the Kelvin scale. How do they compare?

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TEMPERATURE

The **temperature** of a substance is a measure of how hot or cold it is. The units of temperature normally used in the lab are degrees Celsius (°C). Outside the lab, you will often see temperature expressed in degrees Fahrenheit (°F). The SI unit of temperature is the kelvin (K). A temperature change of 1 K is the same as 1°C, but the systems start at different zero values. The degree sign is not used in the Kelvin scale. ☑

Many signs in front of businesses show the temperature in both the Fahrenheit and Celsius scales. On a warm day, a sign might alternate between 82°F and 28°C. The table below compares the Fahrenheit, Celsius, and Kelvin scales.

Fahrenheit, Celsius, and Kelvin Temperature Scales			
	Fahrenheit	**Celsius**	**Kelvin**
Freezing point of water	32°F	0°C	273 K
Normal body temperature	98.6°F	37°C	310 K
Boiling point of water	212°F	100°C	373 K

TIME

The unit of time in the SI system is the second, the same unit that your watch uses. Many scientific experiments are measured in seconds. Scientists often use nanoseconds or even smaller measures of time to measure the behavior of atoms, molecules, and light.

VOLUME

Length is the measure of an object in one direction. To know how much space the object occupies, you need more information. **Volume** is the amount of space that something occupies. For example, the volume of a rectangular solid is its length multiplied by its width multiplied by its height.

The liter (L) is the unit often used to measure volume of liquids and gases. Liters are based on the meter. The SI unit of volume is the cubic meter (m^3). One cubic meter (1 m^3) is the same volume as 1,000 L. This means a box that is 1 meter on each side will hold exactly 1,000 L. ☑

READING CHECK

9. Define What is the SI unit for volume, and what is its symbol?

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Volumes of Selected Substances	
Substance	**Volume**
12 oz can of soda	355 mL
bar of gold	640 cm^3
tank of helium gas	50 L

How Can Measurements Be Combined?

Some quantities used in science are not measured directly. Instead, they are calculated by combining two or more measurements mathematically. Some important combined measurements are density and speed.

DENSITY

You have already learned that mass and the volume of an object can be measured. The values of mass and volume can then be combined to determine another property of matter, its density. **Density** is the amount of matter in a given volume. It's a measure of how compact matter is. For example, liquid water is denser than steam because it is more compact than steam. ☑

READING CHECK

10. Define What is density?

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You cannot measure density directly. It is calculated by using the mass and volume of a substance in this formula:

$$D = \frac{m}{V}$$

In this formula, *D* represents the density of a material, *m* represents its mass, and *V* represents its volume. Density units used in science include grams per milliliter, kilograms per liter, and grams per cubic centimeter, but any combination of mass and volume can be used. The density of pure liquid water is 1.0 g/mL or 1.0 kg/L.

SPEED

Speed is a measure of the motion of an object. Speed is calculated by dividing the distance that an object moves by the time it takes to move that distance.

$$s = d/t$$

In this formula, s represents speed, d represents the distance, and t represents time. You are used to hearing speeds expressed in units of miles per hour or kilometers per hour. The most common unit of speed in the science lab is meters per second (m/s), but any combination of distance and time can be used. ☑

READING CHECK

11. Identify What units would you use to measure the speed of a car on the highway?

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What Is the Difference Between Accuracy and Precision?

Most people use the words *accuracy* and *precision* to mean the same thing. However, they do not mean the same thing. An accurate measurement means a measurement that is correct. A precise measurement means a measurement that is the same every time it is taken. This means that precise measurements can be reproduced.

For example, consider a line that is 15.3 mm long. Suppose that when you measure it five times, your measurement is 15.1 mm each time. Your measurement is not accurate, because it should have been 15.3 mm. However, it is precise because you got the same measurement each time.

Measurements that have good accuracy and good precision are called good data by scientists. These data are used to explain nature and make predictions about things that happen in nature.

CALIFORNIA STANDARDS CHECK

8.9.b Evaluate the accuracy and reproducibility of data.

12. Evaluate While doing a lab, a student collects the following data on the speed of a car: 2.5 m/s, 2.0 m/s, 2.3 m/s, and 2.9 m/s. The correct speed is 2.5 m/s. Were any of the data accurate? Explain your answer.

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Do the data show reproducibility? Explain your answer.

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What Are Models?

Look at the illustration below. It appears to be a space shuttle. However, the wire that holds it in place and the lack of exhaust gases shows it is a model.

Model of a Space Shuttle

What Kinds of Models Do Scientists Use?

A **model** is a way to represent an object or a system. A model uses something familiar to help you understand something that is not familiar. For example, a model of a human skeleton can help you understand how the body works. Models are also used to explain the past or to predict the future.

Scientists use three different types of models: physical, conceptual, and mathematical models. These three kinds of models are used to show different things about objects or concepts. Models cannot show everything, because a model is never exactly like the thing it represents.

Say It

Explore Applications A model is never exactly like the thing it represents. Sometimes the model is larger, sometimes smaller. Some models are the same size as the object but simpler. Discuss in a group what types of models you have used and how they help you understand the object and how it works.

PHYSICAL MODELS

Model airplanes, dolls, and drawings are all examples of physical models. A physical model can show the details of something that is too large or too small to observe directly. For example, maps and drawings of bacteria are physical models. Scientists and engineers can build a simple model of an object to investigate how it works.

CONCEPTUAL MODELS

The second kind of model is a conceptual model, which puts many ideas together to explain something. For example, the big bang theory is a conceptual model that explains why the universe seems to be expanding. Astronomers built the model to explain the data that they had collected.

The big bang theory says that 12 billion to 15 billion years ago, an event called the big bang sent matter in all directions. This matter eventually formed the galaxies and planets.

MATHEMATICAL MODELS

Mathematical models use equations and data to explain or predict things. Weather maps are based on mathematical models of thousands of observations. Other mathematical models are the equations used to calculate force and acceleration. Many mathematical models are so complex that you need computers in order to use them. ☑

READING CHECK

13. Explain Why are computers needed for the mathematical models that represent weather?

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How Are Models Used?

Scientists use models to help represent ideas and objects. Models are also used to help you learn new information. Scientists often use models to explain concepts that are hard to understand. For example, an atom is much too small to see. However, a model of an atom can help you picture the parts of an atom and how atoms can combine with each other.

SCIENTIFIC THEORIES

In science, a **theory** is an explanation that combines many hypotheses and observations. A theory not only explains the observations, but it also makes predictions about what may happen in the future. Scientists use models to help organize information as they develop and test theories. ☑

Models can be changed or replaced as new information is added. The model of the structure of an atom has changed many times in the last 150 years. These changes have resulted in the model of an atom we use today.

READING CHECK

14. Describe What do models help scientists do as they develop theories?

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The compressed coils in the spring toy can be used to model the way air particles are crowded together in a sound wave.

TAKE A LOOK

15. Identify Which part of the spring models how molecules of air are close together?

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SCIENTIFIC LAWS

What happens when a model correctly predicts the results of many different experiments? Then a scientific law may be constructed. In science, a **law** is a summary of results and observations of many experiments. A law tells you how things work.

A scientific law is not a theory, because it does not explain why. For example, Newton's laws of motion explain how objects move. They let us accurately predict where an asteroid will be at a certain time 20 years from now. However, the laws of motion do not explain why the asteroid will be there. For that, you need to use the theory of gravity. Gravity explains the forces that cause bodies in space to attract each other over a distance.

Critical Thinking

16. Apply Concepts Picture the motion of a marble shot by a slingshot. Also picture the motion of a car on a race track. Which motion could you explain using a theory? Which could you explain using a law?

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Section 1 Review

8.9.b, 8.9.f

SECTION VOCABULARY

density the ratio of the mass of a substance to the volume of the substance

law a summary of many experimental results and observations; a law tell how things work

mass a measure of the amount of matter in an object

model a pattern, plan, representation, or description designed to show the structure or workings of an object, system, or concept

temperature a measure of how hot (or cold) something is; specifically, a measure of the average kinetic energy of the particle in an object

theory an explanation that ties together many hypotheses and observations

volume a measure of the size of a body or region in three-dimensional space

1. Identify What formula relates mass, volume, and density?

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2. Classify Fill in the blanks to complete the table of combined measurments.

What is calculated?	Formula	Unit
	$D = m/V$	kg/m^3
	$V = l \times w \times h$	m^3
Speed		

3. Analyze Processes To determine the density of a liquid, you measure its mass and its volume several times. What must the data show if they are good data? What must be the density of the liquid if the data are good?

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4. Analyze Ideas Why did scientists agree to use the SI units worldwide instead of the units common at their locations?

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5. Make Calculations If a bike rider travels 4 km in an hour, what is his speed measured in miles per hour?

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