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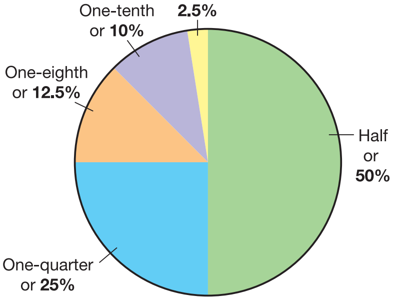
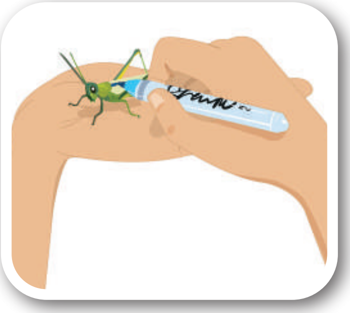
Making Sense of Science

Science Literacy Student Reader

Charts and graphs



Collecting data



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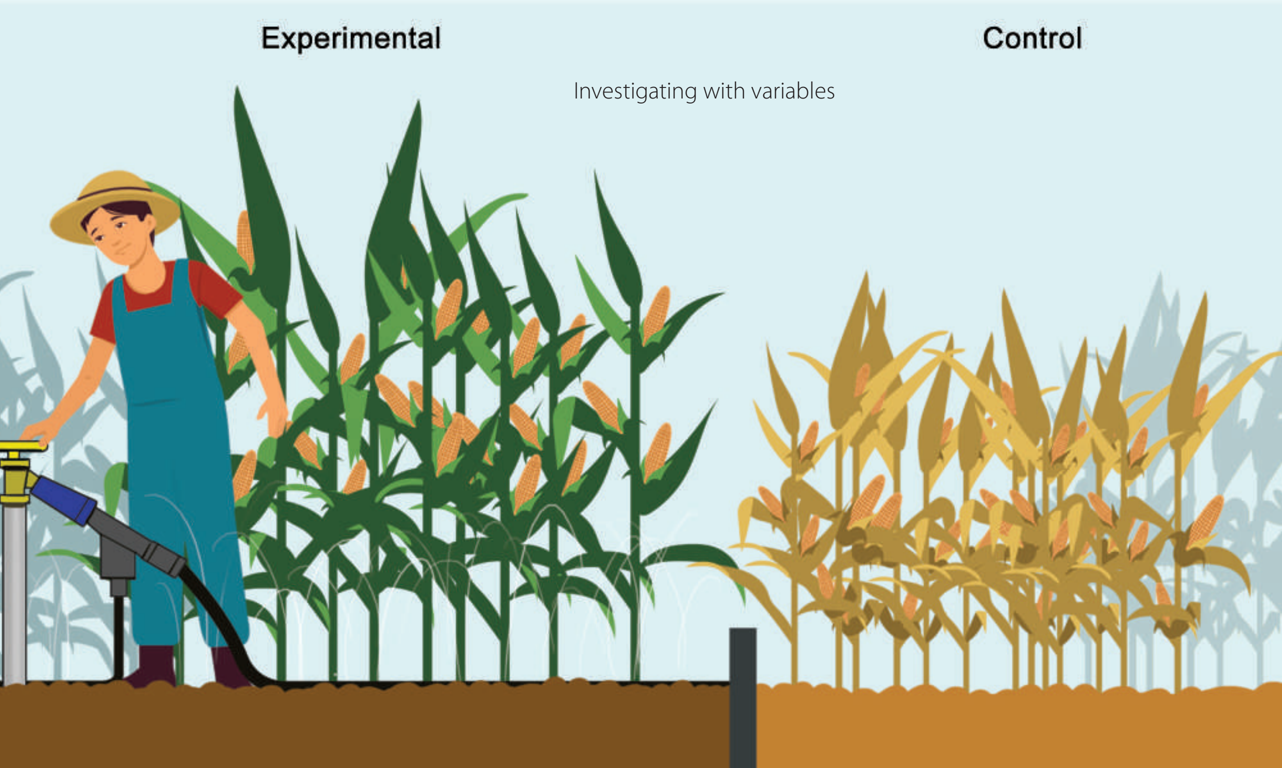

Investigating with variables

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Making Sense of Science

Reader

Core Knowledge®

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Making Sense of Science

Table of Contents

Methods, Tools, and Techniques

Chapter 1

Scientists use a variety of different methods, tools, and techniques to investigate the natural world and share their results.

Observing and Sampling

One method of investigating nature is to make observations and record them. An observation that captures some kind of quantity, such as an animal's mass, width, or length, is called a measurement. Quantitative observations deal with quantities, amounts measured and recorded using numbers.

These field-workers are using a technique that involves water sampling. This allows them to understand the chemistry of the stream.

Words to Know

A *method* is a way of accomplishing something in a systematic way.

A *technique* is a way of carrying out a particular task.

Collecting Specimens

Netting and other sampling techniques can give scientists specimens they can preserve or take a closer look at. Specimens can be whole organisms or small samples of tissue.

This scientist wants to know what kinds of insects live in this field. By using a net, the scientist can collect a sample of insects that might represent many of the kinds of insects that live in the area.

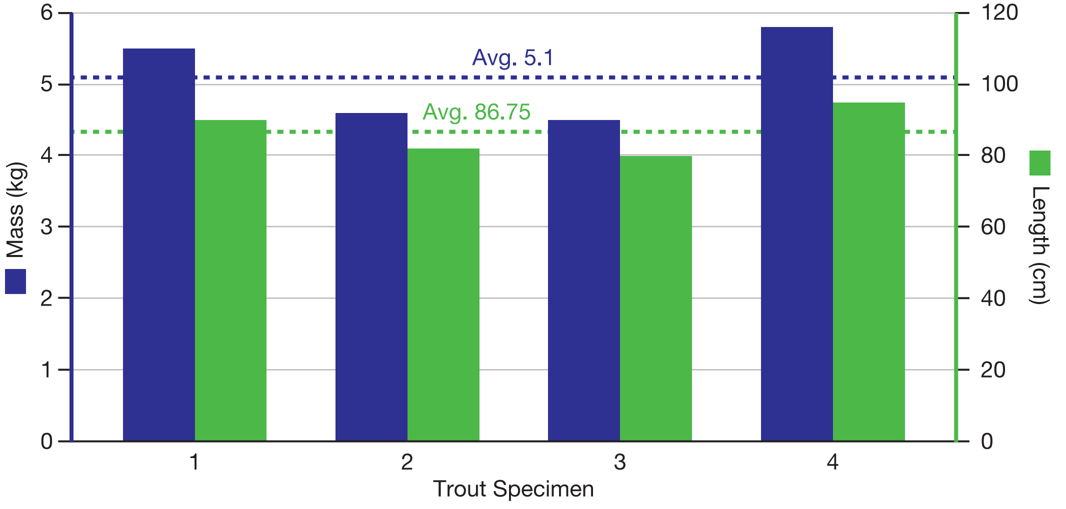
Some specimens, such as the animals shown here, can be preserved and put on display.

Organizing Data

Scientists organize their data to look for patterns. Data organized into tables can help make sense of a lot of numbers.

Trout specimen	Mass (kg)	Length (cm)
1	5.5	90
2	4.6	82
3	4.5	80
4	5.8	95
Avg.	**5.1**	**86.75**

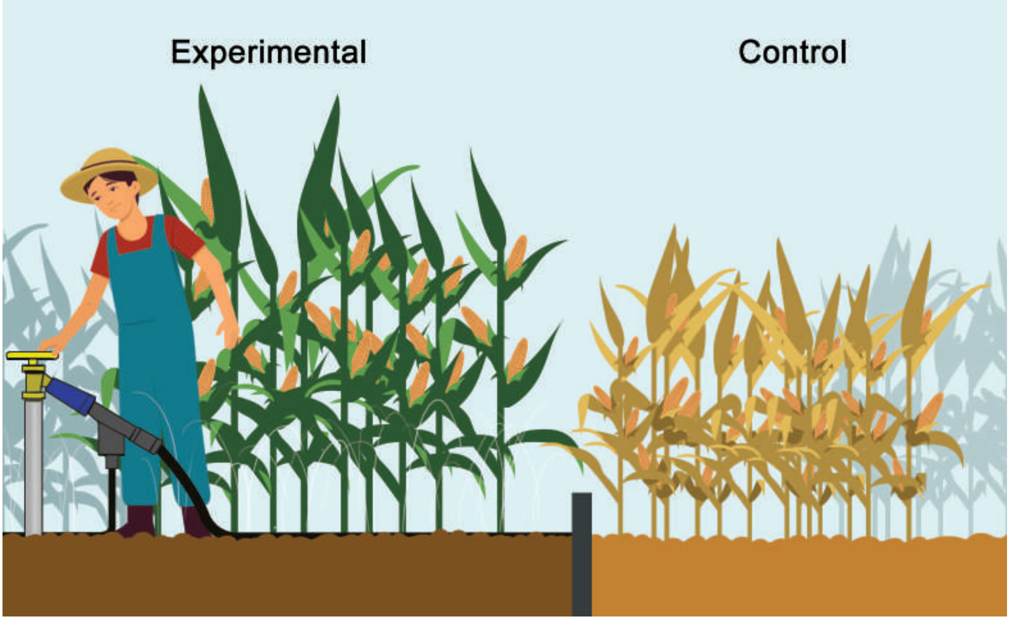
In this table, the masses and lengths of four trout are shown. The bottom row shows the average mass and length.



Data from a table or other format can be graphed. A graph can help a scientist detect trends or patterns. Trout specimens 1–4 are listed along the bottom of the graph. For each fish, the blue graph bar shows its mass and the green bar shows its length.

Controlling Variables

Scientists often conduct experiments. The experiment must be well-designed so the investigators know their results are accurate.



Consider the following example: A farmer is conducting a simple experiment. One row of plants, the experimental row, gets extra water every morning, in addition to rain. Another row of plants, the control row, only gets rainfall.

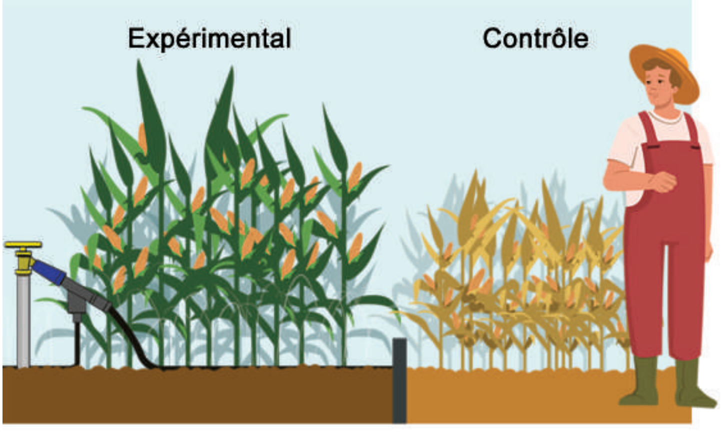
Every other factor is the same for both rows. They are in the same type of soil, they are exposed to the same weather, and they all grew from the same type of seeds. These factors are called variables, and they are all kept the same for both rows.

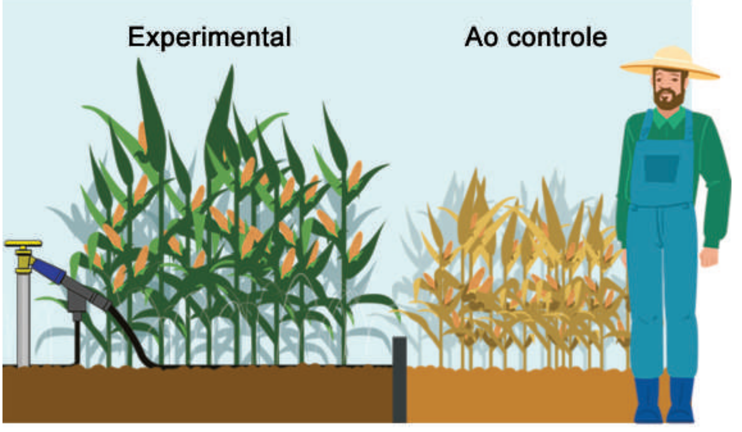
The farmer can be confident that whatever differences he sees in how the two sets of plants grow is a result of the different amounts of water they receive. This is good experimental design because only one variable is being tested at a time: the amount of water available to the plants.

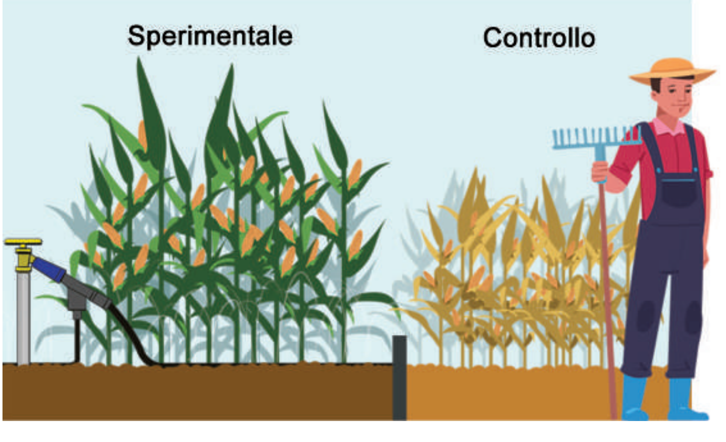
Repeating Experiments

Scientists are never satisfied with the results of only one experiment. They test and retest. Then other scientists repeat those experiments. Scientists ask, “Are the results of many tests consistent?”

The same experiment conducted by the farmer on the previous page can be conducted by other farmers around the world. This is a way of testing the original experiment’s results. Some other farmers might conduct a similar experiment to test a different variable, such as soil, fertilizer, or exposure to pollinators.



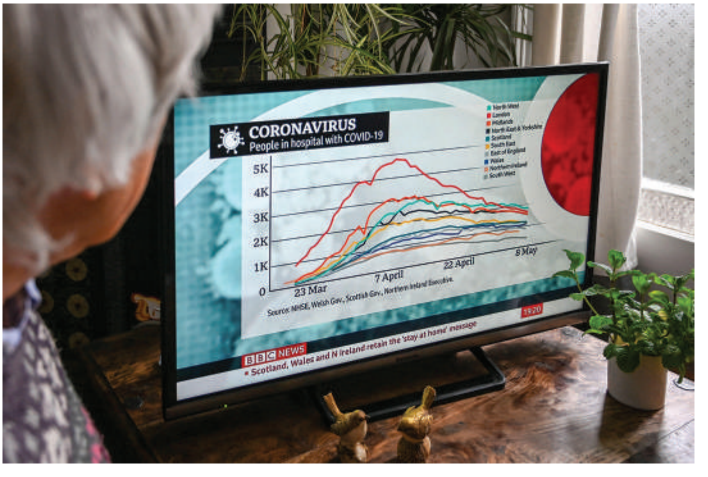




Communicating

Science also involves reporting the results of investigations and experiments. Results are usually published in the form of a scientific paper. A paper will be reviewed by other scientists before it is published. If it is accepted for publication, the paper might be read by hundreds or thousands of other scientists. It might also be read by science journalists, politicians, news editors, and others who can help publicize the findings. Decisions can then be informed by the information in the paper.

Presenting scientific findings in a form that people can understand, even without much science expertise, is important. In some cases, a person might have just a few minutes—or seconds—to pay attention to a science news story, so a graphic may be the best way to convey the key findings of an investigation



This news feature used a graph to show how many people in the United Kingdom were in the hospital with the coronavirus during a six-week period in 2020. Television and the internet can be powerful tools for conveying scientific information.

Main Science Idea

Though they can be very different from one to the next, science investigations share common tools, techniques, and methods.

Laws That Are Never Broken

Chapter 2

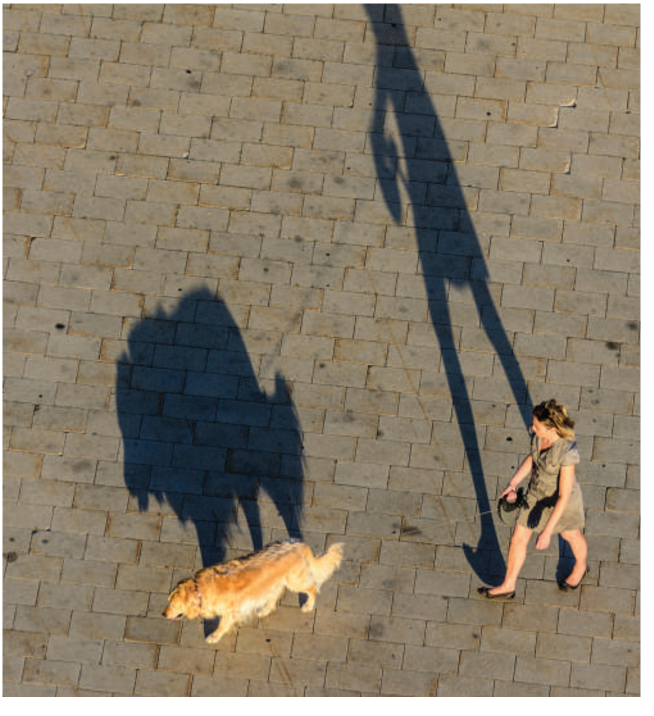
If nature had police officers whose job was natural law enforcement, they would not have much to do. There are some laws of nature that apply wherever you go, no enforcement required!

For example, gravity is a force that pulls objects toward each other, and it exists throughout the universe.

Sir Isaac Newton studied gravitational force. He developed the Law of Universal Gravitation. He used math to define the law. A scientific law is a description of many observations. The description often involves math formulas.

Gravity is a force that causes objects to pull on each other. This results in laws such as "what goes up must come down" and phenomena such as weight, landslides, tides, and the moon's orbit around Earth.

A natural or scientific law is described after a lot of observation. Here's another example. Shadows form on the side of an object that's opposite from the light source.

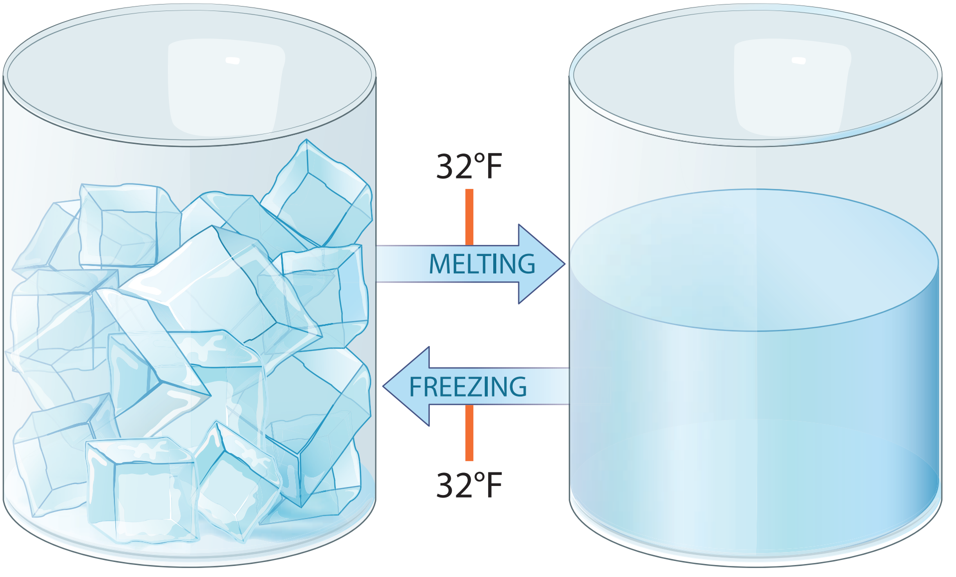


Where must the light source be to cast these shadows of the woman and the dog?

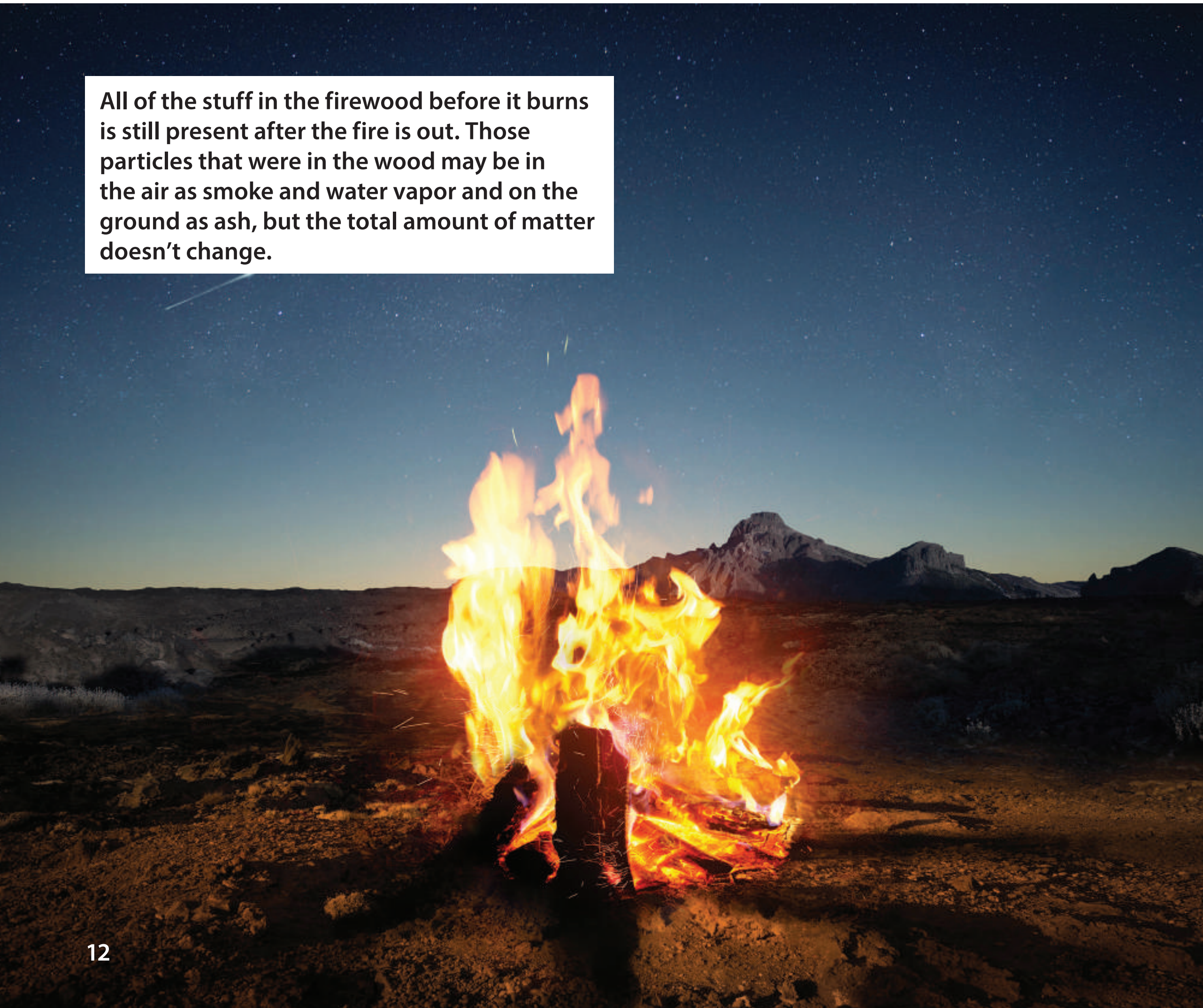
Another law: Objects or substances in contact with each other eventually reach the same temperature as thermal energy moves from warmer things to cooler things.

Suppose the air temperature in the pizzeria is 70 degrees Fahrenheit. The jug of ice water will have a much colder temperature when it is placed on the table. The pizza fresh from the oven will be much warmer. Eventually, the temperatures of both things will reach the temperature of the air, the table, and the other things in the system.

Another law involving temperature: If the surrounding pressure is kept the same, pure water melts and freezes at the same temperature, no matter where it is.



Another natural law: Matter cannot be created or destroyed. New forms of matter can be made or broken down, but the stuff that makes up that matter is constant.



All of the stuff in the firewood before it burns is still present after the fire is out. Those particles that were in the wood may be in the air as smoke and water vapor and on the ground as ash, but the total amount of matter doesn't change.

These young coconut trees are sprouting in a landscape of volcanic ash and rock. They get most of the matter they need from the air around them. Over time, a forest may grow and thrive here. And then it might be burned or buried by another volcanic eruption. The total amount of matter will not change even as the forms of matter continuously change over time.

Main Science Idea

The laws of nature apply everywhere.

Accurate and Precise

Chapter 3

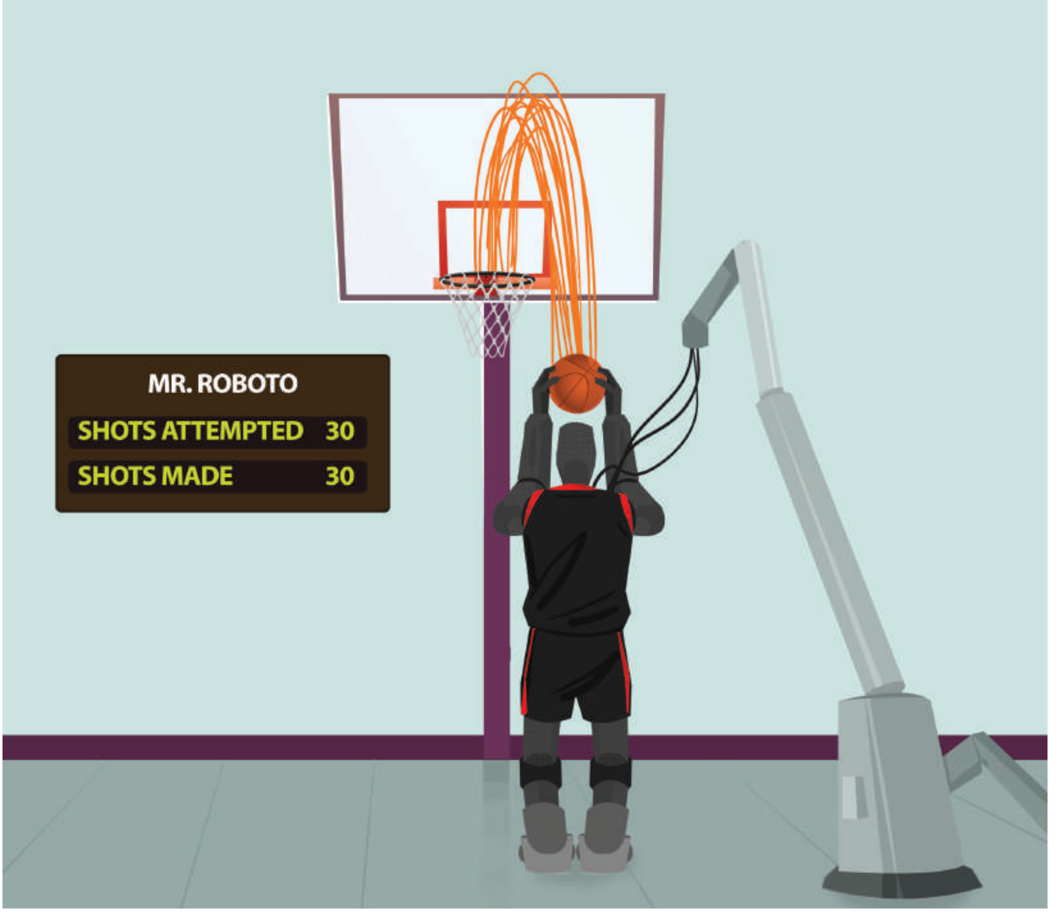
Have you ever heard the terms *accuracy* and *precision* used in advertisements for fancy wristwatches, mobile phones, or other devices? These two terms are sometimes used in everyday language as if they have the same meaning. Here's a scenario to help think about these words.

The Umami Corporation has developed robots for a halftime performance of a basketball game. Each robot has mechanical parts that mimic how humans shoot a basketball. The robots have sensors to help control shooting motion and throw strength based on distance from the basketball hoop.

The halftime show features two Umami robots and two humans to see who—or what—is the best basketball shooter.

Mr. Roboto

The first of the robots to compete is called Mr. Roboto. This is the latest and greatest design. The figure summarizes how Mr. Roboto performs in the contest.



Mr. Roboto's 30-for-30 performance shows that it is both accurate and precise. All of the shots went into the net; this is accuracy. Also, all of the shots were exactly the same; that is precision.

Mr. Roboto's mechanical precision means each shot lands in the same place, and because its sensors are so good, the precisely placed shots all swish through the hoop. "Nothing but net!" the announcer yells as the crowd rises to its feet to cheer on the robot.

Sarah

Sarah is a local high-school basketball star.

In the halftime show, she makes 25 of 30 shots. So, she's less accurate a shooter than Mr. Roboto.

Her shots are fairly precise, but there is more variation in her shots, which means her precision is not as high as Mr. Roboto's.

This is natural. After all, Sarah is not a robot!

Cy Borg

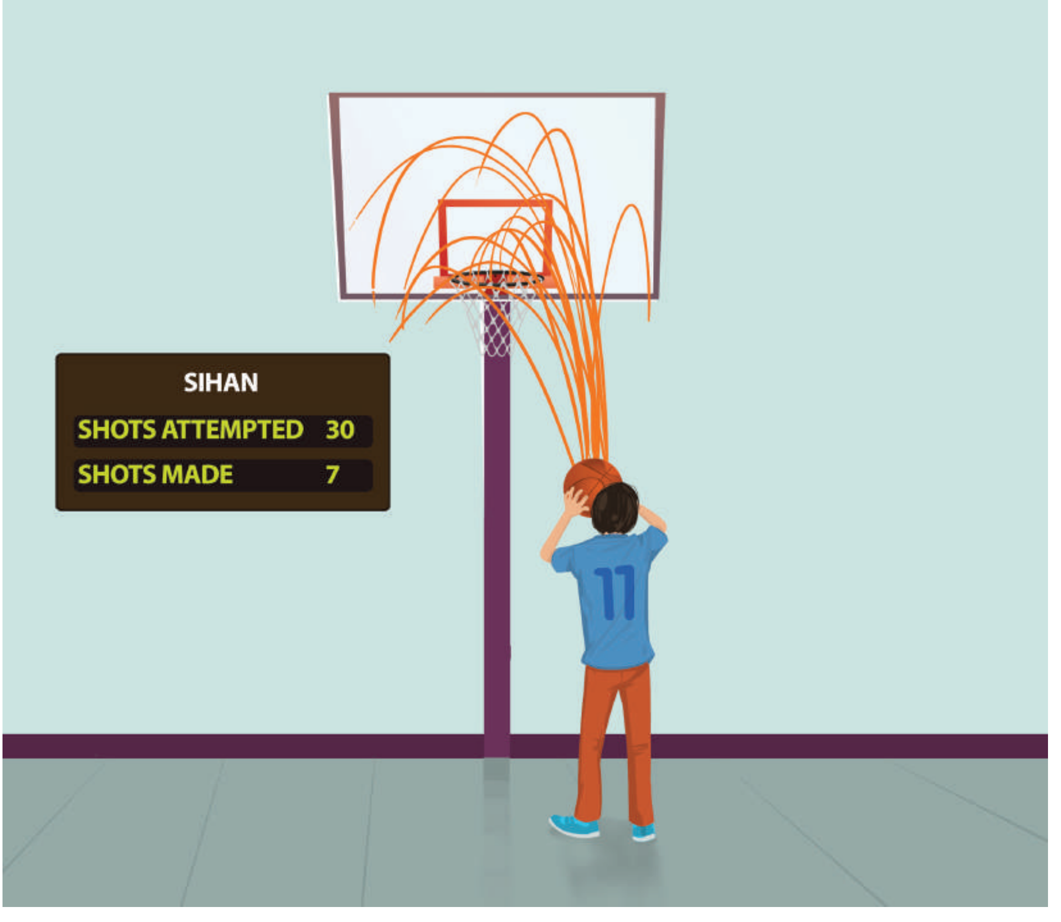
The third participant in the halftime contest is Umami's earlier edition of its basketball-playing robot, named Cy Borg.

Instead of shooting the ball at the center of the hoop, it launches all 30 shots to the left side of the rim. Each shot clangs off and fails to fall through the hoop.

Cy Borg gets a zero for accuracy. But because all of its shots land in the same spot, its precision is extremely high.

Sihan

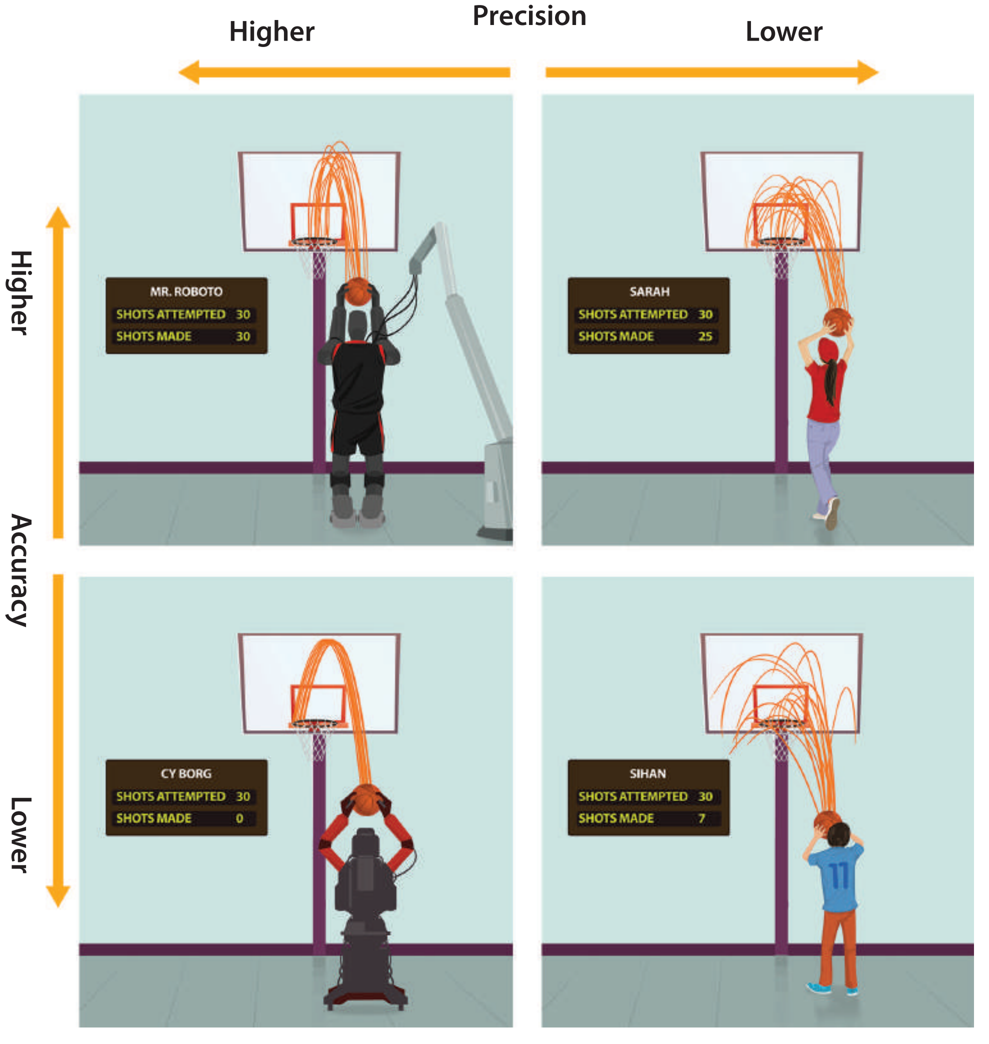
The final participant in the shooting contest is a ten-year-old boy named Sihan. He is an avid youth basketball player, but because the shots taken are from eighteen feet away and he is still fairly small, he struggles with his accuracy and precision.



Compared to the other participants, Sihan's shots are considered both inaccurate and imprecise because he makes just 7 of 30 shots and his shots land in many different places on the hoop.

Comparison

The shooting performances of the two robots and the two humans illustrate four different examples of accuracy and precision.



Mr. Roboto's shots were accurate and precise.
Sarah's shots were less accurate than Mr. Roboto's but somewhat precise.
Cy Borg's shots were as precise as Mr. Roboto's but were less accurate.
Sihan's shots were less precise and less accurate than Mr. Roboto's.

Main Science Idea

Accurate means "on target." *Precise* means "within a narrow range."

Is It Testable?

Chapter 4

How can you figure out the cause of something? Perform a test! A fair test is an experiment. Everything stays the same except one factor. The investigator changes that one factor to see what happens as a result of the change.

Suppose you want to investigate what causes some plants of the same type to grow taller than others. You think it might have something to do with light.

You decide and vary the **independent variable**, or possible cause.	You observe, measure, and record the **dependent variable**, or unknown effect.	You keep all the **controls** the same to make it a fair test.
Example: Varying amount of light	Example: The outcome of how tall a plant grows	Examples: Using the same amounts and types of soil, water, and air

You set up your experiment with controls, the things you keep the same. You also set up the independent variable, the possible cause. You collect data on your dependent variable (the unknown effect). You compare how the dependent variable changes. Is there a difference? Even when you have done everything correctly, you might not see any effect at all. This might seem disappointing, but it is also an answer to your question.

Trey and Taylor Talk Tests

TREY: I want to investigate light or sound. How do I choose?

TAYLOR: Keep it simple. Do you have any hobbies? Maybe you can relate light or sound to something you already know.

TREY: I like to garden. I know that plants use light for energy. So, I'll investigate light.

TAYLOR: OK. Is that your independent variable or your dependent variable?

TREY: The independent variable is the possible cause. The dependent variable is the unknown effect. Since light isn't affected by anything plants do, it must be the independent variable.

TAYLOR: Right! Now you need to come up with a question.

TREY: How about, "Why do plants need light to grow?"

TAYLOR: That's an interesting question! But it's not easily testable at home. How would you figure out *why* plants need light?

TREY: I suppose I could try growing plants with and without light. But that wouldn't tell me why plants need light, would it?

TAYLOR: No. Generally, "why" questions aren't as easy to test. Try starting it with "how."

TREY: What about, "How does light affect the way plants grow?"

TAYLOR: That's a better question. But it's not clear what you're going to be changing. Are you varying the type of light? Its direction? Its brightness? The hours per day that it is shining?

TREY: I want to vary the brightness. I can use three light bulbs with different intensities. That'll be my independent variable.

TAYLOR: So, the question is, "How does changing the intensity of light affect the way plants grow?" It's better. I'm not sure about your dependent variable. What kind of plants will you test? Testable questions are specific.

TREY: I can use radish seeds. They grow quickly, and I'll have enough data in time for the science fair!

TAYLOR: What will you observe, measure, and record? The time it takes the seeds to sprout? The percentage that sprouts? Or something else, like their color?

TREY: Hmm. I want to see if brighter light makes them sprout more quickly. So, I will observe and record how many sprout each day. This is my dependent variable.

TAYLOR: Now what is your testable question?

TREY: "How does changing the intensity of light affect the time it takes radish seeds to sprout?"

TAYLOR: That's a great testable question! So, what data will you compare?

TREY: I can take the average number of days it took the seeds to sprout. I will record the first ten seeds sprouting in each pot, to keep things equal.

TAYLOR: Keeping things equal is good! What else are your controls?

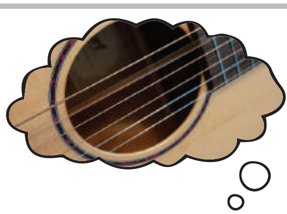
TREY: I will use the same size and type of pot, the same kind and amount of soil, and the same amount of water on the same schedule for all the pots. And I'll leave the same amount of space between the seeds.

TAYLOR: Great! What about the light? How can you be sure that nothing varies except for its intensity?

TREY: I'll put the light bulbs in the same kind of lamp and set it up the same distance from the plant pots. They'll also shine from the same direction onto the plants.

TAYLOR: I think you're going to have a great science fair project!

The next day, Trey takes his testable question to school. Classmates share their questions, and the teacher provides some help.

 **Student Question:** How does tension affect a guitar?	**Feedback:** How will you determine how the guitar string is affected? Think carefully about how you will measure your variables.	**Improved Question:** How does the amount of tension affect the pitch of a plucked guitar string?
 **Student Question:** Which sunscreen is best?	**Feedback:** How are you going to measure "best"? Do you mean that it lasts the longest? That it is safe for ocean animals? Or that it blocks the most UV rays? The science lab has a UV meter that you can use to measure UV light.	**Improved Question:** How does SPF affect the amount of UVB light that passes through a layer of sunscreen on a clear plastic sheet?

 **Student Question:** How well does my dog respond to different sounds?	**Feedback:** How are you going to vary the sounds? And how will you measure how well your dog responds? Tip: Repeat the experiment on more than one dog. Some animals have hearing loss.	**Improved Question:** What percentage of time do dogs turn their heads in response to tones of different frequencies?
 **Student Question:** How do I change the sound produced by rubbing the rim of a drinking glass?	**Feedback:** *What would you ask or tell the person who wrote this question?*	**Improved Question:** *How would you revise the question to make it more testable?*
 **Student Question:** What kinds of sounds can my pet hear?	**Feedback:** *What would you ask or tell the person who wrote this question?*	**Improved Question:** *How would you revise the question to make it more testable?*
Student Question: How would life on Earth be different if the sun's light were green?	**Feedback:** That's an interesting question. But unless you have a spare Earth with a green sun (and a time machine), you have no way to test it!	?

Main Science Idea

Some questions are testable. Others are not.

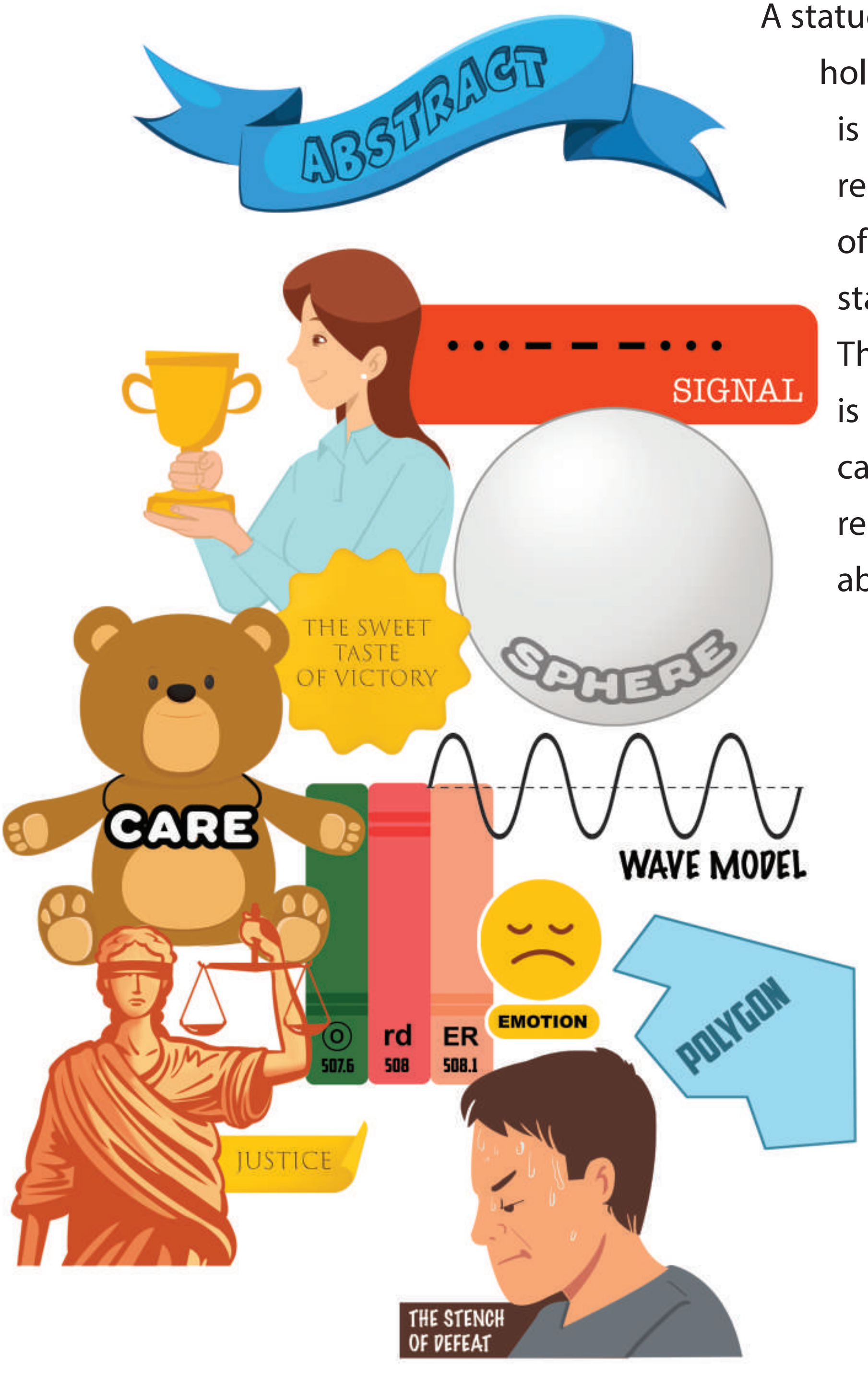
Concrete or Abstract

Chapter 5

When something is concrete, we mean it exists as a real thing. People, places, and objects are concrete things. They are physical. Something concrete can be observed with the senses. It can be seen, touched, heard, tasted, or smelled. Concrete things have physical properties that can be described.

Abstract things are ideas. They cannot be seen and touched, like physical objects. They are not concrete. They cannot be observed with the senses. Abstract things can be represented by symbols. For example, an icon of a frowning face can stand for sadness.

A statue of a woman holding a scale is often used to represent the idea of justice. The statue is concrete. The idea of justice is abstract. In this case, the statue represents an abstract thing.



Concrete Models

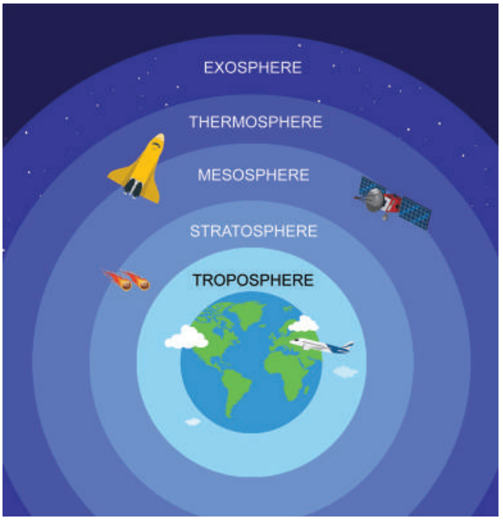
Scientists use models to represent things that are too large, too small, too dangerous, or too complex to investigate directly. Concrete models can be seen and touched.

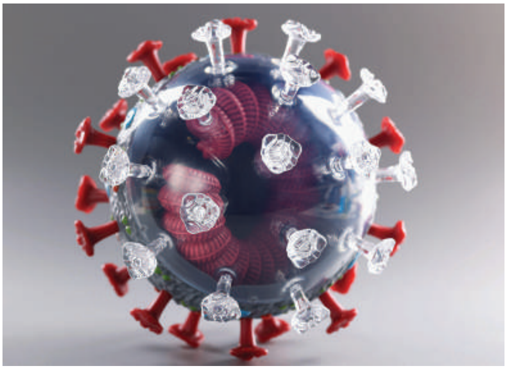
Concrete models can be diagrams and drawings. The diagram of Earth's atmosphere shows each of its layers.

A physical replica is a realistic copy of an original object. This dinosaur model is the actual size a real dinosaur of this type would have been.

Scale models are not actual size but are larger or smaller than the objects they represent. This virus model is huge compared to the size of a real virus. A globe is an example of a model that is much smaller than the real thing, Earth.

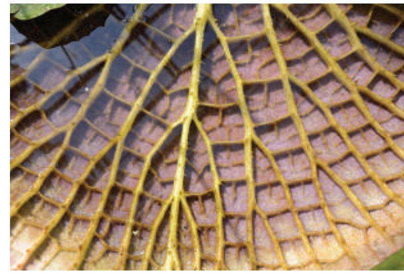
Some physical models allow engineers to test the things they design to make sure the designs will work. Airplane engineers test scale models in wind tunnels.





Abstract Models

Abstract models are ideas, not physical things. They cannot be seen or touched. A simple kind of abstract model is an analogy. An analogy helps explain one idea by comparing it to something else. For an analogy to work, the two things must be similar in some important way. For example, the tubes or veins within a plant leaf are like highways. A highway allows cars to move easily from place to place. The veins in a plant allow water and food to do the same thing. Comparing plant structures to roads is an analogy.



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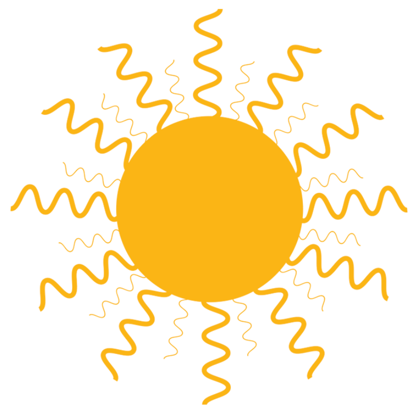
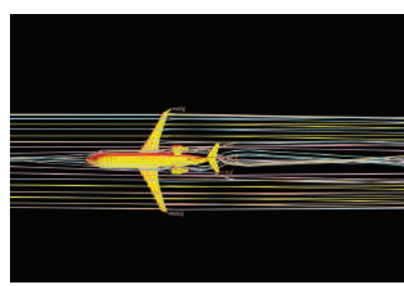
A diagram can communicate an abstract idea. Picturing light as waves is an abstract model of light. In some experiments, light behaves as if it were a wave. But light is not a curvy-shaped physical thing.



Computer simulations can produce abstract models of events. A computer can use data to produce a diagram of the flow of air around a jet airplane. Computer simulations use data to predict where hurricanes will travel. The more real-world data are collected, the more accurate such an abstract model can be.

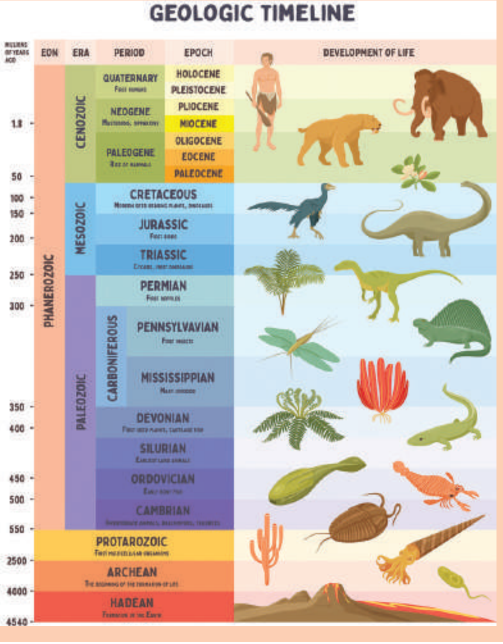


Think about some more examples. Are these models concrete or abstract? What is one benefit of each model? What is one limitation?

A student makes animal and plant cells, with all their parts, out of modeling clay.

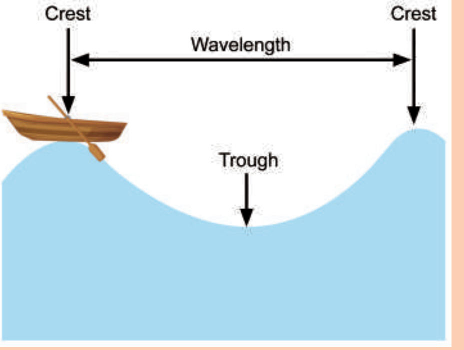
The planets in this solar system model can be spun around the sun.

This is a diagram of the changing nature of life on Earth.



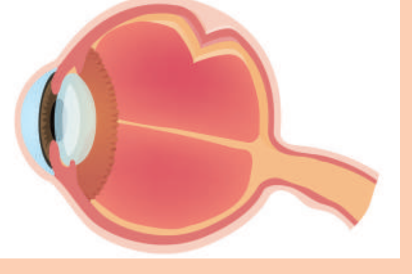
The water cycle is a very complex set of processes. And yet, this model makes it easy to see what happens.

The diagram represents ocean waves. It shows the waves' wavelength and height in a given instant. The wave can physically be measured.



This model flower is called a cutaway. It exposes inside parts.

The human eye is sometimes compared to a simple camera. The iris of the eye controls how much light enters. The lens focuses the light to let us see clear images.



Main Science Idea

Something concrete can be directly observed. Something that is abstract is an idea or concept that can't really be physically represented.

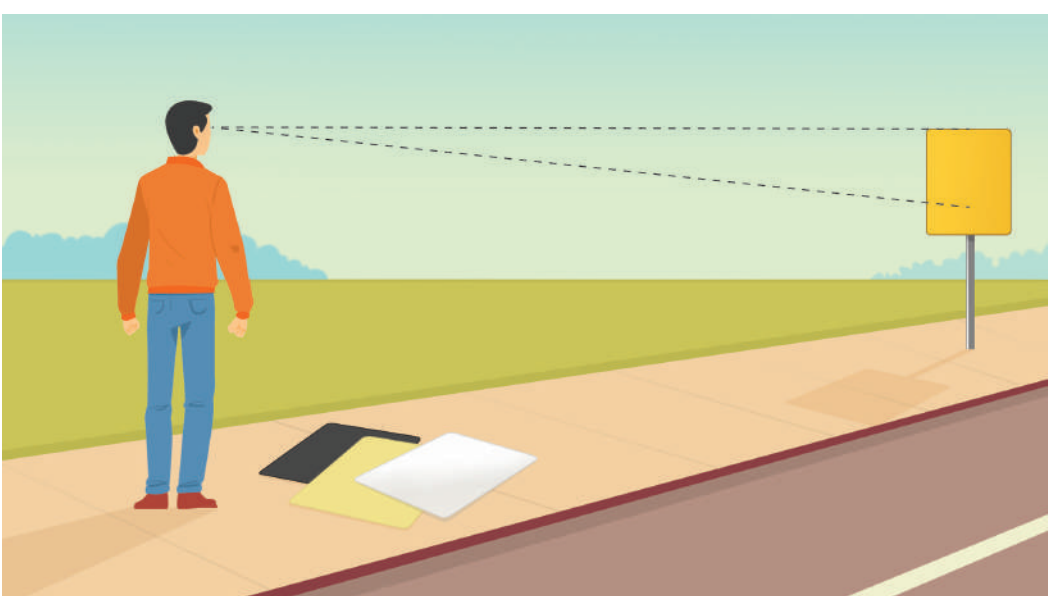
Enough Data

Chapter 6

People who are out at night should wear clothing that makes them easier to see. Safe clothing might be made of fluorescent material, reflective material, or both.

Mel is investigating road safety for a science fair project. She asks, “How well can the average adult see different materials at night?” She decides to test her uncle Fred. His vision seems average.

Mel sets up a square of one test material at the end of her block. Her uncle will start walking from the other end of the block and stop when he can see the square. Mel will measure his distance from the square. She will repeat this for each of four materials.



Distance from Uncle Fred to Safety Material

Material	Fluorescent	Reflective	Both	Black
Distance	42 ft	44 ft	50 ft	10 ft

Her uncle had to get much closer to the black cloth to see it. The combined fluorescent and reflective material could be seen from the farthest distance. It all seems to make sense. Is Mel done? She wonders whether she should test more people. What are some reasons she might want to?

Mel's uncle's glasses might be incorrect. He could be colorblind or have poor night vision. But it's also possible that Mel's uncle is eagle-eyed and can spot the smallest sign on a dark street. Any of these will give Mel a different result.

People's vision can differ. Mel wants to test how well the different materials can be seen by the *average* adult. To do this, she needs to test a *group of adults* and take the averages of their data. How many adults should Mel test?

Mel knows six people who could be part of her experiment. She would have time to test all of them and analyze her data. But maybe *more* data would be even better?

It would take Mel a long time to find and test sixty people. She might not be able to do it in time for the science fair. In Mel's case, testing six adults is not as good as it would be to test sixty, but it is better than testing only one person.

Mel conducted the experiment with six adults, and she found that the combination of fluorescent and reflective materials was the best for safety. Still, she wonders, "What if I had used sixty people?"

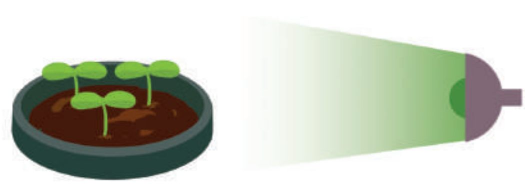
For the science fair, Lorenzo investigates light. He wonders how color affects the way plants respond to light. Lorenzo sets up the experiment using four pots of the same size, with equal amounts of soil. He keeps all other factors the same for all pots.

He will test how radishes grow under red, green, and blue light. A regular, white light bulb will be the control. He will aim a light toward each pot from the side.

After his radish seeds have sprouted, Lorenzo will measure the angles at which the stem bends toward the light. He will determine the average angle for the plants under each color light bulb. Suppose Lorenzo plants three seeds in each condition and gets the results shown in the table.

Seedling	**Stem Angles**			
	Blue Light	**Green Light**	**Red Light**	**White Light**
1	88°	5°	85°	90°
2	84°	10°	89°	80°
3	0°	15°	82°	(didn't sprout)
Average:	**57°**	**10°**	**85°**	**85°**

Blue Light



Green Light

Red Light

White Light

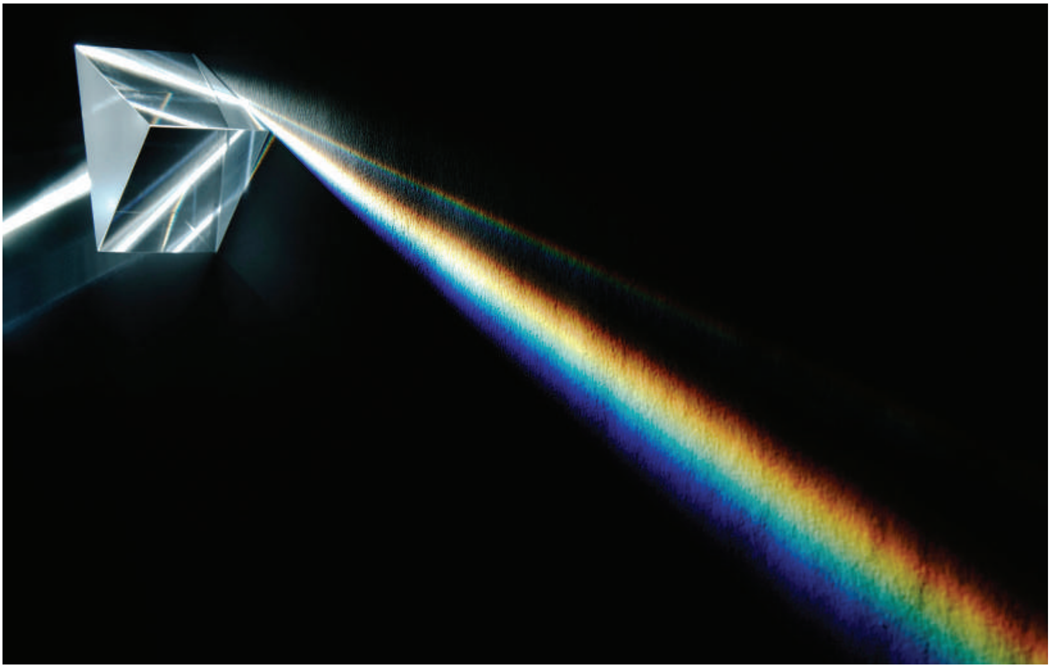
One of the plants under the blue light never grew very tall. Its stem is too short and cannot bend. This one seedling changes the average stem angle. In the control condition, one of the seeds never even sprouted!

With only three seeds, the data from each seed counts for 33 percent of the average. Just one weird seed can change the average a lot! But if Lorenzo planted twenty seeds in each pot, an odd result from one or two seeds wouldn't change the average very much.

Lorenzo could plant one hundred seeds under each color light. But then he would need many more pots and light bulbs. He would have to spend a lot more time measuring leaf angles. And the data probably wouldn't be very different from the data collected from twenty seeds.

Mel and Lorenzo know that recording a lot of data gives the best results. When scientists test new medicines or vaccines, they compare a group of people that take the medicine with a similar group that doesn't. Because these tests are so important, they often include hundreds of people.

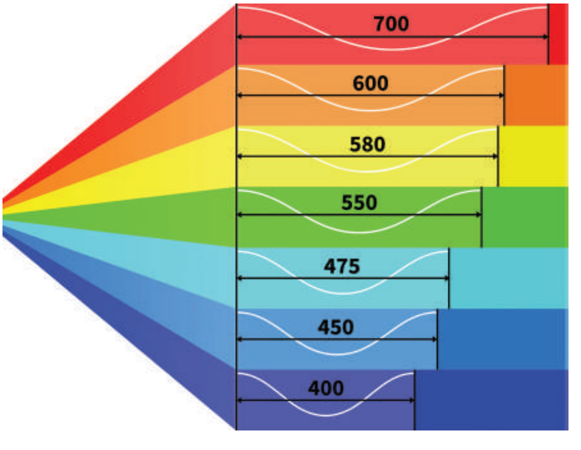
When you compare groups for a science fair project, you probably don't need that much data. But you should include enough data that a weird result from any one person or thing won't affect the average too much.



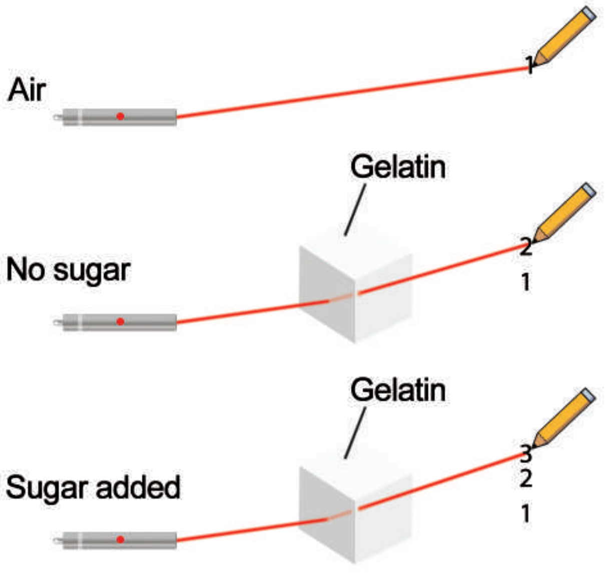
Wavelength (in nanometers)

When light passes through a clear prism, it bends. White light is a mixture of different wavelengths. When they pass through the prism, the shortest wavelengths bend the most. We see these as violet light. The longest wavelengths bend the least. We see these as red light. All the other wavelengths produce the colors in between. In fact, this is how rainbows form when sunlight passes through water droplets.

Noa is curious about how different materials bend light. Laser pointers emit light of a single wavelength. By aiming a red laser beam through a prism, Noa can measure how much it bends. She can compare prisms made of different materials.



Noa makes two prisms out of clear gelatin, adding sugar while making one of them. Then, she aims the laser pointer and marks a "1" where the red light appears on the wall. Next, she places each of the gelatin prisms in front of the laser pointer. For each prism, Noa marks a new number where the red light hits the wall and measures its distance from the original point ("Air"). Noa's data are shown in the table.



	No sugar	Sugar added
Difference from Air	4 cm	8 cm

How could Noa collect more data? She could repeat the test for each prism a few times. She can also test different brands of gelatin or sugar. But a better way might be to make more gelatin prisms with different amounts of sugar.

Each type of gelatin is a condition she is testing. By testing more conditions, she is not just comparing sugar with no sugar. She will be investigating how the light bends as more and more sugar is added. How many types of gelatin do you think Noa should test?

Main Science Idea

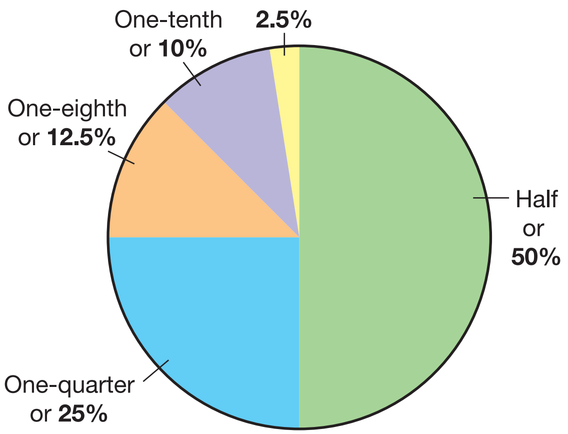
How much you can learn from and trust a test or investigation depends on how much data it produces.

Charts and Graphs

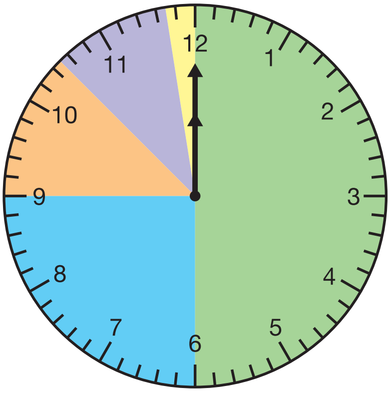
Chapter 7

Scientists work with a lot of data. They need to organize and display the data. They can use graphs and charts to make data easier to understand.

A circle graph is also called a pie chart. It's a circle that's divided into slices or sections. Imagine a pie being cut into different-size pieces. Each slice represents a part of 100 percent, the whole pie. A half circle in a circle graph represents half of the total, or 50 percent. A quarter circle represents 25 percent. Slices represent data. They all add up to 100 percent. Circle graphs are good at showing the portions that make up a total.



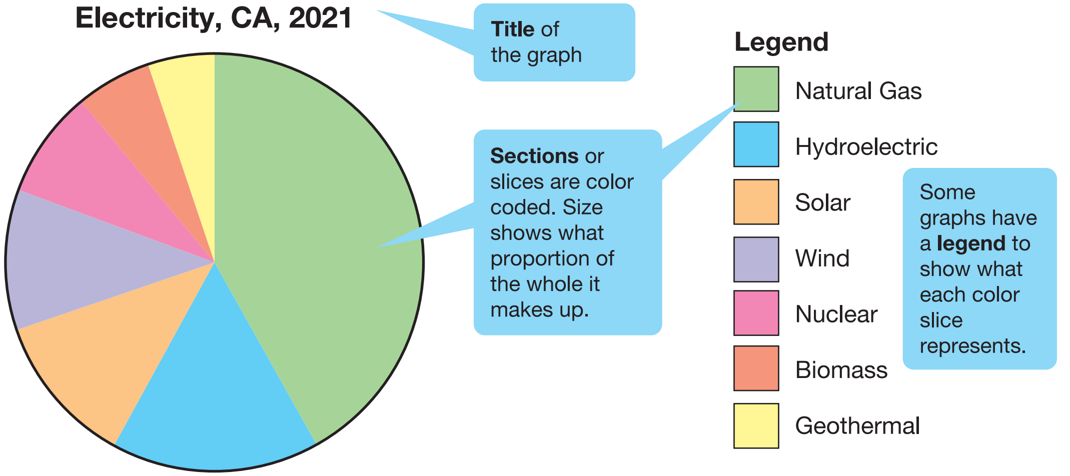
Often, the slices in a pie chart have an order. Think of a clock face. The slices begin at the top, at twelve o'clock. The largest slice is first, starting at the top right. In this case it takes up the entire right half. Going clockwise, the slices get smaller and smaller. The smallest section is found at the top, next to the largest one.



Let's see what we can learn from some examples of data presented in circle graphs.

Did fossil fuels make up more or less than half of the electrical energy sources in California in 2021? About what percentage of California's energy came from water? Did sunlight or wind provide more of the total energy? What source contributed the smallest amount?

Sources of Energy for Electricity, CA, 2021

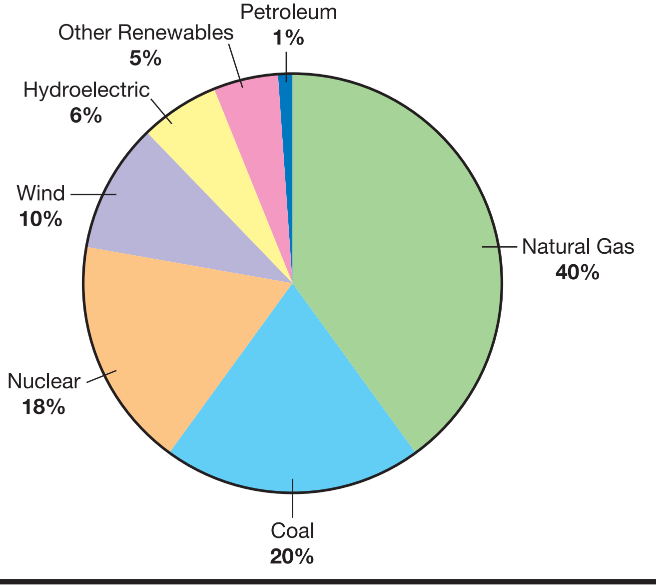


Natural gas is the fuel that is most common. About one-eighth, or 12.5 percent, came from hydroelectric energy. The sections decrease in size, going clockwise. Because solar comes before wind, it must make up a greater percentage. Geothermal is last and therefore the smallest slice.

This circle graph shows the percentages of different energy sources used in the United States for electricity.

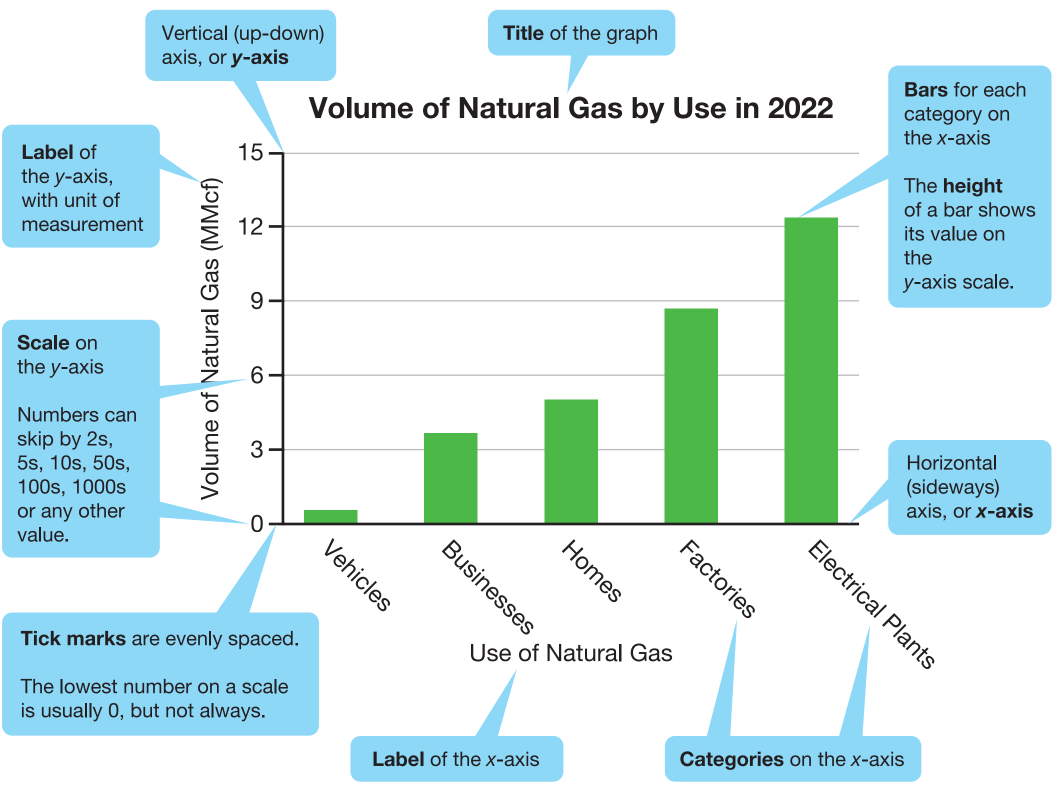
How much total energy did the United States convert to electricity in 2022? You cannot find the answer by looking at this chart. It does not show a value for the total amount. Notice also that this chart does not have units. It doesn't tell you how many kilograms of coal were used, for example.

Sources of Energy for Electricity, 2022



Bar graphs have two sides called axes. The side line that runs up and down is vertical. It is called the *y*-axis. The bottom line that runs from side to side is horizontal. It is called the *x*-axis. Because bar graphs have two axes, they can show two kinds of data. In this example, the *y*-axis has a scale, but the *x*-axis has categories. What two types of data are shown below? What is the range, or span of values, on the *y*-axis?

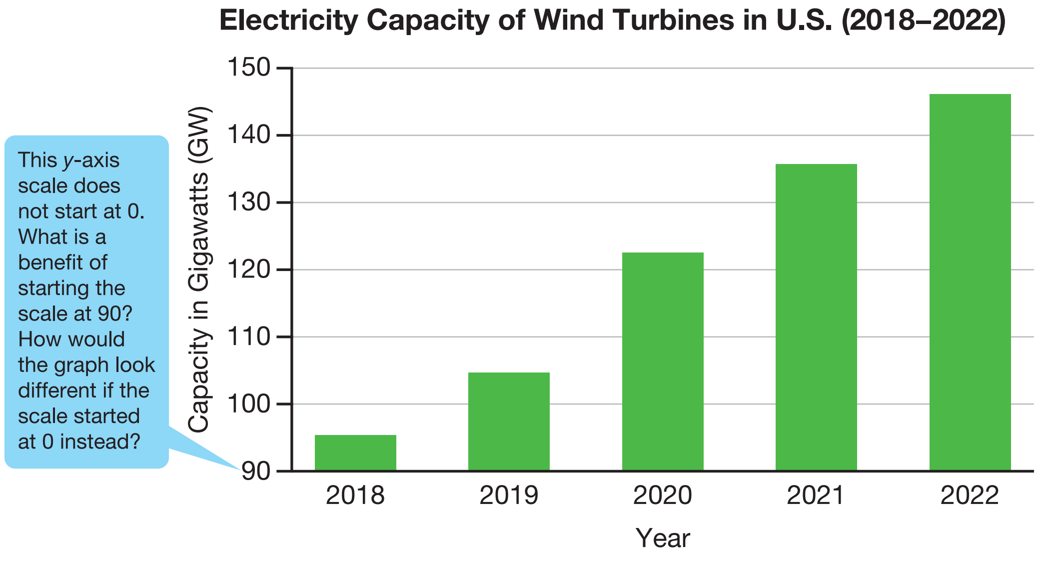
About how much natural gas did homes use in 2022? What unit is it measured in?



One type of data shown in the graph is the volume of natural gas. The other is the use of natural gas.

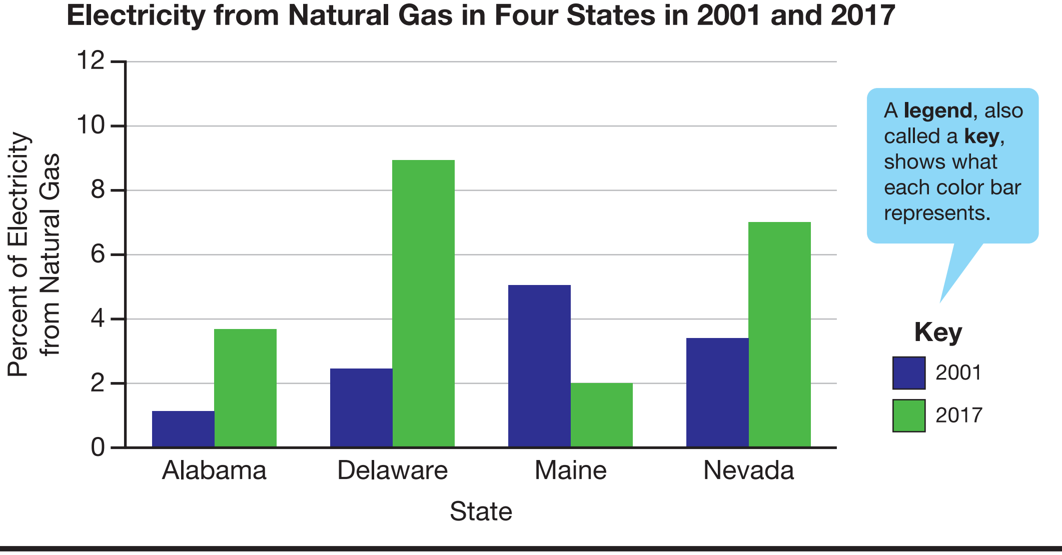
Bar graphs can also show how something changes over time.

This bar graph shows how the capacity of wind turbines has changed. *Capacity* means ability. Wind turbines with a higher capacity are *capable* of producing more electricity. Which year had the biggest increase in capacity?



Bar graphs can show comparisons.

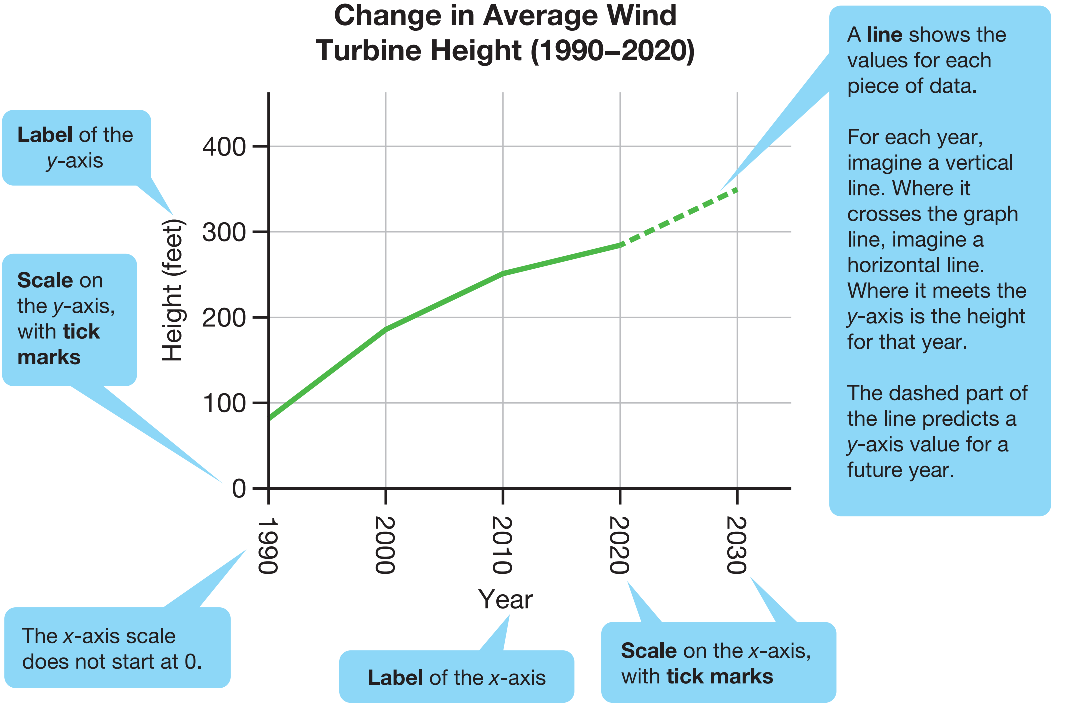
This bar graph shows data from two different years. Which states used more natural gas in 2017 than in 2001? Which states used less?



Line graphs are similar to bar graphs. They have a vertical *y*-axis and a horizontal *x*-axis, and they can show two kinds of data. A line graph uses a line instead of bars. Line and bar graphs have another important difference: Line graphs do not show category data. The data in a line graph have numbers or values.

In the example below, the *x*-axis shows time in years.

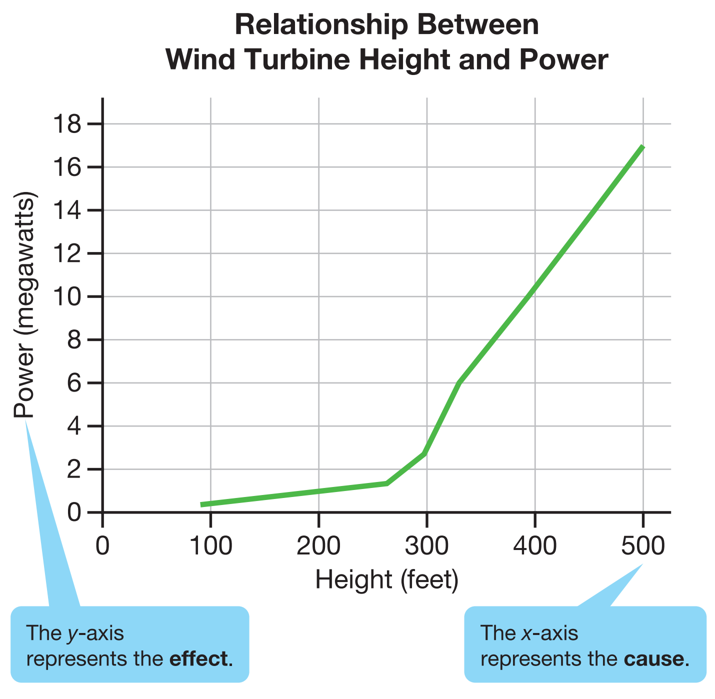
How tall were wind turbines in 2010? How tall will they be in 2030? How has wind turbine height changed over time?



In 2010, wind turbine height was 250 feet. In 2030, it will be 350 feet. Wind turbine height increased over the years shown in the graph.

Line graphs are good at showing relationships between two things. In other words, they show how one thing changes with another.

What is the relationship between the height of a wind turbine and its power? Which is the cause, and which is the effect? How much power can a 450-foot-tall wind turbine generate? About how tall would a wind turbine have to be to generate 10 megawatts of power?



As the height of a wind turbine increases, so does its power. The height is the cause, and the increase in power is the effect. A 450-foot-tall wind turbine can generate 14 megawatts of power. A wind turbine has to be about 400 feet tall to generate 10 megawatts of power.

Think about the data shown in this graph and in the previous graph. What conclusion can you make about the power of wind turbines in the future?

Main Science Idea

Charts and graphs can make data easier to understand and draw conclusions from.

Columns and Rows

Chapter 8

The touch-me-not plant is so called because its leaves quickly fold in response to being touched. When it is touched over and over again, it stops folding its leaves.

Sasha investigates how different stimuli affect the touch-me-not plant's response. She tests two stimuli: light touch and sudden drop. For the second one, she will lift the plant a few inches above a tabletop and let it drop. Sasha will test three plants for each stimulus. She will repeat the stimulus and record how many times the plant folded its leaves.

Are the results clear? Perhaps displaying data in a table would be better.

Observations:
Touch-me-not plant responses to stimuli

Light touch stimulus:
Plant 1: touched 33 times before it stopped folding its leaves
Plant 2: touched 28 times
Plant 3: touched 32 times before it stopped responding

Sudden drop stimulus:
Plant 4: dropped 44 times before it stopped responding
Plant 5: dropped 49 times
Plant 6: dropped 42 times

One column shows the independent variable.

A second column shows the dependent variable.

Stimulus	Number of Times Until Plant Stopped Responding
Touch	
Drop	

Beneath the independent variable, Sasha lists the type of stimulus in each row.

Beneath the dependent variable, Sasha will record her data in the row for each stimulus. But Sasha has data for more than one plant!

Stimulus	Number of Times Until Plant Stopped Responding		
Touch	Plant 1	Plant 2	Plant 3
	33	28	32
Drop	Plant 4	Plant 5	Plant 6
	44	49	42

Sasha makes subcolumns for each plant. She records the data.

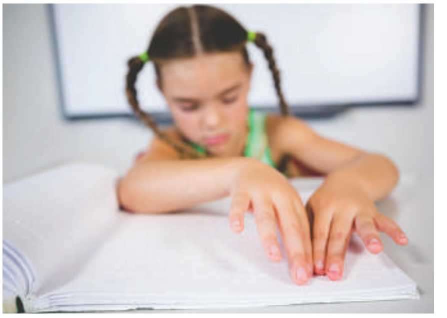
But she wants to take the **average** for each stimulus. Where will she put them?

Stimulus	Number of Times Until Plant Stopped Responding			
Touch	Plant 1	Plant 2	Plant 3	Average
	33	28	32	**31**
Drop	Plant 4	Plant 5	Plant 6	Average
	44	49	42	**45**

Sasha's table needs another subcolumn. She adds a subcolumn to the right of the others to show the averages.

Which stimulus do touch-me-not plants stop responding to more quickly?

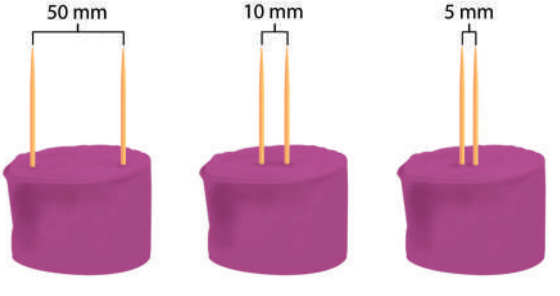
Braille is a form of writing that uses raised dots on paper. It is a writing that can be read by blind people who touch the dots with their fingertips. They have learned that the patterns of dots represent letters.



Could a person learn to read braille with their knees? Our fingertips have about 2,500 nerve endings in a single square centimeter of skin. (This is about the size of a square on a sheet of graph paper.) But other parts of the body have much fewer.

One way to measure this difference is with a pair of toothpicks. When they are pushed lightly onto the skin, the person may feel either a single point or two separate points. You can probably guess that their answer depends on which body part is being tested.

Amy wants to compare the skin of the fingertips and the knees. She invites her classmates to take part in her experiment. Amy builds ten toothpick “probes” by inserting pairs of toothpicks into modeling clay, with different distances between them. She will test each probe against each classmate’s fingertip and knee. She will record the smallest distance the classmate can sense as two separate points.



But before she starts, Amy needs a way to record her data. She could just take notes as she goes, but she wants something quicker and easier. Amy decides to set up a data table. How would you organize a data table for Amy’s investigation?

Amy could have listed her classmates going across instead of down. But then she would have needed a much wider table. It might have not even fit on a single page!

Each row of the data table shows the smallest distance data for each person. Amy can easily compare them.

Classmate	Smallest Distance Reported as Two Points (mm)	
	Fingertip	**Knee**
H. M.	5	40
B. R.		
A. B.		
T. S.		
C. C.		
R. B. G.		
S. O.		
M. J.		
R. D. G.		
F. B.		
Average:		

For each body part, the smallest distance data make a neat column. This is handy when she calculates the averages.

By using a data table, Amy has all her data neatly organized in one place. It makes it easier for her to answer the question “Could a person learn to read braille with their knees?” . . . and other probing questions!

If you have ever taken a very close look at your tongue, you probably noticed that it is covered in little bumps. Each bump is a taste bud. Each taste bud is made up of over one hundred cells, called receptors, that can sense flavors of food. Some people have more taste buds than others.

Both Marcus and Margaret want to investigate how the number of taste buds affects how well people detect sugar. They learn how to safely count the taste buds in a small area on a person's tongue. They convince thirty people to take part in their investigations.

Marcus asks, "How does the number of taste buds affect how well people can detect a very low concentration of sugar?" After recording the number of taste buds on a taster's tongue, he brings out two clear liquids. One is water alone. The other has a very tiny amount of dissolved sugar. Tasters don't know which is which, but they must identify the sugar solution. How should Marcus set up a data table to record his data?

Taster	Number of Taste Buds	Correct?
A. B.	28	Yes
T. S.	13	No
C. C.	26	Yes
R. B. G.	21	Yes
S. O.	15	No
M. J.	35	Yes
	20	No

During the investigation, Marcus needs a quick way to record his data for each taster. A simple table with three columns, similar to Amy's, lets him do this.

But this isn't the best way for Marcus to *display* his data! How should he set up a data table for his science fair poster?

Marcus sorts the tasters into five categories. Each column shows data for one category of taster. This makes it easier to compare categories.

Compare this data table to the one Marcus used to record his observations. What are the benefits of each?

	Testers According to Taste Bud Number				
	Low (less than 15)	**Low-average (15–19)**	**Average (20–25)**	**High-average (26–30)**	**High (over 30)**
Number of Tasters	5	5	10	6	4
Number Correct	2	3	9	6	6
Number Incorrect	3	2	1	0	0
Percent Correct	40%	60%	90%	100%	100%

Of the tasters in each category, Marcus calculates the percentage who identified the sugar water correctly. Calculated data are often shown below or to the right of the numbers used in the calculation.

Would you have set up the table the same way? Would you change anything about it?

Margaret asks, "Do people with more taste buds detect sugar at a lower concentration?" How should Margaret investigate and record her data?

Main Science Idea

Organizing data into columns and rows in a table makes relationships among data easier to see and understand.

Strength of Evidence

Chapter 9

Earl Comments on the Shape of Earth

You might have been told that Earth is round, but there is strong evidence that Earth is flat.

> To evaluate evidence means to decide how strong or weak it is. Strong evidence is convincing and supports the explanation for a claim.

> This is a claim.

First, if Earth were round, there would be pictures that show a round planet. But there are none! Sure, you might have seen an image of Earth taken from the moon. But this image was made up by NASA to trick people.

> This should make you **skeptical**. Where is the evidence that NASA does this? What happens when you try to find pictures of Earth from space?

Second, what do you see when looking at the horizon? A flat line! And if you viewed a ship moving away from you, you would notice the bottom of the ship disappear first, near the horizon.

> Does the evidence really support the explanation? No! The bottom of a ship disappearing first is evidence that the horizon is curved, not flat.

Lastly, gravity proves that Earth is flat. If you pour water over a tennis ball, the water falls away from it. So why doesn't the water in oceans also fall away from Earth? Because Earth isn't round like the tennis ball—it's flat!

> Does the evidence make sense? You already know that gravity pulls things toward Earth's center. Water is going to be pulled toward a round Earth, not fall away from it!

Ancient Planet

Planet Earth is about 4.5 billion years old. How do we know this? People once thought that Earth had existed for only a few thousand years. Scientists who studied fossils and the rock layers that contained them thought it must be much older.

> This is a claim.

> "How do we know this?" is always a good question to ask, especially in science! It is OK to have a healthy skepticism about the things you read and hear.

An answer didn't come until radiometric dating was invented in the 1900s. Radiometric dating measures how isotopes change over time. Because isotopes change in a very predictable way, they can be used as a clock.

> An isotope is a form of an atom or element.

> Even though this is not very strong evidence for Earth's age, it is based on fact, and the reasoning is sound. It supports the explanation.

The problem is the rock cycle. When new rock forms, the clock often resets. The oldest rock on Earth dates to between 4 and 4.4 billion years ago. Since the planet must have existed before the rock, Earth must be older than this.

> Sometimes, an explanation makes an assumption. Scientists assume that the solar system formed all at once.

> Pieces of evidence might be weak on their own, but if they agree, they can more strongly support an explanation. The evidence from rocks agrees with the evidence from meteorites.

Unlike rocks, many meteorites formed at the same time as the solar system. Radiometric dating shows they are 4.5 billion years old. Therefore, we assume Earth must be about the same age.

Tropical Antarctica

Fossils from one continent tell a story of leafy plants, a tropical climate, and all kinds of wildlife, including dinosaurs. You might not guess the continent was Antarctica.

Although it sat at the equator a billion years ago, by the time dinosaurs roamed, it had drifted southward. The reason for these types of fossils is that Earth was once much warmer than it is today.

Fossils of pollen found in Antarctica indicate that warm-climate plants lived there. Scientists also use the shapes of leaves to predict temperature. Leaf fossils show that the Antarctic plants are those usually found in warm climates.

Long after dinosaurs went extinct, ice caps formed over Earth's poles, and the continent became the frozen landscape we know today.

The explanation should give a reason for these unexpected fossils.

This is the explanation.

The evidence is from more fossils! This evidence supports a warm climate in Antarctica, but it doesn't support the explanation that all of Earth was warmer.

Fossils from all around the world, showing a warmer climate, would better support the explanation.

Even though the evidence given here is weak, scientists have many kinds of strong evidence that Earth's climate was indeed warmer in the past.

Asteroid Impact

This is the explanation. It answers the question "Why did dinosaurs become extinct 65 million years ago?"

Dinosaurs became extinct 65 million years ago because a large asteroid struck Earth. The crash caused fires and tsunamis that destroyed ecosystems. The asteroid landed with enough force to smash it into tiny particles. The particles flew into the air and landed everywhere. It also sent dust into the air, changing Earth's climate. There would have been less sunlight and less food to eat.

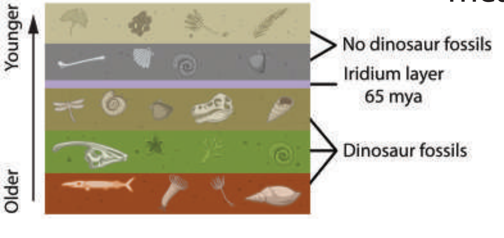
The crater is **strong evidence** of an asteroid crash. Think of evidence as the clues left by something that happens. If someone walked through a kitchen after coming in from the rain, you might find wet footprints. The tracks are strong evidence that this happened.

In Mexico, there is a large, buried crater that is 65 million years old. The rock that makes up the crater has more iridium than usual. Iridium is not common on Earth, but it is often found in asteroids.

The layer of iridium is good evidence for part of the explanation—that the particles from the smashed asteroid flew into the air and landed everywhere.

A thin layer of rock with iridium is found in many places on Earth. This rock is 65 million years old. No dinosaur fossils are found in rock less than 65 million years old. Everywhere on Earth, they are found beneath the iridium layer, meaning that they are older.

The pattern of finding dinosaur fossils in rock underneath the iridium layer (but never above it) is very strong evidence that dinosaurs existed before the iridium layer formed but not after.



Patterns can be evidence. Keep in mind that the pattern does not prove that the asteroid crash caused dinosaurs to go extinct. It only shows the order in which things happened.

The Deccan Traps

This is the explanation. It answers the question "Why did dinosaurs become extinct 65 million years ago?"

Volcanic eruptions, not an asteroid, caused dinosaurs to become extinct 65 million years ago. Unlike the asteroid crash, the eruptions did not happen all at once but over a few million years. Dust, ash, and gases from the eruptions changed the climate all over the world.

The large amount of volcanic rock is strong evidence that the eruptions released a lot of lava over a long time.

Lava from the volcanoes makes up the Deccan Traps in India. The thick volcanic rock, over a mile deep and about the size of Texas, formed between 65 and 60 million years ago (mya). These were no ordinary eruptions.

This example shows what a much smaller eruption can do. Use scale to think about how many larger eruptions, over a long period, can affect Earth's climate.

A single eruption can affect the climate all over the world for a long time. Mount Tambora erupted in 1815. The dust and ash it released blocked sunlight and led to the gloomy "year without summer" in 1816, a whole year later!

This evidence is weak. It might point to volcanoes as a *possible* cause, but more evidence would be needed to support the claim.

There have been four other mass extinctions before the dinosaur extinction. Some happened at the same time as large volcanic eruptions. Scientists think that the eruptions caused those extinctions.

Dinosaurs went extinct during a mass extinction. The fossil records show that many other species started declining earlier than 65 mya. Fossils of other species found below the iridium rock layer are also found above it. This means that they survived the asteroid crash.

This evidence is about what else was going on during the dinosaur extinction. This is not strong evidence, but it is sometimes useful to think about the big picture.

If the asteroid caused the mass extinction, then all animals should have been affected equally. But if the climate changed more slowly because of volcanic eruptions, then some species would have had time to adapt and survive.

Would an asteroid crash really have affected all animals equally? You are right to be skeptical about this line of reasoning.

The mass extinction affected organisms in the oceans. Volcanos release sulfur gases, which form acid rain in the atmosphere. Acid rain would change the ocean ecosystems, killing many of the species that live there.

Stating how something could have worked is weak evidence, but it still supports the explanation.

An explanation can be true even if the evidence for it is weak. And it can turn out to be wrong even if there is a lot of good evidence supporting it.

While an asteroid probably did crash on Earth 65 mya, it did not kill off the dinosaurs. Dinosaurs went extinct because volcanic eruptions changed Earth's climate.

The conclusion restates the explanation. Did you find this explanation convincing?

Main Science Idea

It is good to be skeptical about evidence. Strong evidence that supports an idea can hold up to questioning. It lets us be confident in what we have learned. Weak evidence should make us look further for the truth.

Think It Through!

Chapter 10

What is speculation? To *speculate* means to make a claim without strong evidence or good reasoning. Some of the people at the campground might be speculating about what the volcano will do.

The camper who says, “Let’s get out of here! It’s gonna blow!!!!” is speculating. There is no strong evidence that the volcano is about to erupt. Also missing is good reasoning. The Park Service stated that the campgrounds can remain open. If the volcano were very likely to erupt, they would tell everyone to leave immediately.

Sometimes, you might not have enough evidence to make a strong claim. But you can still use what evidence you do have, along with good reasoning, to make a reasonable judgment.

One camper says, "Gases could be building up inside the volcano. I bet the spectrometers picked it up." This is a reasonable judgment. It is based on evidence—the fact that an alert was issued. It also uses good reasoning. If volcano activity was detected, *something* had to detect it. A spectrometer is a device used to detect gases around a volcano.

Which of the campers' statements are speculation? Which are facts? Which are judgments based on good reasoning?

Imagine *facts*, *judgments*, and *speculation* in order, based on how certain we can be about them. On one end of the scale are facts. Facts include "Volcanoes are often found near plate boundaries" and "Magma that rises to the surface is called lava." People don't often disagree about facts.

At the other end of the scale is speculation. Speculation is more like guessing. It is not certain at all, and people will often disagree about it. "Mauna Loa volcano will erupt next year" might be speculation.

Obviously, knowing facts is better than speculating. But no one can be 100 percent certain about everything. Sometimes, people must make judgments. Judgments are less certain than facts but more certain than speculation.

What separates reasonable judgments from speculation? A reasonable judgment uses all the evidence that is available. It also uses good reasoning.

"Mauna Loa volcano will erupt next year" might be speculation *or* a reasonable judgment. It depends. Was it based on all that scientists know about Mauna Loa? Did they use good reasoning to get to their conclusion? If they did, then they made a reasonable judgment.

Look for facts, reasonable judgments, and speculation as you read this passage:

Coastlines are important habitats. People visit beaches and may even build homes along coastlines. In a process called coastline erosion, waves and storms shape the boundary between land and water.

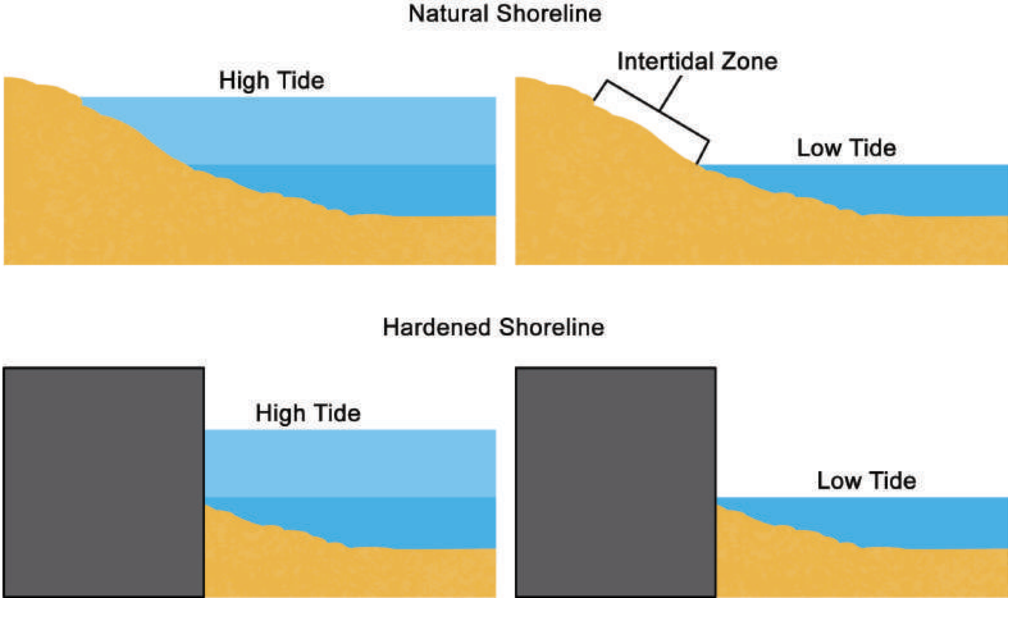
During storms, waves carry sand away from the beach. During calm weather, waves return the sand to the beach. An occasional storm may not change the beach very much. However, several storms in a row would probably erode the coastline. Waves would remove the sand faster than they return it to the shore.

Coastline erosion is a problem for seashore communities. It can force people to move from their homes and into temporary shelters. When a coastline erodes, the land that buildings stand on is no longer there. This makes buildings less stable. Over time, the buildings can collapse. Some places make money from people who visit the beaches. Erosion of the beaches would destroy their economy.

One solution is to "harden" a shoreline by building a wall or other structure to hold the land in place.

But many organisms depend on the intertidal zone. Clams, snails, crabs, and other shellfish live in the sand. During low tide, shorebirds find food in the sand. During high tide, fish feed on the organisms there. If shorelines are hardened, these organisms will go extinct.

An alternative to hardening is a living shoreline that can coexist with housing areas. Adding grasses and other plants to anchor the sand will keep it from eroding. A low bar of rocks may be placed to absorb the energy of the waves. A living shoreline protects habitats and preserves the area's natural beauty. Such efforts are part of shoreline conservation.



Main Science Idea

Making a reasonable judgment means deciding what is probably true based on trustworthy facts and evidence.

Science Reports

Chapter 11

You can follow a few steps to do a good science report!

1. Choose a Topic

How do you decide? You can choose a topic based on the following:

- what you find interesting in science class
- science you've learned outside of class
- your hobbies or interests

2. Pose a Question

Your question is like a compass. Finding and telling the answer to the question is what guides you through the whole process. Keep thinking about the question the entire time you are working.

3. Start Looking for Answers

Sometimes, you will answer your question by using books, encyclopedias, websites, and videos to learn about something. This is one way to do research.

Other times, answering your question means carrying out an investigation or an experiment. You decide what data to collect and how to collect them. You then find the materials you need to do this. This kind of research makes a good science fair project.

Whenever you do an investigation, you still must read information resources. After all, you need to learn about your topic before you can find a good way to investigate it.

4. Organize Your Information

Create an outline. If your question is "How do continents move?" then you might start with an outline like this:

- **Introduction:** Why is "How do continents move?" an interesting question?
- **Background:** What (exactly) are continents? How fast are they moving?
- **Evidence:** What tells us that continents have moved over time?
- **Explanation:** How do Earth's plates and layers cause continents to move?
- **History:** How do we know this? Did people in the past have different ideas? What changed their ideas?
- **Conclusion:** What did it take for scientists to understand how continents move? How can they continue to study continents in the future?

You don't need to have all your information before you begin to organize it. In fact, you should plan how to organize it before (or soon after) you start. As you learn more, your outline can change. In this example, learning about different scientists might lead you to split up the History section into parts: one about Alfred Wegener and one about Marie Tharp, who mapped the Atlantic Ocean floor. Tip: Use sticky notes or index cards to help you arrange your ideas.

For a science project or fair, your teacher might give you an organizing scheme to follow. Usually, it looks something like the diagram at the end of this chapter.

5. Gather Information from Sources

Choose wisely. Find books, articles, encyclopedias, websites, and videos with the information you will need. Choose resources that focus on your topic. There are many other interesting things to learn about, but don't get distracted!

Also choose sources that will be helpful to you. An article on seismic wave velocities in the asthenosphere is probably not going to be helpful. A video made for students that explains how tectonic plates move will be more useful.

Take notes in your own words. As you read or listen to each resource, take notes. Start by writing down a question or questions you think will be answered. Then, jot down the answers that you learn.

6. Collect and Record Your Data

After all your preparation and planning, carrying out an investigation is often the fun part! Setting up a data table beforehand can help you record your data. You might use a science journal or notebook. Be sure to record anything unusual that happened during the experiment or any changes you made to your method.

7. Display Your Data

Choose the best way to display the data you collected.

Use . . .	To show . . .
Circle graph	the parts that make up a whole
Bar graph, pictograph, or data table	values for different categories or how often different things occurred
Bar graph or line graph	how something changed over time or how two things changed together

8. Write Your Best Draft

It's OK to write out of order! You (probably) read the words on a page in order from first to last. But when writers write, they do not always begin with the first sentence, move on to the next, and continue sentence by sentence until the end. Instead, they may write different parts at different times. You don't have to start your science report at the beginning. In fact, you might find it easier to write the introduction last or the Method section first.

Organize before writing. An outline or organizer comes in handy because it lets you work on any of the parts, at any time. Have a great idea for the discussion? Add it to the Discussion section. Did you remember something important about your method? Insert it in the Method section. Write your ideas down when they're freshest in your mind!

Proofread and revise! Proofread your draft, or have someone proofread it for you. Ask if anything is unclear. If your reader is confused, you might need to revise your writing. Revise by doing the following:

- making sentences more clear
- changing the order of ideas
- fixing spelling, punctuation, and grammar

Cite your sources. As you research, write down where your information comes from. A list of the books, articles, websites, and videos you used goes at the end of your report, in a section called Sources, References, or Bibliography.

MODELING CRATERS

Introduction and Background

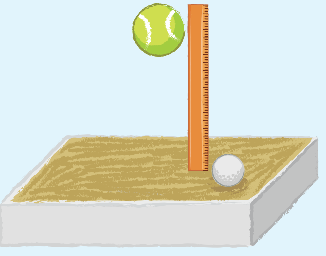
How can we model how craters form? Craters are found on the surface of the moon. A few craters are also found on Earth. An impact crater forms when a meteorite lands on a planet's surface. (Another kind of crater forms when volcanoes erupt.) This project models how objects like meteors cause craters of different sizes to form.

Make the project make sense for your reader. What is your question? Why is it interesting or important? Why did you choose the method you did?

You might decide to write the introduction last. After finishing the project, take a step back and see the bigger picture.

Materials and Method

- tray
- cornmeal
- tennis ball
- golf ball
- ruler
- meterstick



To model a planet's surface, I filled a large tray with cornmeal. I made the top of the cornmeal level to control its height and texture. I dropped a tennis or golf ball (the meteor) onto the surface from different heights. I then removed the ball and measured the crater and the size and mass of the ball.

The independent variable was the height of the ball. I dropped from heights at every 10 cm from 10 to 50 cm. The dependent variables were the width and depth of the craters. The experiment was done with each type of ball.

List the materials, equipment, and organisms you used. If any people participated, state the number, their ages, and how you chose them.

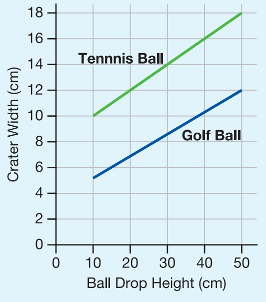
Describe how you carried out the investigation. What were your independent and dependent variables? What factors did you control? What groups did you set up? What data did you measure and record?

Use images to show what and how you are investigating.

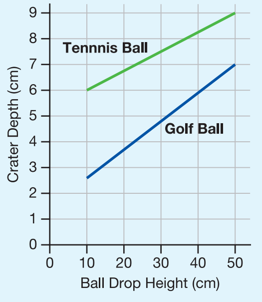
Results

For both balls, as the height of the drop increased, the depth and width of the crater also increased. The tennis ball formed larger craters than the golf ball.

Relationship Between Height of Ball Drop and Crater Width



Relationship Between Height of Ball Drop and Crater Depth



Discussion and Conclusions

My method can be used to model how impact craters form. The golf and tennis balls were models of different-size meteorites. The height that the ball was dropped from affected the speed. Things that fall longer distances go faster. The larger tennis ball formed wider and deeper craters. Dropping the ball from a taller height led to faster speed, which led to wider and deeper craters.

My method only modeled perfectly round meteorites that hit the surface from directly above, instead of at an angle. A question to ask in the future is how the angle of the ball affects the size of the crater.

Sources

Creating Craters. Science Buddies. www.sciencebuddies.org/stem-activities/creating-craters
Why Does the Moon Have Craters? NASA. https://spaceplace.nasa.gov/impact-crater/en

Your results should show and describe the data you collected. Graphs, charts, and tables go here.

You can describe the data in words, but don't include any claims or conclusions.

Write your discussion after collecting data. Conclusions and claims based on evidence and reasoning go here.

Also, reflect on your investigation. What were the limits of the method you used? How could it be improved? Did anything go wrong during the experiment, or did something unexpected happen? What questions do you want to explore in the future?

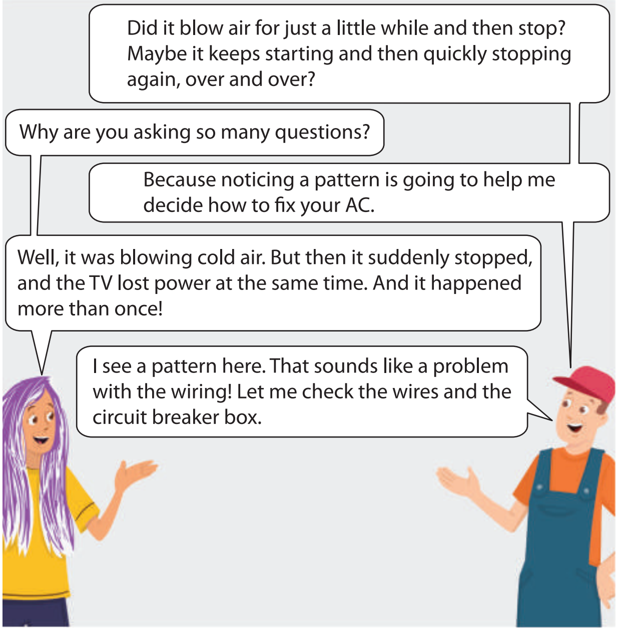
Cite your sources. List all of the books, articles, websites, and videos where you found the information you used. Your teacher may tell you exactly how to write this section.

Main Science Idea

Following a thoughtful process helps make a science report clear and understandable.

How to Decide

Chapter 12

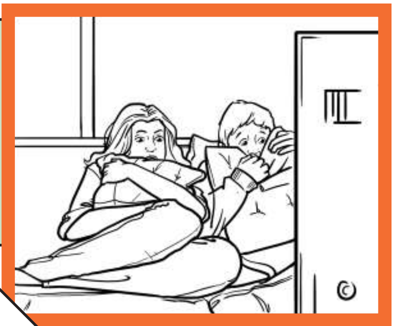


A decision is a choice about what to do next. The technician wanted to make a good decision about how to repair the air-conditioning system. Observing a pattern helped him do this.

A pattern can tell you something about a cause-and-effect relationship. The air-conditioning and the television stopped working at the same time. This happened a number of times. Only a few things could have caused this pattern. Noticing the pattern narrowed down the possible causes.

Other problems with the air-conditioning system would have shown different patterns. A pattern of starting and quickly stopping, over and over again, could be caused by having too little of the special fluid that cools the air. A pattern of blowing air that is not cold would have a different cause than a pattern of not blowing any air at all.

It's late at night, and you and your cousin are watching a scary movie. Suddenly, the power goes out, leaving you and your vivid imagination in complete darkness! What should you do? Don't panic! Look for a pattern.

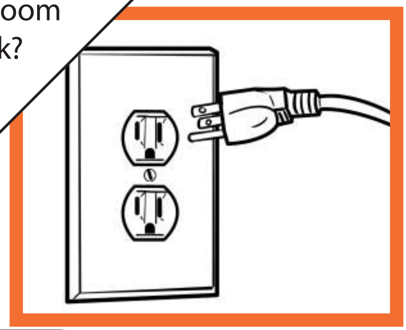


Try the light switch in the room. Does a light come on?

YES → Do the other outlets in the room work?

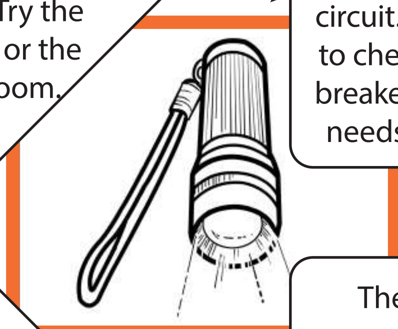
YES → NO → The problem may be with a single circuit. Ask an adult to check the circuit breaker and see if it needs to be reset.

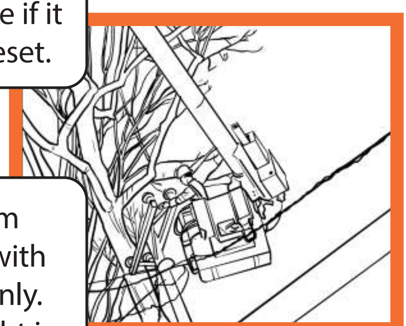
NO → The problem may be with a single circuit. Ask an adult to check the circuit breaker and see if it needs to be reset.



NO → Is the power working in the rest of the house? Try the hallway or the next room.

YES → The problem may be with a single circuit. Ask an adult to check the circuit breaker and see if it needs to be reset.

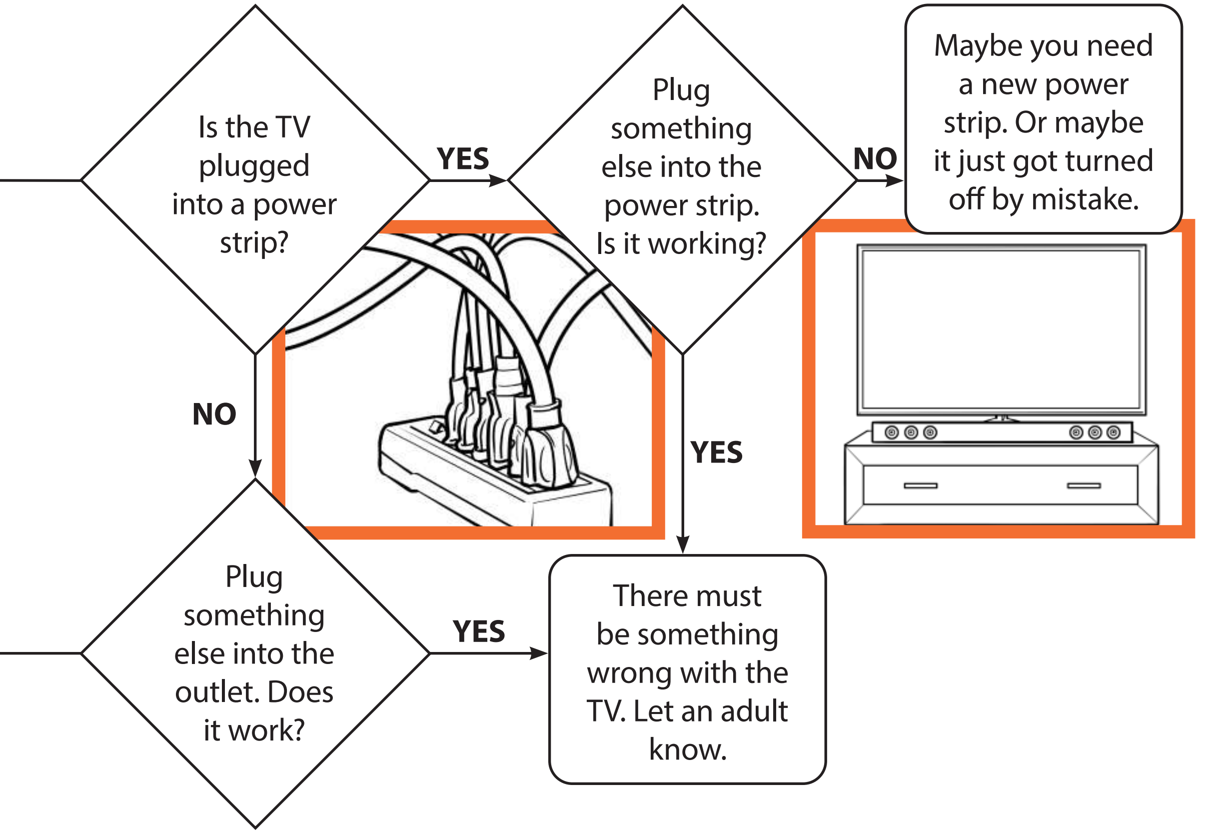




NO → Is the power working in the rest of the block? Look out the window.

YES → The problem seems to be with your house only. Keep a flashlight in each room in case this happens, and tell an adult.

NO → It may be the electrical grid. Check for text messages, or use an emergency radio for updates. It can sometimes take the electric company a few hours to fix the problem. In the meantime, you can tell each other ghost stories to calm your nerves!



When devices don't work, looking for a pattern can help you decide what to do. Suppose you finish typing a report and are ready to print it. But sometimes, nothing comes out of your printer! Look for a pattern. Are you able to print from some devices and not others? Does it work when there is a wire connecting the computer to the printer but not wirelessly? Do some types of documents print fine but other types not at all? Each pattern points to a different cause.

At some point, you will probably experience a problem like this. Figuring out the cause of a problem is called *troubleshooting*. What are some other times when troubleshooting can help?

A thermostat lets people control the temperature in their homes. Most people are comfortable at temperatures between 68°F and 72°F, or "room temperature."

People change their thermostat settings every day. They often lower the temperature before leaving in the morning or when going to bed at night. With a traditional thermostat, they do this by moving a dial. When they get home on a cold day, they must adjust the thermostat again and wait for the air inside to be heated.

Digital thermostats can be preset to different temperatures for different times of day. People do not have to remember to change the setting. But if someone gets home earlier than usual, they will need to adjust it. And if they stay out later than normal, the heat will still turn on at the usual time. This wastes energy.

A smart thermostat uses patterns to solve these problems. Smart thermostats heat and cool a space only as much as is needed to keep people comfortable. This helps conserve natural resources by not wasting energy. It also saves money.

A smart thermostat can sense whether people are in the house. It senses when someone walks past it. If there is nobody home, it will not heat or cool the space.

A smart thermostat can be controlled through a smartphone, computer, or other electronic device. It can even respond to voices.

Would you choose a smart thermostat?

Main Science Idea

Patterns in data can help us make decisions. Some devices are designed to use computers to do that "thinking" for us.

What's a Feedback Loop?

Chapter 13

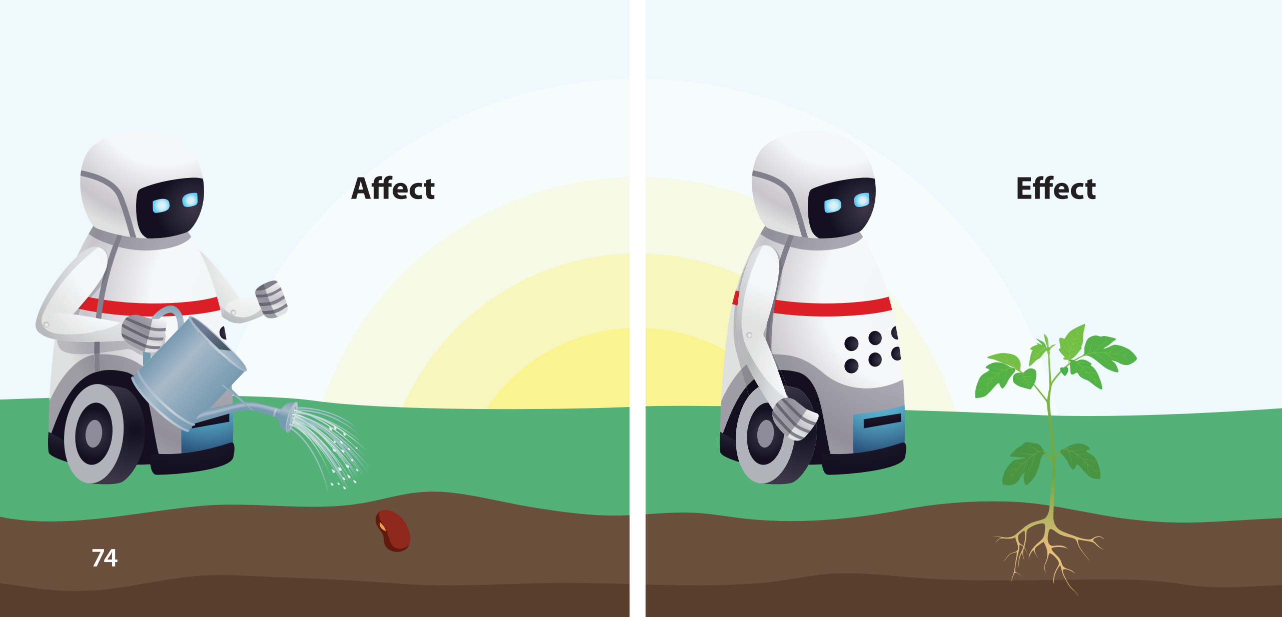
Suppose you are learning how to hit a softball. "Good swing," says the coach. "Your feet are in just the right place. Now hold the bat a little higher, and keep your eyes on the ball." What the coach tells you is feedback. As a result of the feedback, you hit the ball better than before!

Feedback is a response to something that happens that provides information or input into what happens next time. It is a part of cause-and-effect relationships. Feedback about a working system then affects the way the system functions.

Words to Know

Affect and *effect* are similar words, and it can be easy to get them confused.

- *Affect* is a verb. It means to cause a change. One thing affects another thing. Water affects a seed.
- *Effect* is a noun. An effect is the change that happens. Affecting something causes an effect. Plant growth is the effect of a seed being watered.



Think about this example. A thermostat controls the temperature in a room. You set the thermostat to the temperature you want the room to be. The thermostat senses the temperature in the room. If the room temperature is lower than the setting you chose, the thermostat turns on the heater. The heater causes the room temperature to increase. When the thermostat senses a higher room temperature than the setting, the thermostat switches off the heater. This allows the room to cool.

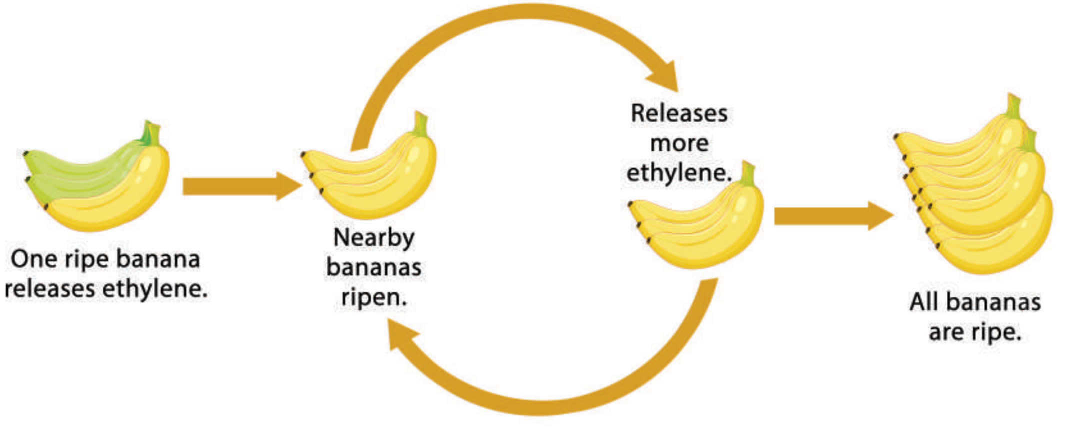
The thermostat, the heater, and the temperature of the room form a feedback loop. In a feedback loop, effects become causes of future effects. The feedback loop in this example occurs as follows:

- A too-low temperature is a cause.
- The effect is that the thermostat turns on the heater.
- The effect of the heater running is that the temperature increases.
- The temperature then becomes too high, causing the thermostat to switch off the heater.
- This causes the space to cool.
- After a while, the temperature falls below the set point again.

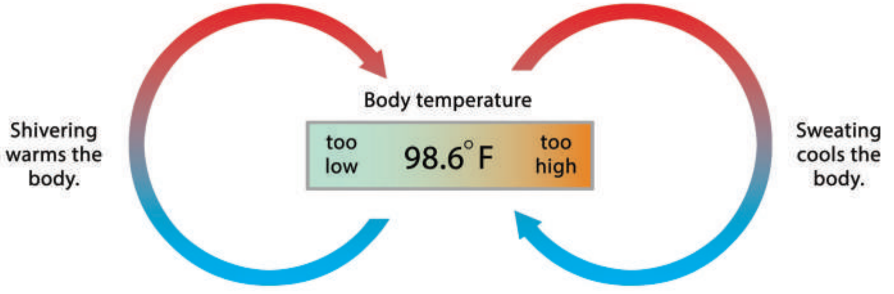
The cycle repeats over and over again. This feedback loop keeps the temperature stable. Anytime the temperature becomes too different from the setting, the thermostat and heater bring it back to that point.

The thermostat is an example of a **negative feedback loop**. The feedback keeps things stable. It keeps things consistent. Just because it is called “negative” doesn’t mean that it is bad or harmful. It means that the feedback reverses (or *negates*) any change, so things stay the same over time. Negative feedback loops are helpful when they keep systems stable.

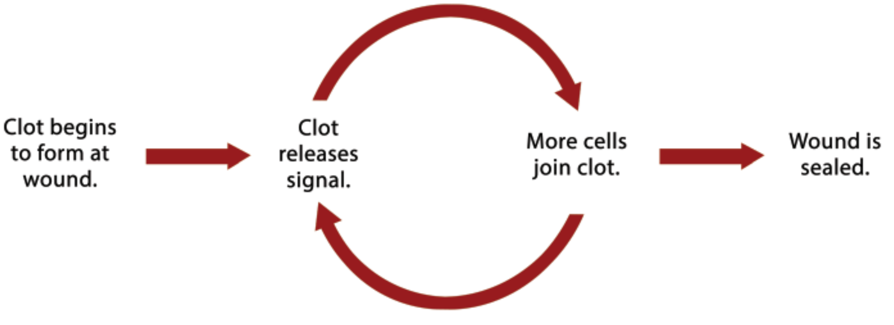
A **positive feedback loop** works in the opposite way. A small change causes even more change. An example is fruit becoming ripe. When fruit ripens, it releases a gas called ethylene. Ethylene affects other fruits nearby. It causes them to start to ripen. As a result, they also release ethylene. The gas causes nearby fruit to ripen . . . and repeat. This loop can cause all of the fruits on a tree to ripen in a short amount of time. This loop does not keep things stable; it moves everything in one direction over time.



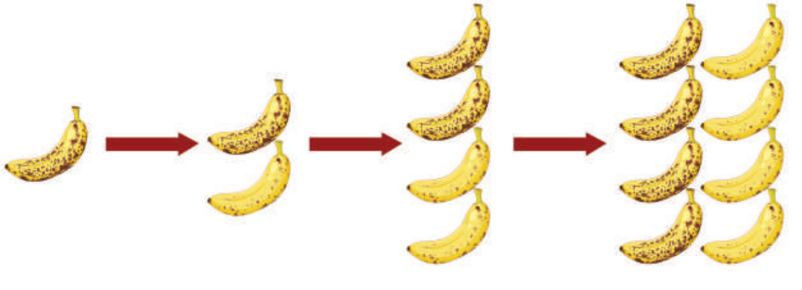
Both positive and negative feedback loops are found in nature. Living things often use negative feedback loops. For example, mammals' bodies use negative feedback to maintain a constant temperature.



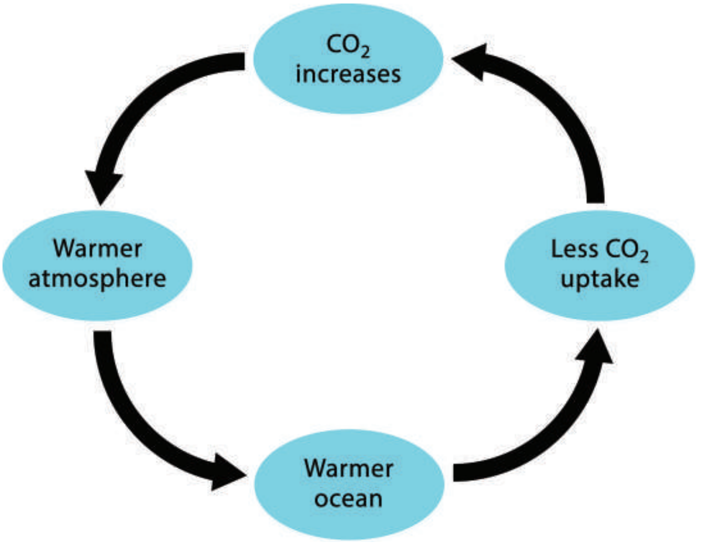
A positive feedback loop controls blood clotting. When tissue is injured, a chemical is released that signals blood parts called platelets. The platelets join together to clot the blood. Once they are part of the blood clot, they signal more platelets to join. This continues until the clot is big enough to seal the wound.



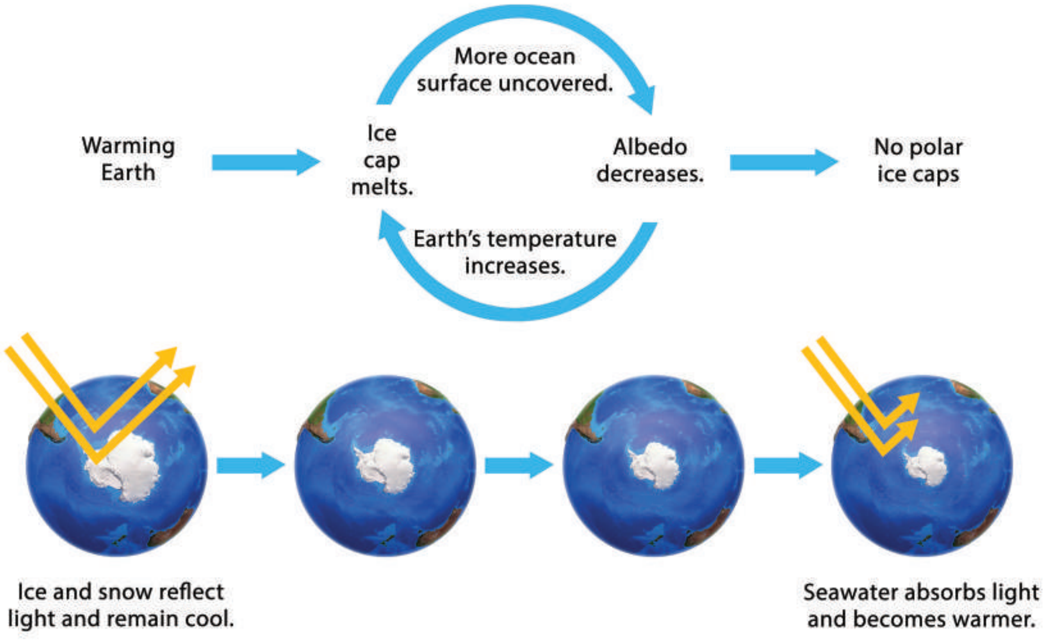
Notice how a positive feedback loop has a beginning and an end. It starts out with a small change, which increases and increases. It ends with a large change. It is not stable. Positive feedback is what causes that annoying squeal you sometimes hear from loudspeakers.



Planet Earth also has positive and negative feedback loops. Some of them take only a few months, but others take millions of years. One important feedback loop involves the amount of carbon dioxide gas in the atmosphere. As the amount of this gas increases in the atmosphere, it causes a warmer atmosphere and then warming of the ocean. As the ocean warms, more gas goes into the atmosphere. Things get hotter and hotter as this positive feedback loop keeps churning.



The ice and snow near the North Pole reflect a lot of light into the atmosphere. Ocean waters reflect less. Higher temperatures cause polar ice to melt, uncovering the ocean's surface. The darker surface absorbs more of the sun's energy, causing Earth's temperature to increase. The warmer temperature, in turn, causes more of the polar ice to melt.



There is positive feedback between temperature and water vapor in the atmosphere. As temperature increases, more water evaporates. Water vapor is a greenhouse gas. It traps heat and makes Earth warmer. The effect is even more evaporation.

There is also negative feedback between temperature and water vapor. Water vapor forms clouds. Clouds reflect some of the sun's energy, causing Earth's surface to absorb less heat. Cooler temperatures cause less evaporation.

How could you draw positive and negative feedback loops for temperature and water vapor?

Main Science Idea

In cause-and-effect relationships, the effects can become causes that affect later effects! That's called a feedback loop.

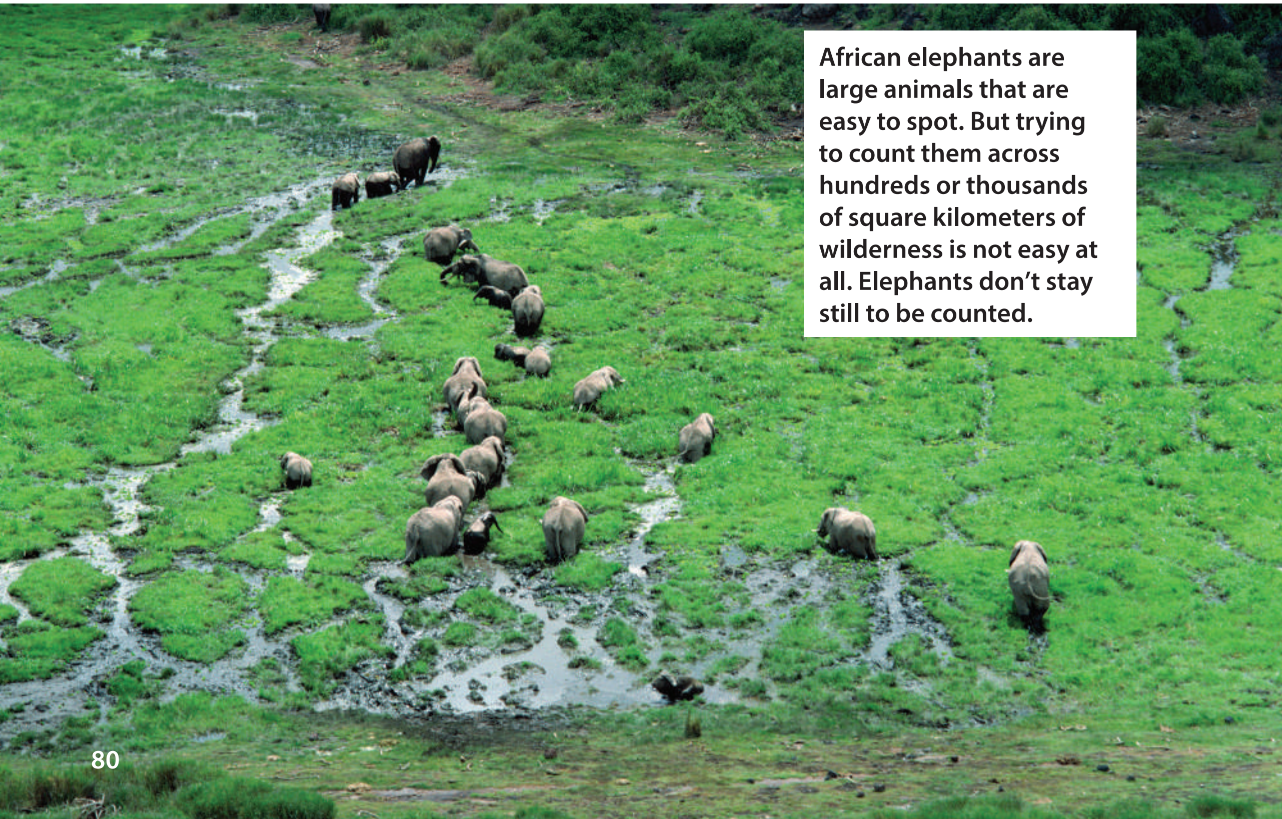
Counting Populations

Chapter 14

How many students are in your class? How about your school? Can you answer these questions?

Knowing the size of a population can help people make decisions about how many resources the population needs. For example, cafeteria operators can better manage a school lunchroom if they know exactly how many students there are.

Knowing the size of a population in nature can help biologists track the number of animals and how it changes over time. This is especially important when studying threatened or endangered species that live in a large habitat. Counting organisms can be pretty challenging when they are moving around.

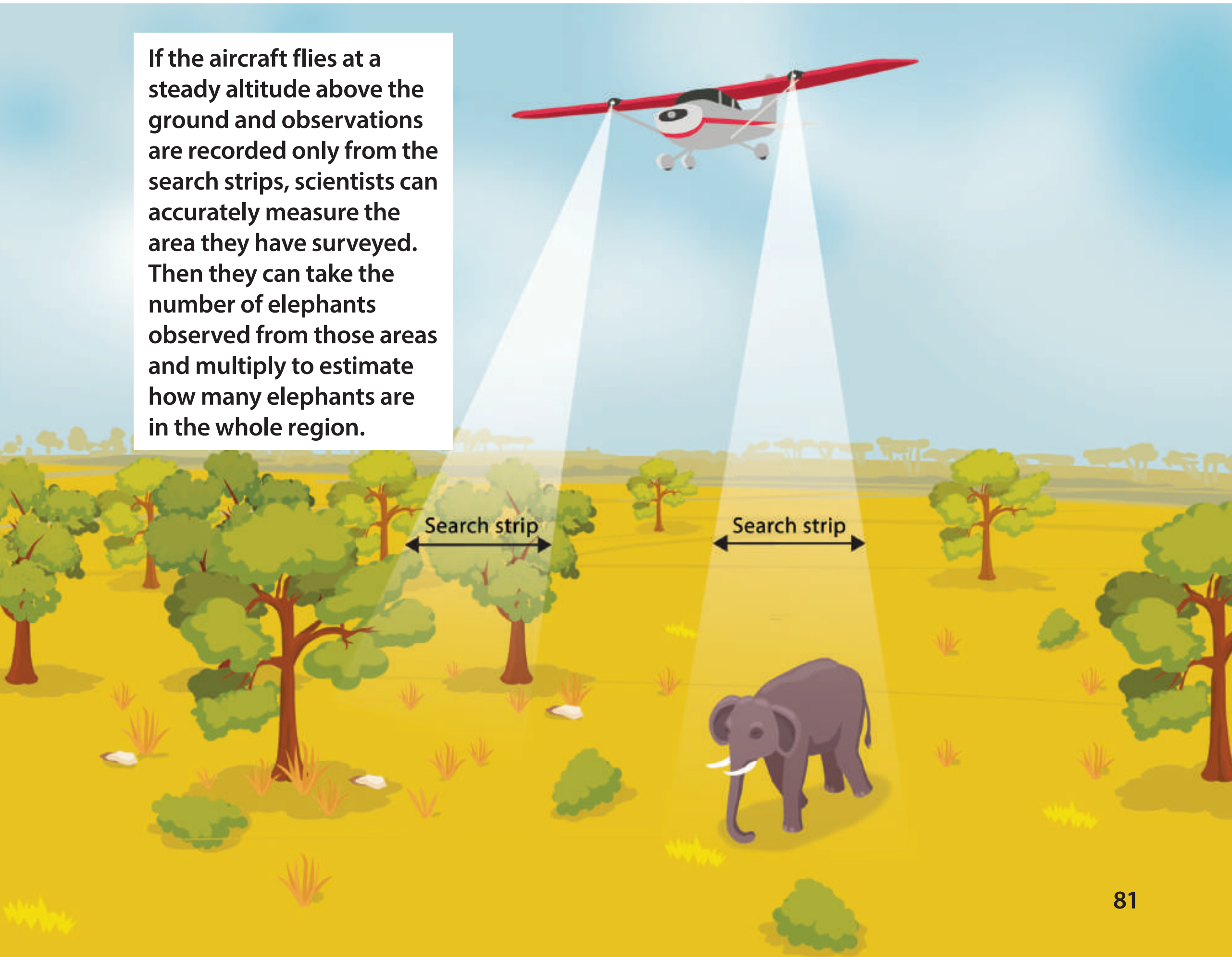


African elephants are large animals that are easy to spot. But trying to count them across hundreds or thousands of square kilometers of wilderness is not easy at all. Elephants don't stay still to be counted.

One way to come up with an informed estimate of a wild population's size is to sample the population. It means counting the individuals from a small portion of the area they live in. You can then multiply the number of individuals counted by whatever factor makes sense for the larger, total area.

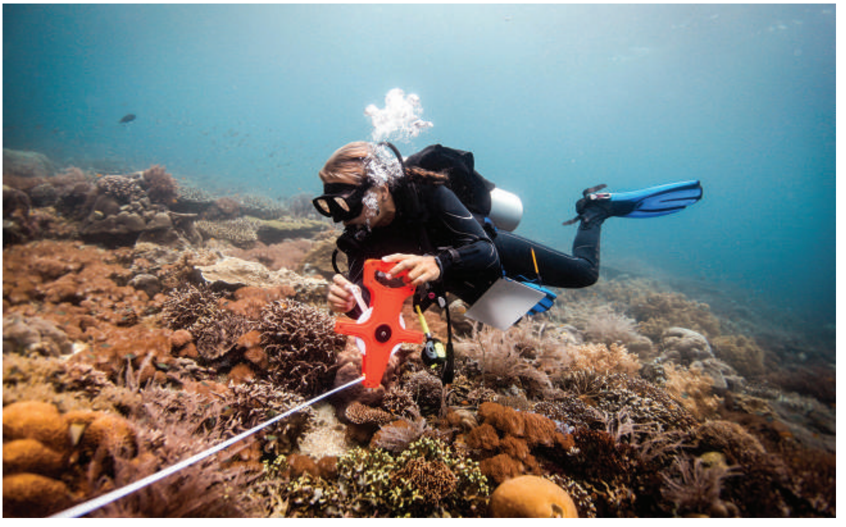
For example, if 10 percent of the area is observed and 200 animals are counted in that small area, then an informed population estimate for the whole area would be 2,000 animals—10 × 200.

Observing from the air can be an efficient way of counting animals such as elephants because an airplane can fly over a large area while people or cameras focus on counting elephants within specific bands called search strips.

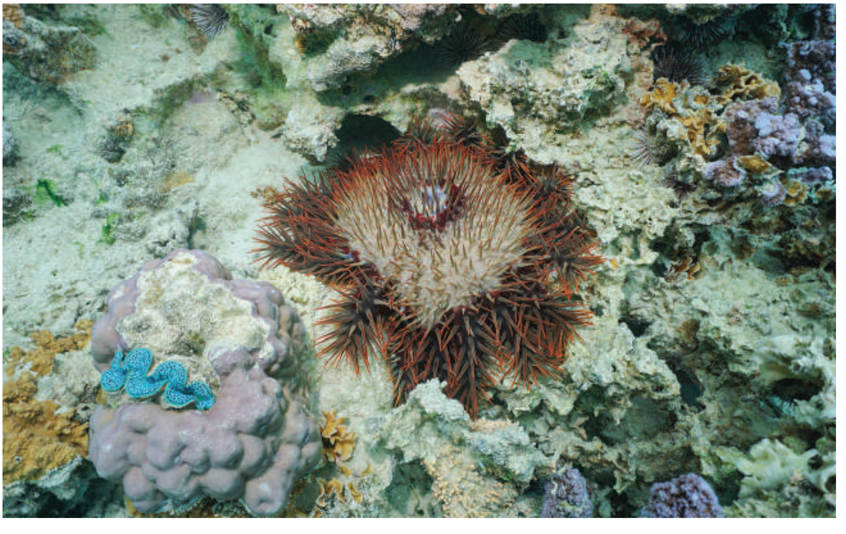


If the aircraft flies at a steady altitude above the ground and observations are recorded only from the search strips, scientists can accurately measure the area they have surveyed. Then they can take the number of elephants observed from those areas and multiply to estimate how many elephants are in the whole region.

Similar methods are used in some underwater habitats. Coral reefs and their inhabitants can be observed by a diver who is towed by a boat in straight lines, similar to the flight paths used in aerial surveys. The diver can scan the habitat for specific animals, such as sharks, record the data, and then calculate an informed population estimate for the whole reef.

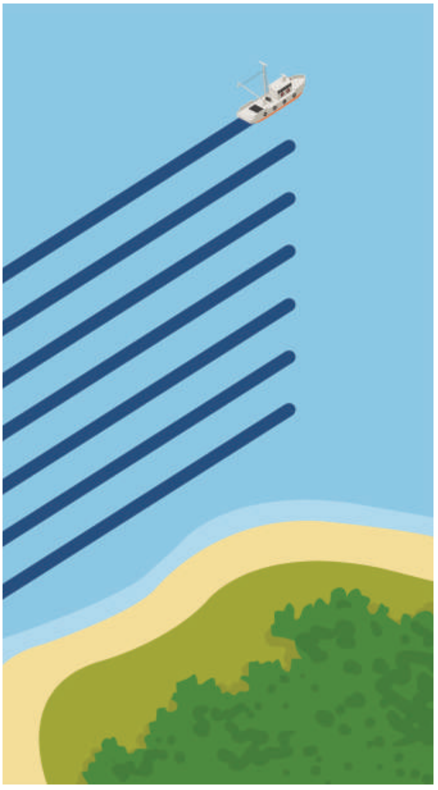


This diver is taking measurements of some of the animals on the coral reef and the space between them.



The crown-of-thorns sea star is an animal that preys on coral. A population survey of a reef can help biologists estimate how much damage these sea stars are doing.

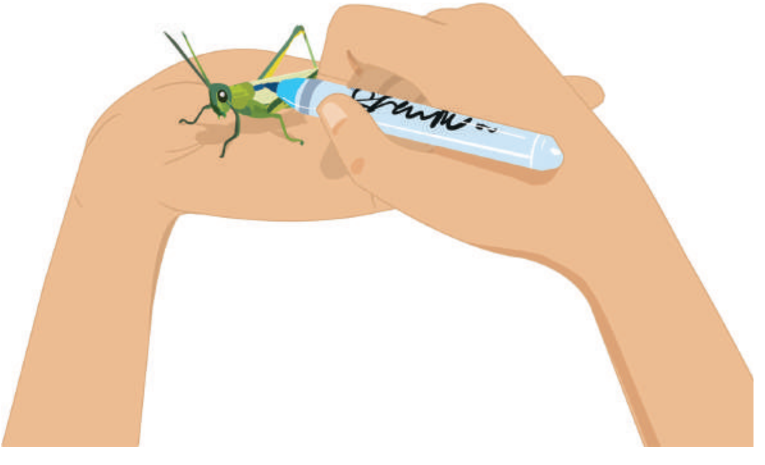
In water that is deeper or less transparent, it may not be possible to use visual observation to count animals. Instead, fishing techniques can be used to sample a population or multiple populations that occupy the same habitat.



A trawl survey can be used to sample the populations of fish. A trawl net is towed through the water just above the bottom, capturing fish. The captured population sample can produce an informed estimate of the entire population.

Collecting, counting, tagging, releasing, and then resampling animals is another way of estimating a wild animal population. This is called mark-recapture.

Grasshoppers are small and sometimes hard to spot, but they can be captured by dragging a net across their grassy habitat. However, the success rate of this collection technique is far less than 100 percent because the net cannot sweep through the tall plants as neatly as a fishing net can sweep through water.

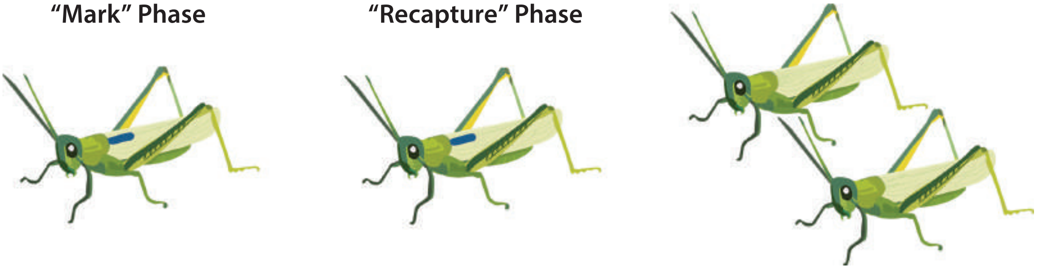


After a population sample is collected, a marker can be used to mark each of the collected grasshoppers. These marked specimens can be counted and then released back into the same habitat. This is the "mark" phase of a mark-recapture study.

Suppose 100 grasshoppers are marked and released. The "recapture" phase involves resampling the population in the same area and then comparing the number of caught grasshoppers that have marks—meaning they are recaptured—with the number that are unmarked.

"Mark" Phase

"Recapture" Phase



Original number of grasshoppers sampled, marked, and released: **100**

Number of grasshoppers recaptured: **40**

Number of new, unmarked grasshoppers captured: **80**

If twice as many grasshoppers caught in this phase were unmarked than marked, this suggests only one-third of the grasshoppers in the habitat were caught in the first phase. With 100 caught in the first phase, the total population in the area was probably 100 (caught) + 200 (uncaught) = 300.

Sometimes the animals have their own unique markings, which means a photo of those markings can serve as a natural mark or tag, with no need to capture the animals.

This whale's tail markings are unique. Scientists can record this whale's photograph and use it to track the whale over time as well as study the entire population.

Main Science Idea

Counting exact numbers of living things isn't always possible. Researchers can estimate populations using sampling methods.

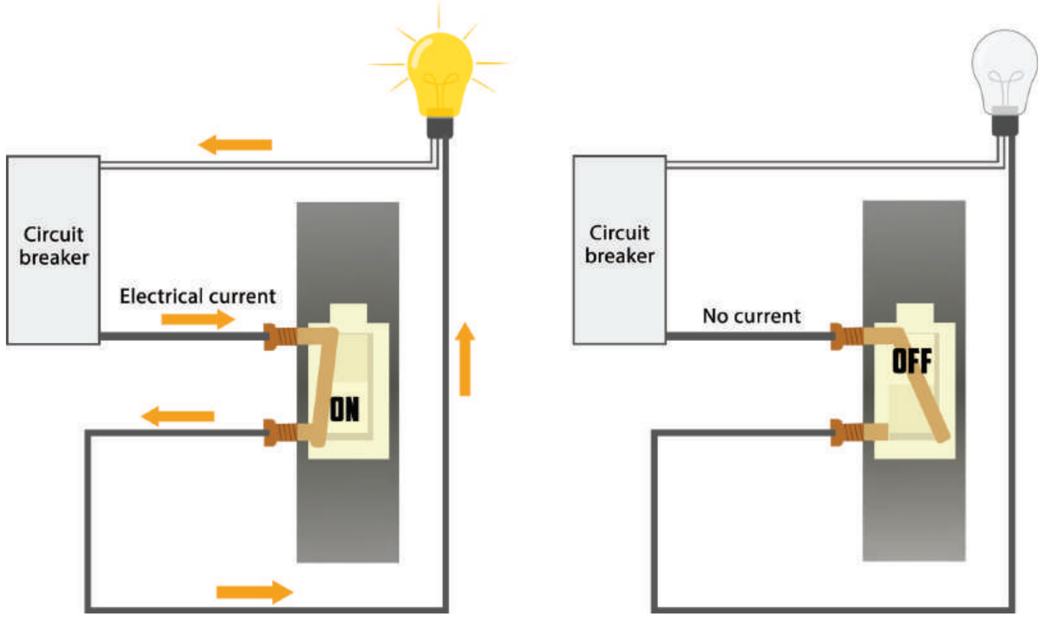
Simple Versus Complex

Chapter 15

Let's look at some systems that are simple and others that are complex.

A light switch, some wires, and a light bulb can form a simple system called a circuit. The metal wires allow an electrical current to exist but only if the current is in an unbroken circuit.

That's where the switch comes in. When the switch is "on," the circuit is unbroken. When the switch is flipped to the "off" position, the circuit is broken, cutting off the electrical current to the light bulb.



A circuit and a switch is a pretty simple system. There are only two options—on and off.

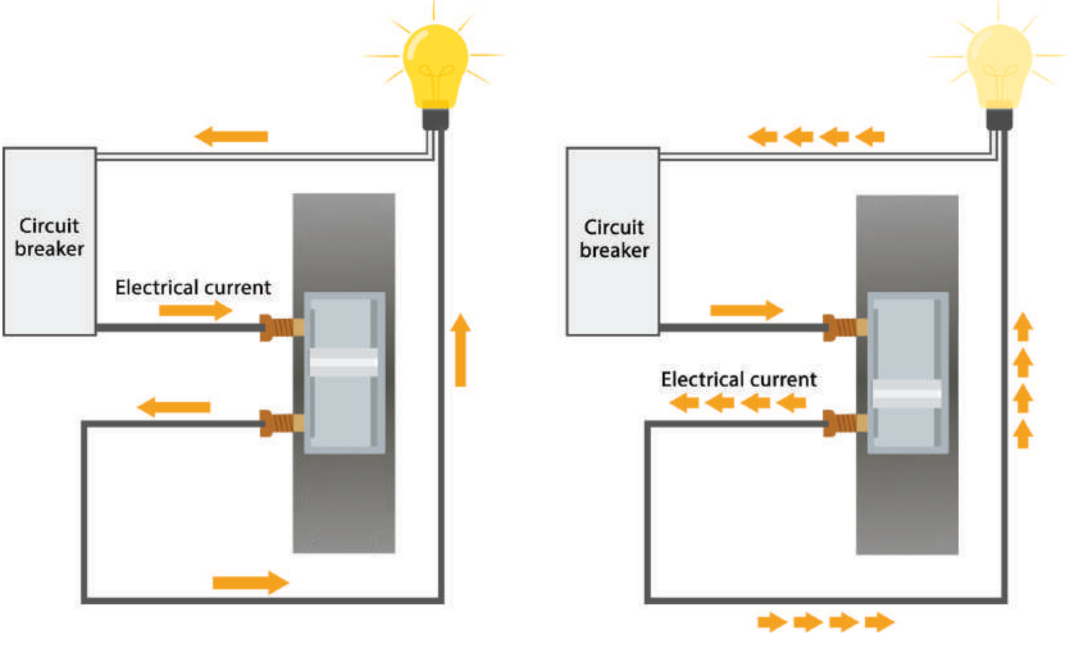
A system that is a little more complex is a tetherball setup. It consists of a post, a rope (or tether), and a ball. Opposing players try to hit the ball so the tether winds around the post in a particular direction.

The system has few parts, but because there are so many different possibilities of how the ball can be struck, it's somewhat complex. For example, when the tether winds around the post, the tether gets shorter, so the ball gets closer to the post with each wrap. This makes it harder for a player to anticipate the position of the moving ball.

Once the ball is in motion, the tetherball system gets a bit more complex.

A more complex system might be a light dimmer. A dimmer allows a light to shine more brightly or less brightly.

What makes the dimmer system more complex than a simple on-off system is that the slider part changes the lighting through a range of brightness

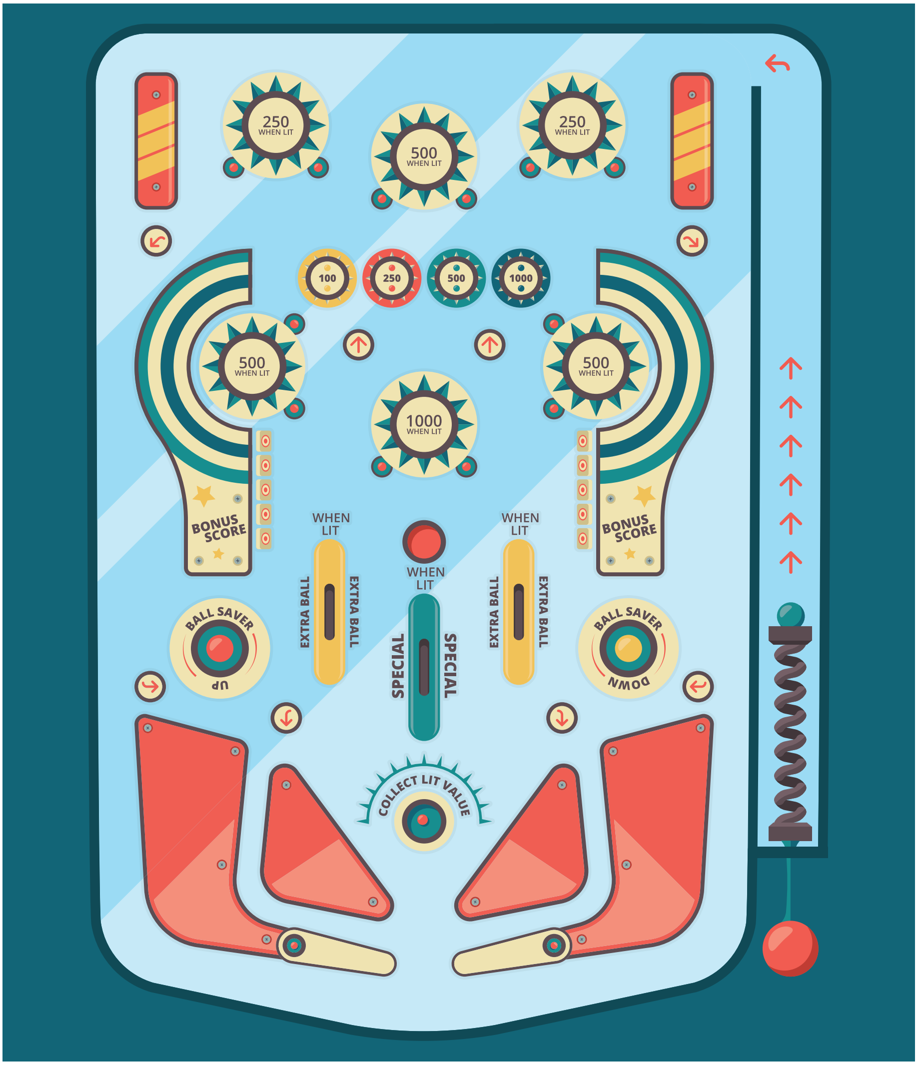


A dimmer switch changes the electrical current, resulting in more or less electricity reaching the light bulb.

A system that is even more complex is an electric guitar. The guitar is a system consisting of many parts, including a neck, a body, strings, switches, and electricity.

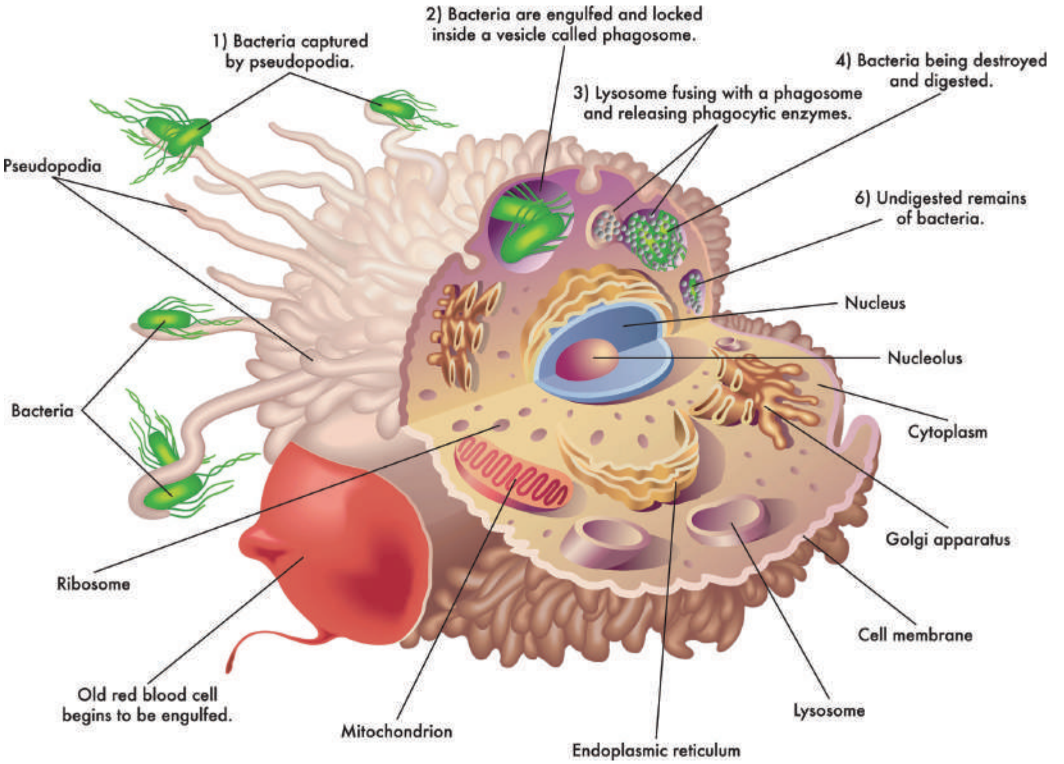
The guitars shown here have sets of round metal pickups. Pickups "pick up" vibrations from the strings above them. Depending on how much electricity is flowing through the electromagnets, greater or lesser current flows out of the guitar to an amplifier that emits a louder sound than a normal string. Compared to a simple circuit with a switch, an electric guitar is a complex system.

Before video games, pinball games were popular. These machines consist of mechanical and electrical parts that interact with a metal ball as it rolls up and down the slanted playfield. Talk about complex!



These are some of the different flippers, bumpers, targets, saucers, and ramps found in a pinball machine. These components interact with the ball and with the electronics that determine and display the player's score.

An example of a tiny yet very complex system is a human cell.



A macrophage is type of white blood cell. It surrounds and kills microorganisms that can threaten the body. It removes dead cells and works with other immune system cells.

Every cell is a system by itself. Every part of this cell can have many interactions with the other parts. Compared to the rest of the examples in this chapter, a cell is a vastly more complex system, even though it is too small to be seen without a microscope.

Main Science Idea

A system with few parts might be called simple. A system that is complex has many structures that all interact.

It’s Still There

Chapter 16

A chicken egg falls to the floor. The collision between the egg and floor causes the eggshell to break, leaving a mess. The egg doesn’t look the same, and it can’t be put back together. But everything that was part of the egg is still there. Things can change shape and form, but the matter that composes them doesn’t disappear.

When you read about science, you can understand better when you know some of science’s basic rules. Here’s some useful background knowledge:

- Objects and substances are made of matter.
- If something happens to an object that changes it in some way, all the matter that was in the original object is still present in the world, even if the object doesn’t look the same—or doesn’t appear to be there at all.

This is the concept of conservation of matter.

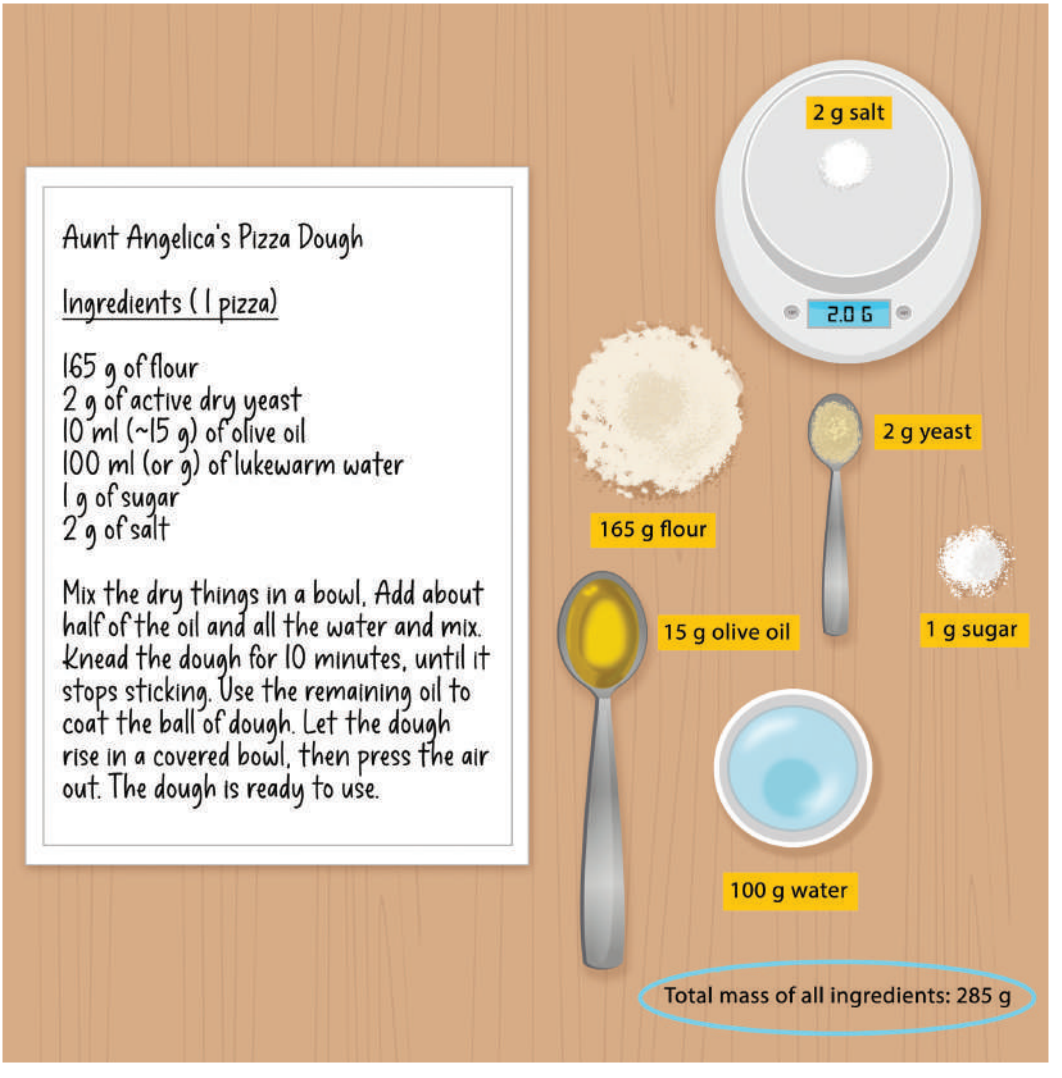
An ice sculpture is another example of how an object or substance can change but the matter sticks around.

This block of ice is being chiseled into a sculpture. The bits of ice chipped away as the chisel collides with the ice can become liquid, evaporate, or be swept down a drain, but the water particles that made up the ice do not disappear. The matter is conserved.

By this point, the sculpture has taken on a different form. The original ice block has lost some matter, but none of that matter has been destroyed.

This ice sculpture is losing some mass as it melts from a solid to a liquid. The meltwater might evaporate into the air, but none of the water particles are lost or destroyed in either of these processes.

Matter is conserved in the kitchen, too. Suppose you want to make pizza from scratch. You start by making some dough. You carefully measure the ingredients using a digital scale.



The total mass of all the ingredients that went into the dough was 285 grams. When you weigh the finished dough on the scale, it says it's 285 grams.

The pizza dough doesn't really look like any of the individual ingredients, but it's made of the same stuff, and it has the same mass as all that stuff put together.

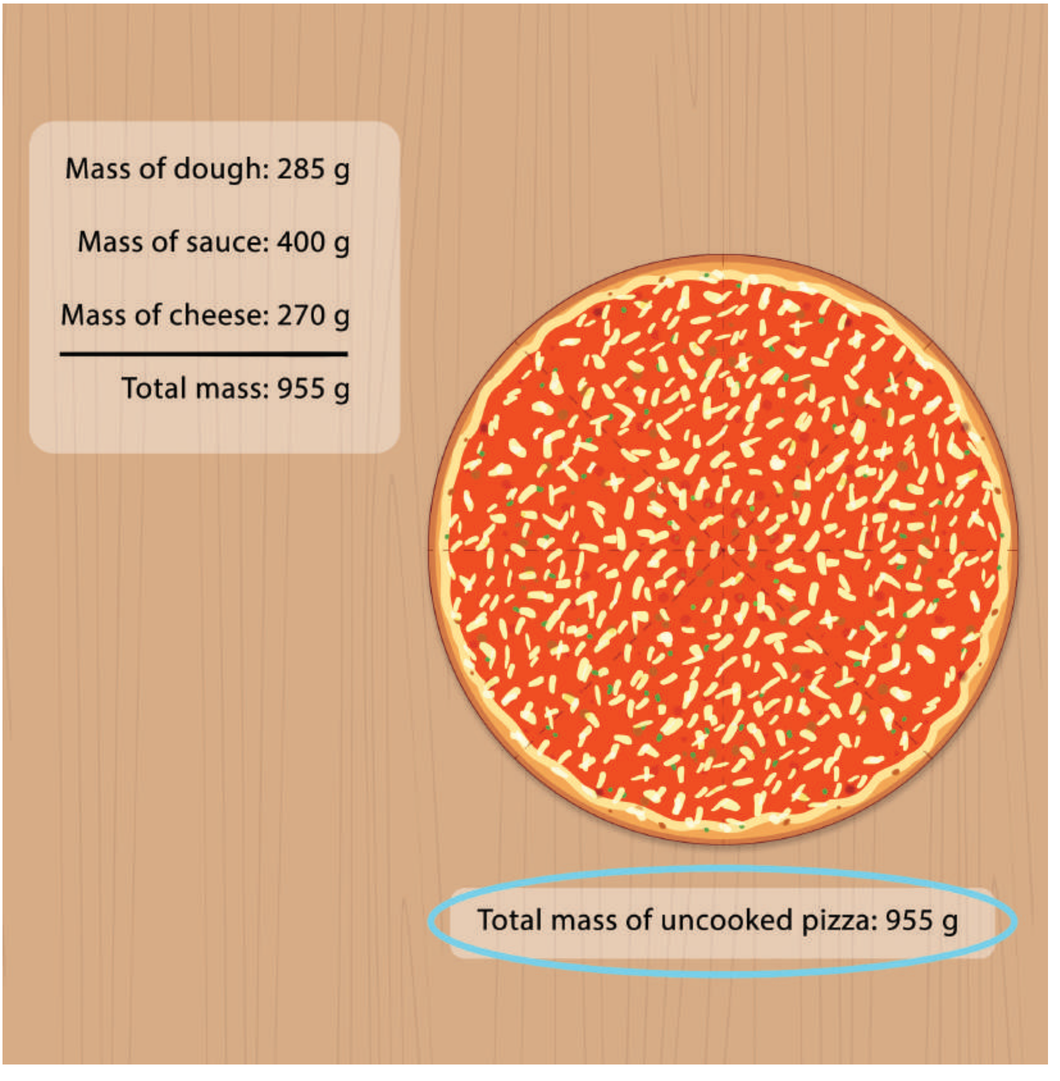
Next, you make some sauce for the pizza using a can of crushed tomatoes, some olive oil, salt, sugar, and basil. You weigh the ingredients before mixing them and then weigh the prepared sauce. The weights match—400 grams.

The only thing that seems to lose some mass during the prep phase of making pizza is a pepper. The 30-gram pepper turns into slices that weigh 27 grams all together—until you decide to just eat all the pepper slices!

After weighing the sliced pepper, you notice the stem, some seeds, and a small puddle of pepper juice on the cutting board. That must be the missing 3 grams of matter!

So, you have a dough that's 285 grams, 400 grams of sauce, and 270 grams of sliced mozzarella cheese. The total mass of these three things is 955 grams.

You flatten the dough on a thin metal sheet, ladle the sauce on, and carefully lay the mozzarella slices on top. You measure the weight of the completed pizza: 955 grams. So far, mass has been conserved.



What about when the pizza cooks? The texture and appearance of the pizza certainly change. The white dough puffs up around the edges and turns brown and crusty. The mozzarella melts, spreads out, and turns slightly yellow in color. The sauce appears to thicken.

You remove the steaming pizza from the oven and weigh it on the scale. The scale reads 900 grams. The remaining 55 grams of matter are unaccounted for!

Where did those 55 grams of matter go? Reread the previous paragraphs, and think about what happens to liquid water when it gets very hot. That's right—some of the water that had been in the dough, the sauce, and the cheese left the pizza as steam, or vaporized water. If you could collect the water vapor that left the pizza and weigh it on the digital scale, it would add up to 55 grams.

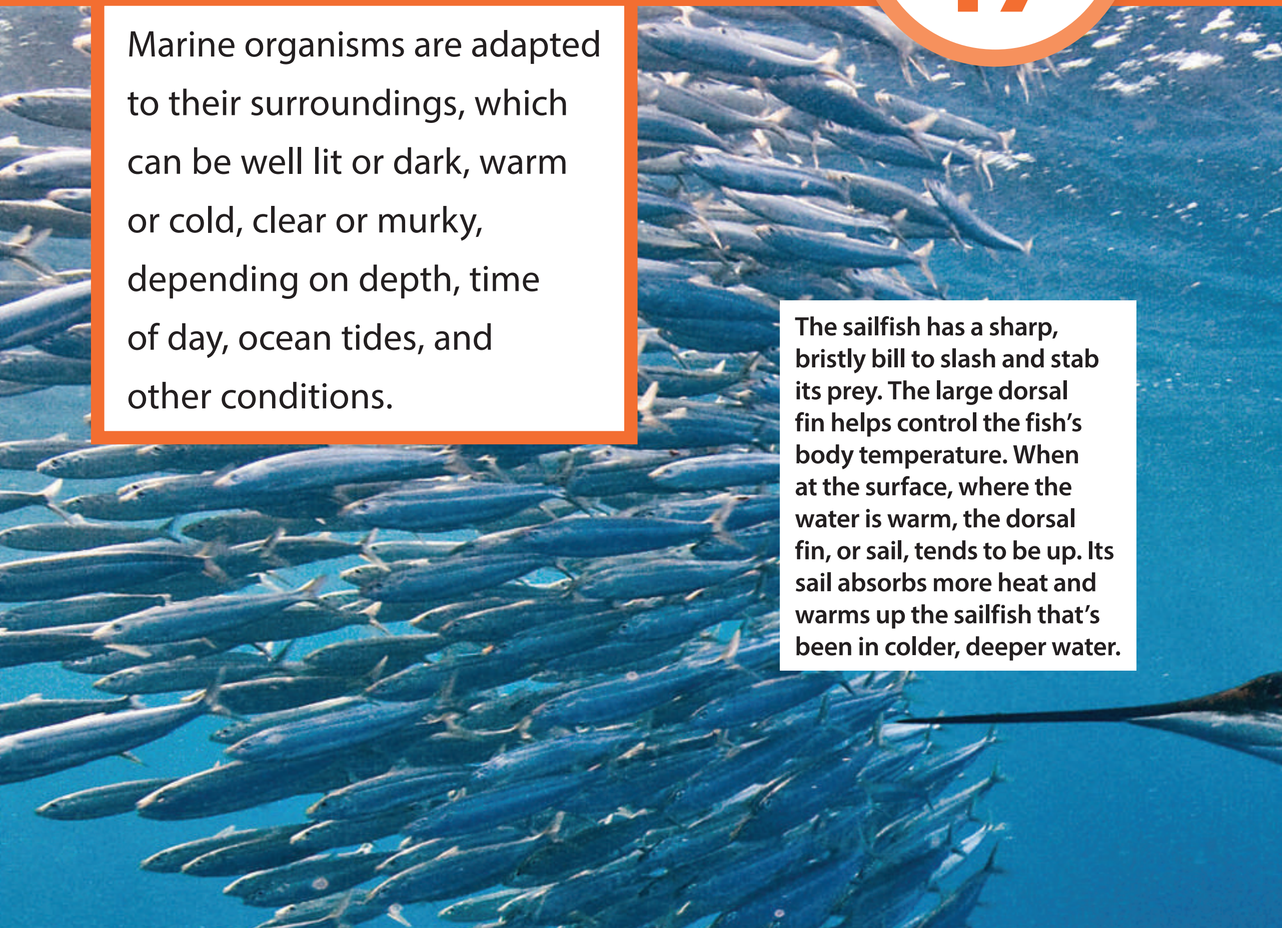
No matter what happens to matter—whether it's mixed, chopped, kneaded, cooked, or sliced—the small particles that make up the stuff you can see, touch, taste, and smell do not get destroyed.

Main Science Idea

Conservation of matter is a law of chemistry and physics. The idea states that matter isn't created or destroyed; instead, it is just rearranged into different forms when it is changed.

Fantastic Functions

Chapter 17



Marine organisms are adapted to their surroundings, which can be well lit or dark, warm or cold, clear or murky, depending on depth, time of day, ocean tides, and other conditions.

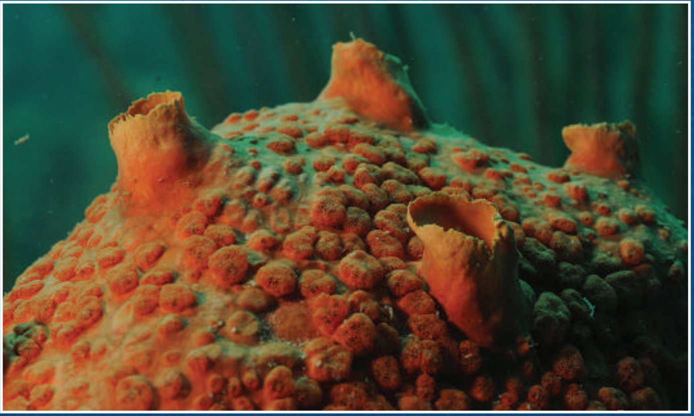
The sailfish has a sharp, bristly bill to slash and stab its prey. The large dorsal fin helps control the fish's body temperature. When at the surface, where the water is warm, the dorsal fin, or sail, tends to be up. Its sail absorbs more heat and warms up the sailfish that's been in colder, deeper water.

This anglerfish has a special fin atop its head. At the end of the fin is a lure that glows and attracts prey in the darkness of the deep sea. Once the prey is near, the fish opens its huge mouth and sucks in its meal. Daggerlike teeth prevent the prey from escaping.

This scallop has no legs or fins, but it can swim by squeezing its shells together and forcing water out like a jet.

Baleen whales have feathery structures in their mouths that act like strainers. The whale can take in tons of water and food, then use its tongue to squeeze out the water while the baleen traps the food.

Jellies have stinging tentacles to capture prey that are swimming or drifting through the water.



Sponges are animals that draw water into themselves and strain microscopic food out of the water.

Corn is a type of grass that has been modified by humans and many years of selective breeding.

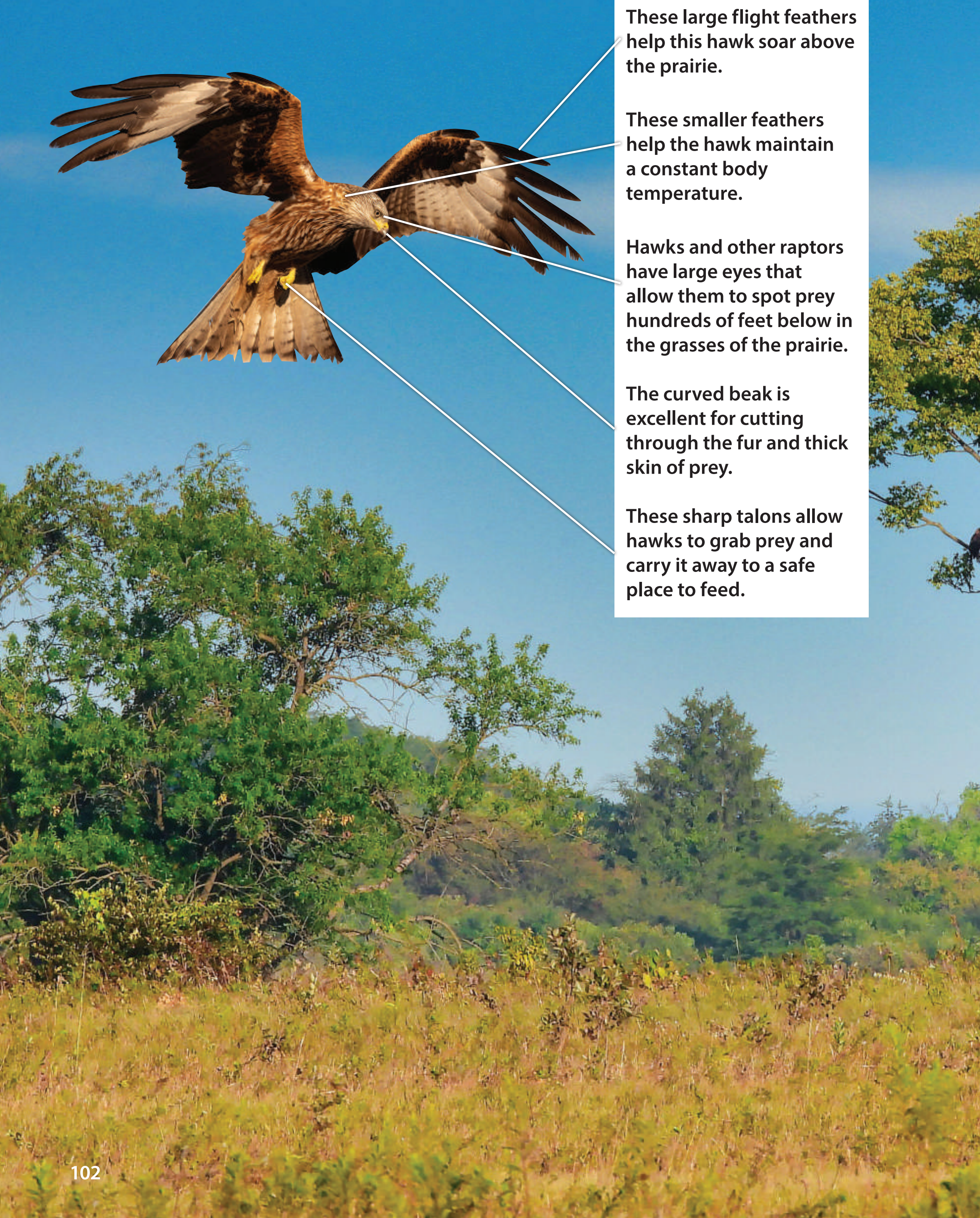
Each strand of the "silk" of a corn flower is a tube that can deliver male reproductive cells to female reproductive cells in the plant structure.

Fertilized female cells become kernels of corn. Each kernel of corn is an individual fruit. Tough green leaves protect the kernels from hungry consumers while they grow.

Corn and other plants have chloroplasts, which are special parts within plant cells that absorb sunlight and help use its energy to turn carbon dioxide and water into sugar and oxygen gas. This chloroplast image was taken by a high-powered microscope.

Corn plant roots anchor the plants in the soil and absorb water and nutrients that allow the plant to grow. The woody stalks keep the plants upright in an environment that can get quite windy.

A prairie is a type of ecosystem. Both predators and prey are adapted to life here. Special features aid them in the struggle for survival.



Main Science Idea

What a structure is made of and how it is formed determine how it can function.

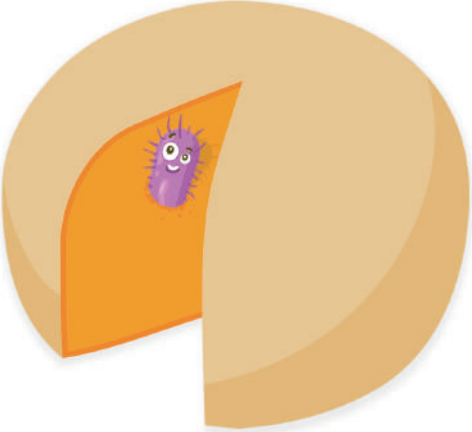
Was That Fast?

Chapter 18

Organism: Bacteria

Life span: hours

My name is *Lactobacillus bulgaricus*. We have probably met before if you have ever eaten a fermented dairy product such as Parmesan or Romano cheese or yogurt, which I help make.



Wait, if you've eaten me, how am I talking? Well, we bacteria reproduce by dividing in two, over and over again, sometimes many times a day. The bacteria I produce when I divide are copies of me. Each copy of me doesn't live for very long, though—a few hours to a day, tops.

I take the sugar in milk, called lactose, and break it down into something called lactic acid. This gives cheeses and yogurts their tartness. I can also live in your digestive system and break down lactose so you don't get an upset stomach after eating ice cream or drinking milk.

Anyhow, I—or should I say we?—have to run. Life is short, and there's a lot of lactose to process before the next generation takes over.

Organism: Mayfly

Life span: months (larvae) to a few days (adults)

I'm a mayfly on the shores of Lake Michigan. Life as a mayfly can be divided into two phases. First, for some months or maybe a year or two, we live in streams, ponds, or lakes. We don't have wings during this stage, but we have feathery gills to allow us to absorb oxygen from the water. We mostly cling to rocks, feed on algae, and dodge predators such as trout.

If we survive the aquatic stage, we float to the surface and molt, meaning we shed our skeletons and change shape. The first molt gives us wings to fly away from the water. We then rest for a few minutes or hours before molting yet again. Then, as adults, we gather in large swarms to mate. We lay our eggs in water.

We live for only a day or two, so for most of our lives we live more like fish than flies.

Organism: Giant Pacific Octopus

Life span: 3–5 years

I am feeling tired today. It's been about six months since my last meal, which was a small shark that I grabbed with one of my tentacles as it swam by. I laid about 80,000 eggs a few days after that last meal, and since then I've been taking care of the eggs to make sure they get plenty of oxygen-rich water and stay clean.

I'll keep doing this until the eggs are ready to hatch, and then I'll pass away, as my mate did soon after we got together. It beats getting caught and grilled by humans or getting whacked around and chomped by a sea lion.

Organism: Greenland Shark

Life span: 450 years

Life as a Greenland shark is chilly, dark, and long. I have been around for nearly four hundred years, and I've ranged from the Arctic to the depths of the Caribbean Sea.

I am about twenty-one feet long, and I weigh more than one ton. It takes us about one hundred years just to reach maturity, meaning the age at which we can reproduce. I have given birth to several dozen offspring, though I can't say I got to see much of them, since it's so dark where I live.

What do I eat? I mostly scavenge, which means I feed on animals whose remains sink down to where I live. Sometimes I get lucky and come upon a large whale carcass. The food I can get from that can sustain me for many months. I have also eaten reindeer and other animals of the Arctic that happened to fall through sea ice or got swept downstream by rivers.

Organism: Giant Sequoia Tree

Life span: 3,000 years

The older I get, the farther I can see. This is partly because I am hundreds of feet tall but also because some of my siblings have fallen to the ground over the centuries, leaving me with more of a view to myself. I am a giant sequoia tree, one of the largest and longest-living organisms on Earth.

A couple advantages I have over some of the other trees of the forests here in California is my thick, fire-resistant bark and the fact that my branches are so high off the ground. Fires can destroy and clear out shrubs and other vegetation on the forest floor without harming me very much at all.

The fires help dry out and open up my cones, allowing my seeds to drop to the ground and sprout in the ashy but cleared-out soil.

Fossilized Organism: Fern Leaves

Age: Millions of years

I'm a fossil fern. You could say I've lived two lives. The first lasted just a few years and occurred 300 million years ago, during the Carboniferous Period. This was before the time of the dinosaurs.

When I died, my remains became part of a layer of sediment, along with lots of other remains of different organisms. The sediment got buried under more layers, and then, over millions of years, it got turned into sedimentary rock. My remains were replaced by minerals. This is called fossilization.

After that, I remained buried as processes such as erosion and weathering broke down the layers of rock above me. One day, a human who was hiking found me. Now, I sit on a bookshelf in her home.

Main Science Idea

Some living things change, grow, and survive for a very short time. Other organisms have very long life spans. They change, grow, and survive over a long period of time.

The Better Plan

Chapter 19

Solar Arrays for Tropical Island Use

By Jean-Michel Lorthe and Maui Folau

Introduction

We set out to test solar panels that would work on the roof of a house in a tropical island location such as Haiti or Tonga. Both are nations in tropical climates. Shipping fossil fuels to these places to power electric generators is expensive and not very practical. Sunlight, however, is abundant and intense in both places. This makes solar power a potential solution in both Haiti and Tonga. Jean-Michel's family is from Haiti, and Maui's family is from Tonga, so this project interests us.

Constraints

All engineering solutions have to worry about constraints. Constraints are limits to a plan. The typical home in Haiti and Tonga has a roof made of corrugated aluminum. Rooftop solar arrays must sit on this roof without adding too much weight.


Typical home in Tonga

Another constraint is the overall roof size and shape. On average, a roof has just 360 square feet to hold solar panels, because some of the space is triangular and cannot hold panels. Most solar panels are 3 feet by 5 feet, so solar arrays must be based on arrangements of panels of that size.

Word to Know

Criteria are things that need to be included or satisfied in a solution to a problem.

Criteria

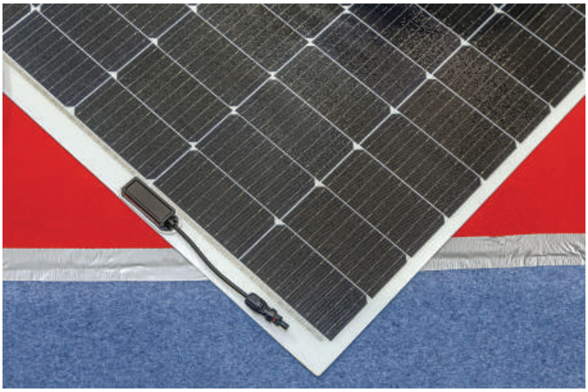
The criteria for our project are the following:

- Design and compare two types of solar panel arrays that would fit within 360 square feet of space using panels that are 3 feet by 5 feet in size, without causing any damage to the structure of the roof.
- Generate at least 1,500 watts of electricity per hour.

Methods

For Option A, we selected a standard rooftop solar panel with glass and metal framing.

For Option B, we chose a flexible type of panel that lacks glass and metal and is therefore more lightweight, but it produces less electricity. Both panels are about 3 feet by 5 feet in size.



To test both options, we traveled to our relatives' hometowns in Haiti and Tonga and worked with electricians and builders there to install the two types of arrays on two different homes in each location.

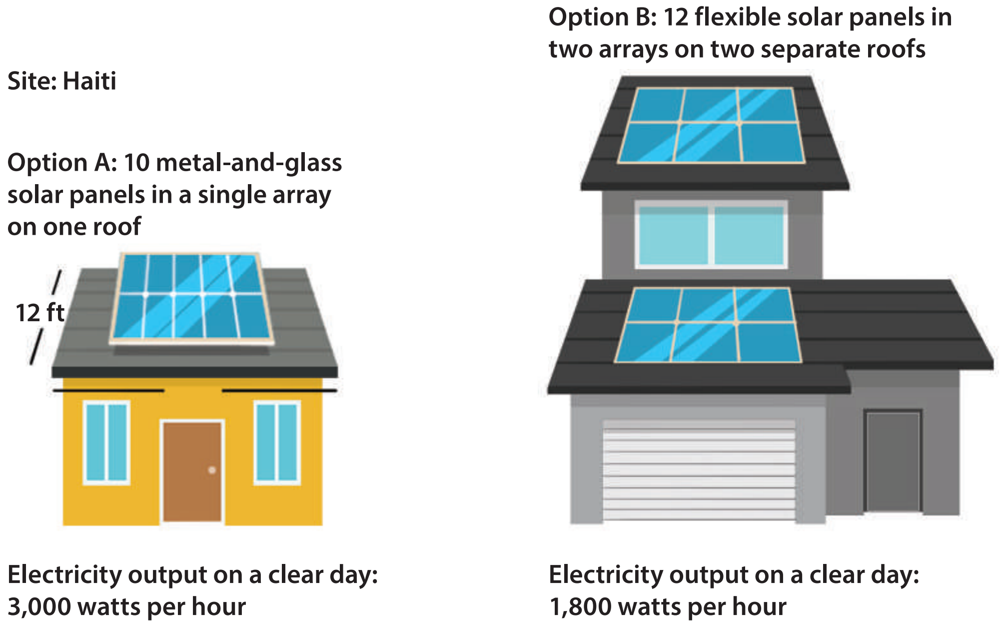
We selected homes whose roofs were similar in size and pointed toward the midday sun. We could afford enough panels to cover only 50 percent of the 360 square feet that we intended to test on each roof. So, we had to modify that criterion as follows:

- Design and compare two types of solar arrays that would fit within 180 square feet of space using panels that are 3 feet by 5 feet in size, without causing any damage to the structure of the roof.

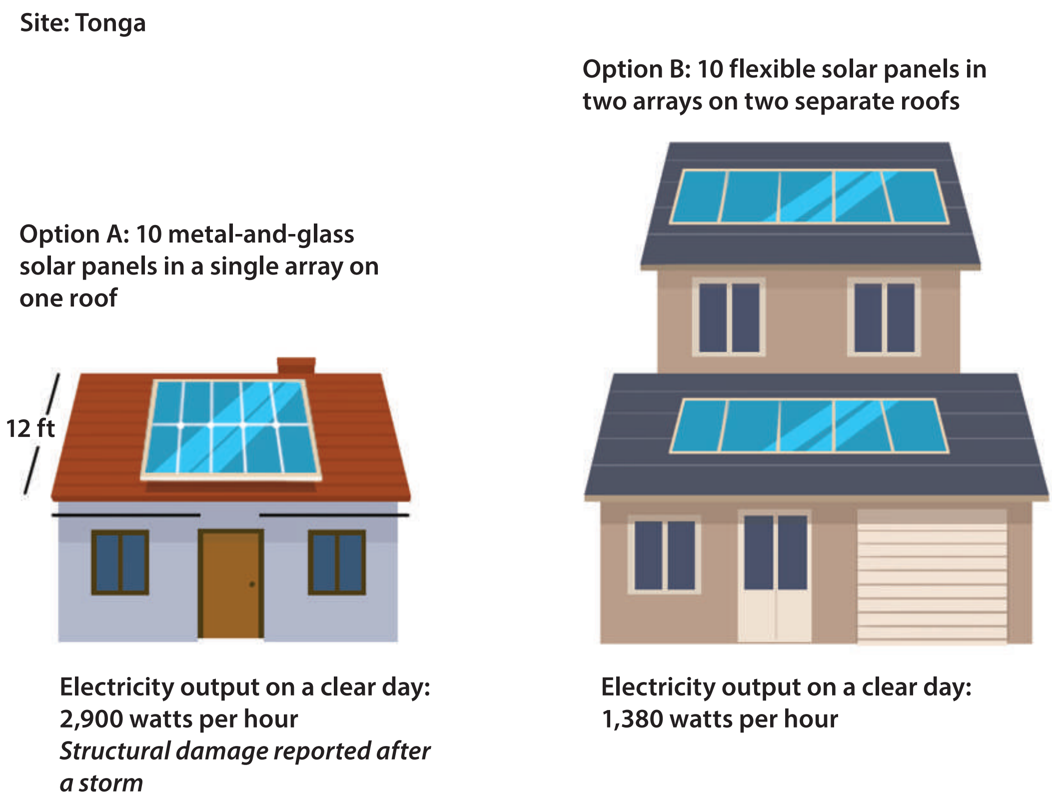
Meters were installed to measure the electricity produced by each solar array.

Results

The figure below summarizes the results at Jean-Michel's site in Haiti.



The figure below summarizes the results at the Folaus' village in Tonga.



The Tongan home with Option A suffered some damage to the roof structure after a cyclone's heavy rains and winds added stress to the roof. The home with Option B did not suffer any roof damage, perhaps because of the lighter weight of the flexible solar panels.

Four homes were involved in this project. Only one suffered any damage that seemed related to the installation of solar panels.

The overall results are shown in the table below. We did a lot of calculations to be sure we kept the tests fair. But pay attention to the scores and final scores

Solar Array	Number of Panels	Electrical Output (W/h)	Structural Damage	Weight	Score	Total Score
A—Haiti	10	3,000	No		3,000	4,450
A—Tonga	10	2,900	Yes	–1,450	1,450	
B—Haiti	12	1,800	No		1,800	3,180
B—Tonga	10	1,380	No		1,380	

Discussion

- The Option A type of solar array performed best in both locations, earning a score of 4,450. It generated nearly 3,000 watts per hour on sunny days.
- However, the weight of Option A seemed to be a problem in Tonga when a cyclone added stress to the roof in the form of wind and heavy rain. This damage resulted in some points being deducted from Option A's overall score. Option B generated about half as much electricity per hour, but it did not cause any damage, and it still met the target of 1,500 watts per hour when we took the average of both Option B arrays.

Option A is the clear winner. Our suggestion is to undertake a multiyear study to evaluate which type of solar array holds up best over time.

Maui and Jean-Michel,

Nice job with this report and with the project overall! I think it's great that you and your families were able to work together to bring solar power to some homes in Haiti and Tonga and that you were able to turn it into an investigation with a science and engineering theme!

Here are a few suggestions you might want to apply to your next project:

- It would probably make more sense for all of the homes or roofs to get the same number of panels so comparisons across would be more fair. In science, it's best to focus on just one variable at a time, if possible.
- It was smart to give some weight to damage caused by the solar arrays by applying a negative factor. How did you determine the weighting?
- In general, it might make sense to compare costs and benefits of the solar panels with standard electricity.

Solar Array	Number of Panels (fitting in <180 square feet)	Electrical Output on Clear Days (W/h)	Structural Damage	Weight	Score	Total Score
A—Haiti	10	3,000	No		3,000	4,450
A—Tonga	10	2,900	Yes	−1,450	1,450	
B—Haiti	12	1,800	No		1,800	3,180
B—Tonga	10	1,380	No		1,380	

Main Science Idea

Planning ways to test and compare solutions can sometimes reveal which solution would be better, even without building the solutions or performing the tests. Planning the evaluation causes you to look carefully at what a design is supposed to do and how it is supposed to succeed.

Risk

Chapter 20

In this century, many light bulbs aren't even bulbs at all. Instead, they are small light-emitting diodes, or LEDs. If you look closely at an LED light fixture, it looks more like rows of circles than a traditional light bulb.

LED light

For a time, compact fluorescent light bulbs were the norm. They are energy efficient, but they contain mercury, a dangerous element. (Hg is the chemical symbol for mercury.)

LEDs are energy efficient, very small, and relatively cool to the touch, which makes them less dangerous than many other sources of light, including incandescent or fluorescent light bulbs that were the norm just a few years ago.

So, how did we get from the first sources of indoor lighting, such as fire, to the LED? It's a story of the changes that happened in both engineering and science.

The sun is the light source that humans by far use the most. Moonlight, which is sunlight reflected off the surface of the moon, can also illuminate our world when the moon is full and the sky clear, but it isn't very reliable.

Fire has been used by humans as another light source for tens of thousands of years. A controlled fire in a cave would have been a source of heat and light. Torches consisting of balled-up wood fibers soaked in a natural flammable substance such as animal fat or coconut oil were used as portable lights or to travel at night.

Torches made of coconut husk fibers and oil allowed Pacific Islanders to light their way and entertain each other long before light bulbs and electricity were available.

The fire risk is important in most places, but there wasn't as much risk in using a torch along a castle wall made of stone.

The problem with using fire as a light source is the large risk it poses to anything nearby that is flammable. Risk is a dangerous or unwanted result. Fire emits a lot of heat, so it can cause something to burn.

At least 2,400 years ago, humans developed candles. The wick that runs down the length of the candle soaks up wax that is liquified as the top of the candle is melted by the flame.

The soaked wick is what burns and emits light and heat.

The candle burns only at the top and slowly eats away at the candle until the wick and wax are used up. This is a way of controlling the amount of fire so there is less risk. Even so, a candle produces a flame, and that makes it a riskier source of light than today's light bulbs. Candles also emit smoke.

Candles allowed people to light their indoor spaces at night. This allowed for more reading, learning, thinking, and other activities—including the kind that led to other inventions. Beeswax, animal fat, and whale oil were all used by different cultures around the world to make candles.

A lamp enclosed a flame in glass. The risk is much less than an open candle. These lamps often used oil.

But many lamps were fueled by oil taken from the bodies of whales. So many whales were hunted for oil that many whale populations declined. As whale populations declined, whaling ships had to travel farther to look for whales. This added cost and risk to whaling activities and caused the price of whale oil to increase.

Millions of gallons of whale oil were produced each year in the 1800s by hunting whales around the world.

As the whaling industry—and whale populations—declined, humans used other options for lighting lamps. Lamps fueled by coal gas were common in London, England, in the early 1800s. Petroleum oil was processed into different fuels, including kerosene, which became a common lamp oil that is still used to this day. Like a candle, a kerosene lamp has a wick that soaks up the fuel and burns it in a manner that limits how much light is emitted.

Lamps with glass globes like this are also called hurricane lamps, because the tall glass protects the flame from being blown out by a gust of wind.

In 1879, Thomas Edison developed the first light powered by electricity. These bulbs offered flameless light. Eventually, they were used in automobile lights, too. An incandescent light bulb features a thin filament that glows when electricity passes through it.

But even these light bulbs had risks. Electricity passed through them, so you could not touch any inside part of the bulb. A very dangerous shock might occur, and they got very hot.

Edison developed many different types of light bulbs.

The twentieth century saw the use of incandescent light bulbs become very widespread. Other types of lights were invented, too, such as high-intensity discharge (HID) lights. A gas was sealed inside glass. When electricity was turned on, it excited the gas and caused it to glow. Depending on the type of gas, the glow might be very white and “cool,” or more yellow and “warm.”

This streetlight uses a bulb filled with sodium halide gas. This bulb lasts longer than an incandescent bulb. A bulb that lasts a long time is helpful if you have a tall lighting fixture that hangs over a busy road.

Any gas that leaks out could potentially cause harm. These HIDs were safe in many ways, but risk was always present.

This lighting strip consists of many different LEDs. The strip can be stuck onto a wall or other flat surface. The LED is much safer than many other types of light because it gives off less heat, it uses less electricity, and it does not involve glass or flames. Science and engineering found a way to minimize risk.

Light-emitting diodes (LEDs) were invented in the 1960s but did not become inexpensive enough to be widely used until the 2000s. An LED converts electrical current but in a different way than old light bulbs. LEDs do not need to be surrounded by glass, and they don’t use much electricity. They can also last for months or even years.

Main Science Idea

Many things studied in science and designed by engineers can do harm. They can unintentionally hurt people, other organisms, and environments. It’s important to pay attention to the risk of negative outcomes.

Glossary

A

abstract, adj. can't be physically represented

accurate, adj. on target

adapt, v. to change to a new circumstance

affect, v. to create a change in something

C

cause, n. the reason something happens

chart, n. a graphical representation of information

claim, n. a statement that answers a question or poses a solution to a problem

column, n. a vertical arrangement of related items or data

complex, adj. describes a system with many parts that interact with each other and many other systems

concrete, adj. can be directly observed

conservation, n. the preservation and careful management of the environment

constraint, n. a limitation on the designed solution to a problem

control, n. the unchanged thing or group used as a comparison to the results of an experiment

convincing evidence, n. evidence that is more likely to be true than untrue

criteria, n. conditions that a solution to a problem must meet for the solution to be considered successful

D

data, n. information collected by observation or measurement

data table, n. a grid that organizes data into rows and columns

decision, n. a choice made after thinking about several possibilities

E

effect, n. a change that happens because of a cause

evaluate, v. to examine the details of something and determine the value or effectiveness of it

F

feedback, n. response to something that happens that provides information or input into what happens next time

feedback loop, n. a cause-and-effect relationship in which the effects become causes that affect later effects

function, n. the way something works to achieve a task or serve a purpose

G

graph, n. a diagram that organizes and displays data in a way that reveals patterns and makes the data easier to understand

I

informed estimate, n. a count of individuals in a small portion of an area, multiplied by a factor that makes sense

L

law, n. a statement based on many observations and pieces of evidence

lifespan, n. the length of time a living thing lives or functions

M

mass, n. the amount of matter in an object

matter, n. anything that has mass and takes up space

maturity, n. the age at which an organism can reproduce

method, n. the way that data is gathered

model, n. a representation of something that can help people learn about the real thing

P

pattern, n. a recognizable or recurring design or sequence of events

population sample, n. the specific group data is collected from

precise, adj. within a narrow range

R

reasonable judgment, n. judgment based on good reasoning and facts

reasoning, n. a scientific mindset that connects claims and evidence

report, n. explanation of a science investigation

risk, n. something that involves danger

rows, n. a part of a data chart that displays related data horizontally

rubric, n. a scoring guide that addresses the criteria and constraints

S

simple, adj. describes a system with few parts

skeptical, adj. questioning nature, unsure if a statement is accurate or based on evidence

speculation, n. an opinion about something without necessary or sufficient evidence or information

structure, n. the arrangement of parts that make up something

system, n. a set of parts that work together to complete a task

T

technique, n. how scientists conduct a test

testable question, n. a scientific question that includes a cause and effect, independent variable, and dependent variable

theory, n. a set of ideas used to explain something

tool, n. a device that helps in the performance of a task

troubleshoot, v. to identify and correct the problem in a system

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