chapter 2

Measurement

section 1 Description and Measurement

Before You Read

Weight, height, and length are common measurements. List at least five things you can measure.

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What You'll Learn
- how to estimate
- how to round a number
- the difference between precision and accuracy

Read to Learn

Study Coach

Make an Outline Make an outline of the main ideas in this section. Use the headings in the section as major headings. Be sure to include all words in bold.

Measurement

A **measurement** is a way to describe objects and events with numbers. You use measurements to answer questions like how much, how long, or how far. You can measure how much sugar to use in a recipe, how long a snake is, and how far it is from home to school. You also can measure height, weight, time, temperature, volume, and speed. Every measurement has a number and a unit of measure. There are many different units of measure. Some are meter, liter, and gram.

How do measurements describe events?

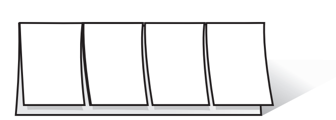
Events like races can be described with measurements. In the 2000 summer Olympics, Marion Jones of the United States won the women's 100-m dash in a time of 10.75 s. In this example, measurements tell about the year of the race, its length, and the runner's time. The name of the event, the runner's name, and her country are not measurements.

Estimation

What happens if you want to know the size of something but it is too large to measure or you don't have a ruler? You can use **estimation** to make a rough guess about the size of an object. You can use the size of one object you know to help you estimate the size of another object. Estimation can help when you are in a hurry or don't need an exact measurement. You will get better at estimation with practice.

FOLDABLES™

A Organize Make a Foldable, as shown below, and label the tabs Measurement, Estimation, Precision, and Accuracy.



Picture This

1. Draw and Compare You can show how the tree is about twice as tall as the person. Draw another person the same height that is standing on the shoulders of the person in the figure.

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Reading Check

2. Identify What word tells you that a measurement is an estimate?

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Think it Over

3. Apply Give a time when estimating might be helpful.

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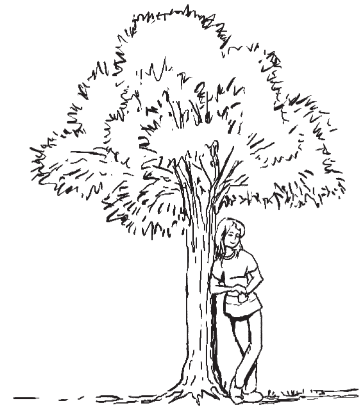
How do you estimate measurements?

You can compare objects to estimate a measurement. For example, the tree in the figure is too tall to measure. You can estimate the height of the tree by comparing it to the height of the person. The tree is about twice the height of the person. If the person is about 1.5 m tall, the tree must be 2×1.5 m, or about 3 m tall.



Estimated measurements often use the word *about.* For example, a soccer ball weighs about 400 g. You can walk about 5 km in an hour. When you see or hear the word *about* with a measurement, the measurement is an estimation.

When is estimation used?

Estimation is not only used when an exact measurement cannot be made. It is also used to check that an answer is reasonable. A reasonable answer makes sense. Suppose you calculate a friend's running speed as 47 m/s. Does it make sense that your friend can run that fast? Think about how far 47 m is. That's almost a 50-m dash. That means your friend could run a 50-m dash in about 1 s. Can your friend do that? No, he can't. So, 47 m/s is too fast and is not a reasonable answer. You need to check your work.

Precision

Precision describes how close measurements are to each other. Some measurements are more precise than others. Suppose you measure the distance from home to school four times. Each time you get 2.7 km. Your neighbor measures the same distance four times. He measures 2.9 km two times and 2.7 km two times. Your measurements are closer to each other than your neighbor's measurements. So, your measurements are more precise.

The timing for Olympic events has become very precise. Years ago, events were measured to tenths of a second. Now they are measured to hundredths of a second. The instruments we use to measure today are more precise than those used years ago.

Accuracy

Accuracy is the closeness of a measurement to the true value. Suppose you measured the length of your shoelace two times. One time you measured 12.5 cm and the other time you measured 12.3 cm. Your measurements are precise because they are close together. However, if the shoelace is actually 13.5 cm long, the measurements are not accurate.

What makes a good measurement?

A good measurement must be both precise and accurate. A precise measurement is not always a good measurement. A watch that has a second hand is more precise than a watch without one. But, the watch with the second hand could be set 1 hour earlier or later than the real time. In that case, the watch would not be accurate at all. Since the time on the watch is precise but not accurate, the time on the watch is not a good measurement.

How do you round a measurement?

Suppose you need to measure the length of the sidewalk outside your school. You could measure to the nearest millimeter. But, you probably only need to know the length to the nearest meter or tenth of a meter. Suppose you find that the length of the sidewalk is 135.481 m. How do you round this number to the nearest tenth of a meter? Follow these two steps:

1. Look at the digit to the right of the place being rounded to.
   - If the digit is 0, 1, 2, 3, or 4, the digit being rounded to stays the *same.*
   - If the digit is 5, 6, 7, 8, or 9, the digit being rounded to *increases by one.*

So, to round to the nearest tenth of a meter, look for the digit in the tenths place, 4. Find the digit to the right of 4. The 4 increases to 5 because the digit to the right of 4 is 8.

2. Look at the digit being rounded to. Then look at the digits to its right. If those digits are to the right of a decimal, they are removed. If they are to the left of a decimal, change them to zeros. For example, 432.9 rounded to the nearest hundred is 400. Since the 9 is to the right of the decimal, it is removed.

So, 135.481 rounded to the nearest tenth of a meter is 135.5 m.

Think it Over

4. **Apply** Give another example of a measurement that is precise but not accurate.

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Applying Math

5. **Rounding Values** What is 135.481 m rounded to the nearest ten meters?

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Some measurements are not precise.

If a measurement doesn't need to be precise, you can round your measurement. For example, suppose you want to divide a 2-L bottle of soda equally among seven people. When you use a calculator to divide 2 by 7, you get 0.285 714 28. You can round this number to 0.3. This is a little less than 0.333…, or $\frac{1}{3}$. You pour a little less than $\frac{1}{3}$ L of soda for each person.

What are significant digits?

Significant digits are the number of digits that show the precision of a number. For example, 18 cm has two significant digits: 1 and 8. There are four significant digits in 19.32 cm: 1, 9, 3, and 2. All non-zero digits are significant digits. Sometimes zeros are significant and sometimes they are not. Use these rules to decide if a zero is a significant digit.

	Rule	Example	Number of Significant Digits
Always significant	Final zeros after a decimal point	4.5300	5
	Zeros between other digits	502.0301	7
Not significant	Zeros at the beginning of a number	0.00059	2
May be significant	Zeros in whole numbers	16,500	3 or 5

Applying Math

6. **Counting Significant Digits** How many significant digits are in 28.070?

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How do you calculate with significant digits?

There are rules to follow when deciding the number of significant digits in the answer to a problem.

Multiplying or Dividing First, count the significant digits in each number in your problem. Then, multiply or divide. Your answer must have the same number of significant digits as the number with fewer significant digits in the problem. If it does not, you must round your answer.

6.14	×	5.6	=	[34].384
3 digits		2 digits		round to 2 digits

Adding or Subtracting When you add or subtract, find the least precise number in the problem (the number with the fewest decimal places). Then add or subtract. Your answer can show only as many decimal places as the least precise number. If it does not, you must round your answer.

$$\begin{array}{rl} 6.14 & \text{(hundredths)} \\ +\ 5.6 & \text{(tenths)} \\ \hline \boxed{11.7}4 & \text{(round to the tenths)} \end{array}$$

Applying Math

7. **Calculate** What is 13.2 × 4.628, rounded to the nearest significant digit? Show your work.

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After You Read

Mini Glossary

accuracy: the closeness of a measurement to the actual measurement or value

estimation: a method used to guess the size of an object

measurement: a way to describe objects and events with numbers

precision: describes how close measurements are to each other

1. Review the terms and their definitions in the Mini Glossary. How is precision different from accuracy?

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2. Complete the chart that shows how to round a number.

Look at digit to the ______________________________ of the place being rounded to.

If the digit is less than 5, the digit being rounded to ______________________________.

If the digit is 5 or greater, the digit being rounded to ______________________________.

If digit(s) to the right of the digit being rounded are to the *right* of a decimal, they are ______________________. If they are to the *left* of a decimal, they are ______________________________.

3. You were asked to make an outline as you read this section. Did your outline help you learn about measurement? What did you do that seemed most helpful?

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Science Online Visit **ips.msscience.com** to access your textbook, interactive games, and projects to help you learn more about description and measurement.

End of Section

chapter 2 Measurement

section 2 SI Units

What You'll Learn
- what the SI is and why it is used
- the SI units of length, volume, mass, temperature, time, and rate

Before You Read

Some people use metric units such as meters, grams, and liters. Others use units such as feet, pounds, and gallons. Explain why using different units might cause a problem.

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Mark the Text

Identify Definitions As you read, highlight the definition of each word that appears in bold.

Read to Learn

The International System

Scientists created the International System of Units, or SI. The **SI** is a system of standard measurement that is used worldwide. Some of the units in the SI system are meter (m) for length, kilogram (kg) for mass, kelvin (K) for temperature, and second (s) for time.

Units in the SI system represent multiples of ten. You know the multiple of ten by looking at the prefix before the unit. For example, *kilo-* means 1,000. So, one *kilo*meter is equal to 1,000 meters.

To change a smaller unit to a larger SI unit, multiply by a power of 10 as shown in the table. To rewrite a *deci*meter measurement in meters multiply by 0.1.

$10 \text{ dm} \times 0.1 = 1 \text{ m}$

1 dm and 0.1 m describe the same length. So do 5 km and 5,000 m.

Prefix	Meaning	Multiply by:
giga-	one billion	1,000,000,000
mega-	one million	1,000,000
kilo-	one thousand	1,000
hecto-	one hundred	100
deka-	ten	10
[Unit]		1
deci-	one-tenth	0.1
centi-	one-hundredth	0.01
milli-	one-thousandth	0.001
micro-	one-millionth	0.0001
nano-	one-billionth	0.000 000 001

Applying Math

1. **Converting Measurements** What do you multiply by to change a hectometer measurement into meters?

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Length

Length is the distance between two points. Metric rulers and metersticks are used to measure length. A **meter** (m) is the SI unit of length. One meter is about as long as a baseball bat. A meter is used to measure distances such as the length and height of a building.

Some units are used to measure short distances. One millimeter (mm) is about the thickness of a dime. A millimeter is used to measure very small objects, such as the length of a word on this page. One centimeter (cm) is about the width of a large paper clip. A centimeter also can be used to measure small objects, such as the length of a pencil.

A kilometer is used to measure long distances, such as distances between cities. A kilometer (km) is a little over half of a mile.

Volume

Volume is the amount of space an object fills. To find the volume of a rectangular object like a brick, measure its length, width, and height. Then multiply them together.

$$\textbf{Volume} = \textbf{length} \times \textbf{width} \times \textbf{height}$$
$$V = l \times w \times h$$

The volume of a cube with side lengths of 10 cm is $10 \times 10 \times 10 = 1{,}000$ cubic centimeter (cm^3). You probably have seen water in 1-L bottles. A liter is a measurement of liquid volume. One liter is equal to 1,000 cm^3. So, a cube with side lengths of 10 cm has the same volume of a 1-L water bottle. A cube with side lengths of 1 cm has the volume of 1 cm^3. It can hold 1 mL (1 cm^3) of water.

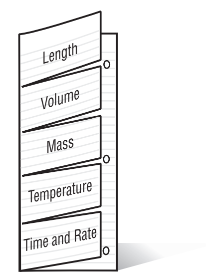
How can you find the volume of ice cubes in water?

What happens when you add ice cubes to a glass of water? The height of the water increases, but the amount of water does not change. The ice cubes take up space because they have volume, too. So, the glass contains both the volume of the water and the volume of the ice.

Not all objects have a regular shape like a brick. A rock has an irregular shape. You cannot find the volume of a rock by multiplying its length, width, and height. When you want to measure the volume of an irregular object, you can find the volume by immersion.

FOLDABLES™

B Compare and Contrast Make the Foldable below to help you understand the different types of measurement using SI units. Take notes on each type of measurement as you read.



Think it Over

2. **Infer** The volume formula can be used to find the volume of
   - **a.** a tissue box.
   - **b.** a lamp.
   - **c.** a computer mouse.

Applying Math

3. **Calculating Volume** Find the volume of a cube that measures 2 cm on each side. Show your work.

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What is immersion?

Start with a known volume of water and place the object in it. Then find the volume of the water with the object in it. The difference between the two volumes is equal to the volume of the object.

For example, to find the volume of a rock, first find the volume of water in a container. Next, place the rock in the water, making sure the water covers all of the rock. Then find the volume of the water and rock together. Subtract the smaller volume from the larger one. The difference is the volume of the rock.

Mass

The **mass** of an object measures the amount of matter in the object. The **kilogram** (kg) is the SI unit for mass. One liter of water has the mass of about 1 kg. Smaller masses are measured in grams (g). The mass of a paper clip is about 1 g.

Mass versus Weight Why use the word *mass* instead of *weight?* Mass and weight are not the same. Mass depends only on the amount of matter in an object. Your mass on the moon would be the same as it is on Earth. **Weight** is a measure of the gravitational force, or pull, on the matter in an object. In other words, weight depends on gravity. You would weigh much less on the moon because the gravitational force on the moon is less than on Earth.

Reading Check

4. **Determine** What does weight depend on?

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How much would you weigh on other planets?

Keep in mind that weight is a measure of force. The SI unit for force is the newton (N). Suppose you weigh 332 N on Earth. That would be a mass of about 75 pounds, or 34 kg. Remember that the gravitational force is different on different planets. On Mars, you would weigh 126 N. On Jupiter, you would weigh much more—782 N. Your mass would still be the same on all the planets because the amount of matter in your body has not changed.

Think it Over

5. **Infer** Which has more gravity, Mars or Jupiter?

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Time

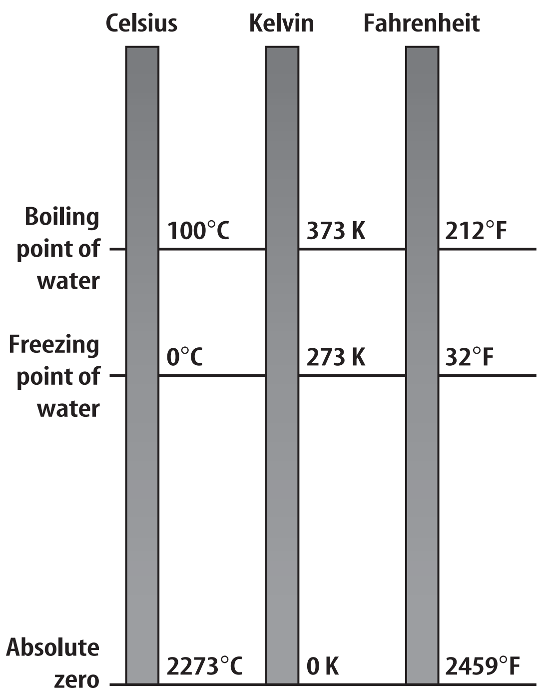
Time tells how long it takes an event to happen. The SI unit for time is the second (s). Time is also measured in minutes (min) and hours (h). Time is usually measured with a clock or a stopwatch.

Rate

A **rate** is the amount of change in one measurement that takes place in a given amount of time. To find a rate, a measurement is divided by an amount of time. Speed is a common rate that tells how fast an object is moving. Speed is the distance traveled in a given time. The formula for speed is distance (length) divided by time, such as 80 kilometers per hour (km/h). The unit that is changing does not have to be an SI unit. You can use rate to tell how many cars pass through an intersection in an hour (cars/h).

Temperature

Temperature is how hot or cold an object is. The **kelvin** (K) is the SI unit for measuring temperature. The Fahrenheit (°F) and Celsius (°C) temperature scales are the scales used on most thermometers. Compare the scales in the figure. The kelvin scale starts at 0 K, absolute zero, the coldest possible temperature. One degree of change on the kelvin scale is the same as one degree of change on the Celsius scale.



Reading Check

6. Explain How do you calculate a rate?

Picture This

7. Interpreting Graphs What is the boiling point of water on each of the temperature scales?

Celsius:

Kelvin:

Fahrenheit:

After You Read

Mini Glossary

kelvin: SI unit for measuring temperature (K)
kilogram: SI unit for measuring mass (kg)
mass: amount of matter in an object
meter: SI unit of length (m)
rate: the amount of change in one measurement that takes place in a given amount of time
SI: a system of standard measurement that is used worldwide
volume: amount of space that fills an object
weight: a measure of the gravitational force, or pull, on the matter in an object

1. Review the terms and their definitions in the Mini Glossary. What are four examples of rate?

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2. Complete the table to identify common SI base units.

Quantity	SI Unit
Length	
Volume	cubic centimeter or _________
Mass	
Temperature	
Time	

3. Sometimes you need to find your own way to remember terms and main points. How could you remember what mass and volume mean?

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End of Section

Measurement

chapter 2

section 3 Drawings, Tables, and Graphs

Before You Read

A common saying is "A picture is worth a thousand words." Use the lines below to explain what this means.

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What You'll Learn
- how pictures and tables give important information
- how to use three types of graphs

Read to Learn

Mark the Text

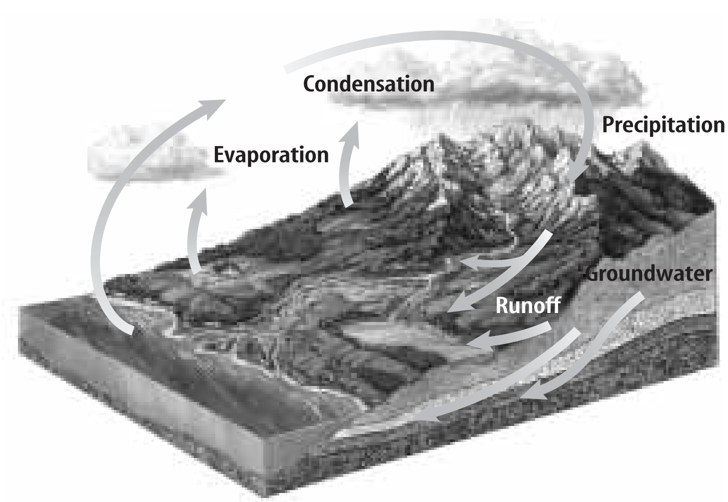
Identify the Main Point As you read, highlight two main points about pictures, tables, and each kind of graph.

Scientific Illustrations

Most science books include pictures. These pictures can be drawings or photographs. Drawings and photographs can often explain new information better than words can.

What does a drawing show?

Drawings are helpful because they can show details. Drawings can show things that you cannot see. The drawing below shows details of the water cycle that can't be shown in a photograph. You can also use drawings to help solve problems. For example, you could draw the outline of two continents to show how they might have fit together at one time.



Picture This

1. **Interpret a Drawing** What parts of the water cycle can be shown in a drawing but not in a photograph?

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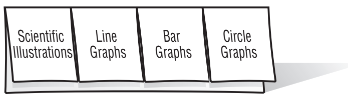
FOLDABLES™

C Compare and Contrast
Make a Foldable as shown. Use the sections to draw a sample of a scientific illustration, a line graphs, a bar graph, and a circle graph.



What does a photograph show?

A photograph shows an object at one moment in time. A video or movie is made of a series of photographs. A movie shows how an object moves. It can be slowed down or sped up to show interesting things about an object.

Tables and Graphs

Science books contain tables and graphs as well as drawings and photographs. Tables are a good way to organize information. A **table** lists information in columns and rows so that it is easy to read and understand. Columns are vertical, or go up and down. Rows are horizontal, or go across from left to right. This table shows the number of endangered animal species for each year from 1984 to 2002.

Endangered Animal Species in the United States

Year	Number of Endangered Animal Species
1984	192
1986	213
1988	245
1990	263
1992	284
1994	321
1996	324
1998	357
2000	379
2002	389

A **graph** is a drawing that shows data, or information. Sometimes it is easier to see the relationships when the data is shown in a graph. The three most common types of graphs are line graphs, bar graphs, and circle graphs.

Applying Math

2. **Interpret Data** How many animal species were endangered in 1992?

   a. 192

   b. 284

   c. 321

   d. 389

What does a line graph show?

A **line graph** shows changes in data over time. Things that change, like the number of endangered animals and the year, are called variables. A line graph shows the relationship between two variables. Both variables in a line graph must be numbers. ✓

✓ Reading Check

3. **Describe** How many variables are shown on a line graph?

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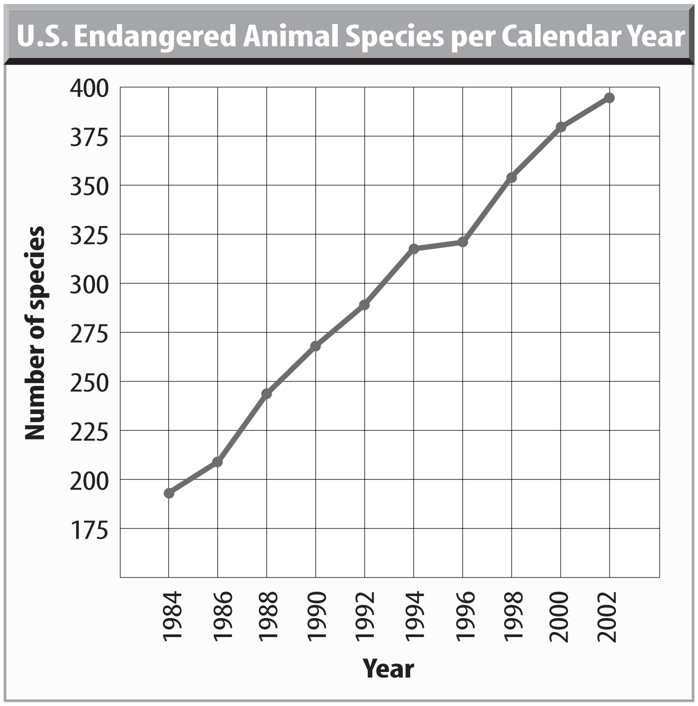
In the line graph at the top of the next page, the horizontal axis, or *x*-axis, shows the year. The vertical axis, or *y*-axis, shows the number of endangered species. The line on the graph shows the relationship between the year and the number of endangered species. To find the number of endangered species in a given year, find that year on the *x*-axis. Find the point on the line that is above that year. See what number on the *y*-axis lines up with the point.



Picture This

4. Interpret Data Look at the line graph. Between which two years did the number of endangered species increase the least? Circle your answer.

a. 1986–1988

b. 1992–1994

c. 1994–1996

d. 2000–2002

What does a bar graph show?

A **bar graph** uses rectangular blocks, or bars, to show the relationships among variables. One variable must be a number. This variable is divided into parts. The other variable can be a category, like kinds of animals, or it could be another number. In the bar graph on endangered species, the height of each bar shows the number of endangered species in each animal group. For example, there are about 30 species of endangered insects. Bar graphs make it easy to compare data.

Picture This

5. Describe Look at the bar graph. How many animal groups have fewer than 30 endangered species?

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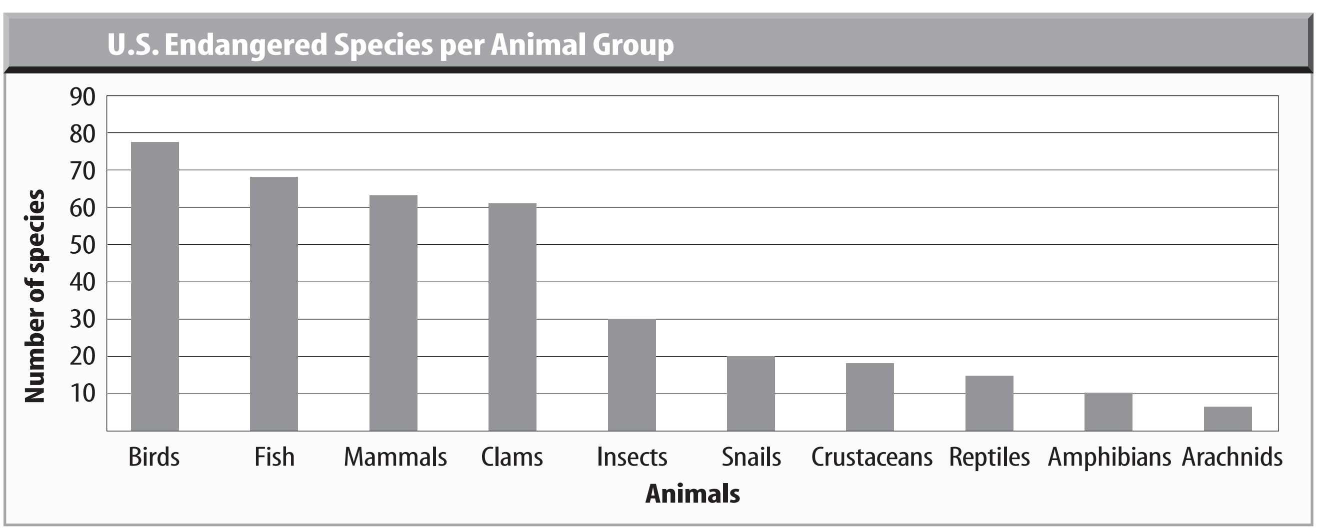
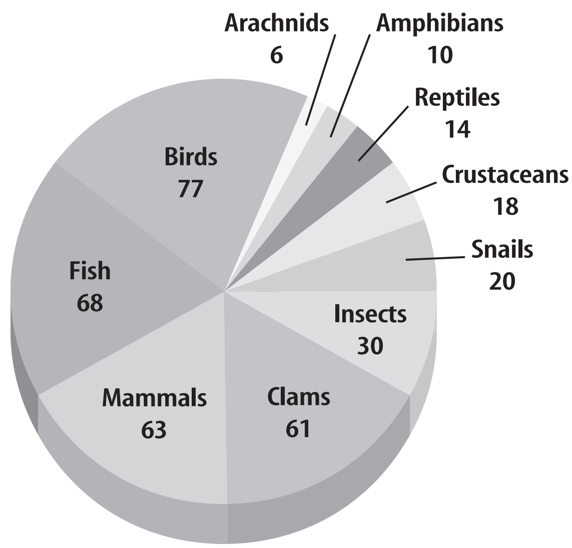


What does a circle graph show?

A **circle graph** shows the parts of a whole. It is sometimes called a pie graph because it looks like a pie. The circle represents the whole pie. The slices are the parts of, or fractions of, the whole pie. Circle graphs help you compare the sizes of the parts. It is easy to see which parts are largest and which are smallest.

Look at the circle graph on endangered species. What is the largest piece of pie? Birds is the largest piece. This tells you that there are more endangered bird species than any other animal group. What is the smallest piece of pie? Arachnids is the smallest. There are fewer endangered arachnids than any other animal group.



Picture This

6. **Interpret Data** Use the circle graph. Which animal group has the second largest number of endangered species? How many endangered species does this group have?

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Applying Math

7. **Find the Ratio** Look at the circle graph. Write a fraction to show the number of bird species compared to the total number of endangered animal species.

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How do you make a circle graph?

A circle has 360°. To make a circle graph, find what fraction of 360 each part is. First, find the total number of parts in the whole. The total number of endangered species is 367. Then, compare the number of each animal species with the total. Look at the part of the circle labeled Mammals. There are 63 endangered mammal species. Make a fraction to show 63 out of 367, which would be $\frac{63}{367}$.

Now find the part of 360° that are mammals. To find this, set up a proportion and solve for x. The answer is the size of the angle to draw in the circle graph.

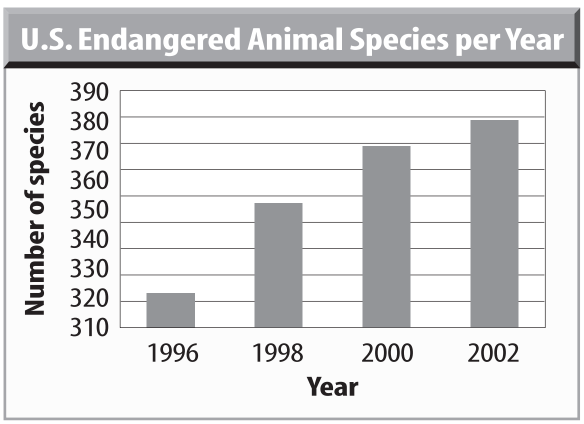
$$\frac{63}{367} = \frac{x}{360°} \qquad x = 61.8°$$

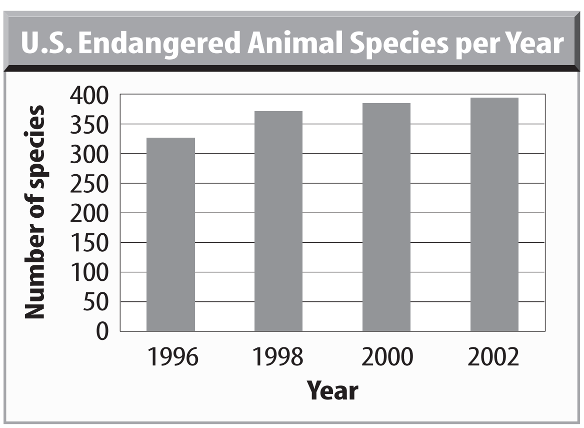
The angle at the center of the circle for the part that represents mammals will have a measure of 61.8°. Use the same method to find the other angles to show data.

Why is the scale of a graph important?

The two graphs below do not look the same, but they both show the same data. Why do the graphs look different? The graphs look different because their scales are different. Look at the scale on the y-axis in each graph. Look at the lowest number. The first graph begins with 310 instead of 0. It appears as though there was a great increase in the number of endangered species from 1996 to 2002. The second graph does begin at 0. It shows that there was a slight increase in endangered species during these years.

A scale that does not start at 0 is called a broken scale. A broken scale makes it easier to see small changes in the data. However, you must read the graph carefully to see if there is a broken scale. When you see a bar graph or a line graph, look at the data carefully. If the graph seems odd, take a closer look at the scale.





Reading Check

8. **Explain** What is a broken scale?

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Picture This

9. **Describe** In your own words, tell when a broken scale in a bar graph or a line graph is useful.

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After You Read

Mini Glossary

bar graph: a graph that uses bars to show the relationships between variables.

circle graph: a graph that shows the parts of a whole

graph: a kind of drawing that shows data, or information

line graph: a graph that shows changes in data over time

table: lists information in columns and rows so that it is easy to read and understand

1. Review the terms and definitions in the Mini Glossary. Write a sentence that tells how a graph helps you understand data.

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2. Complete the chart below to describe when each graph is most useful.

Graph Type	When Useful
Line graph	
Bar graph	
Circle graph	compare parts to a whole

3. You were asked to highlight two main points about pictures, tables, and each kind of graph. How did you decide what to highlight?

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End of Section

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