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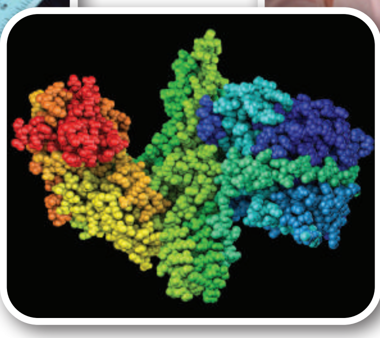

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Reading About Science

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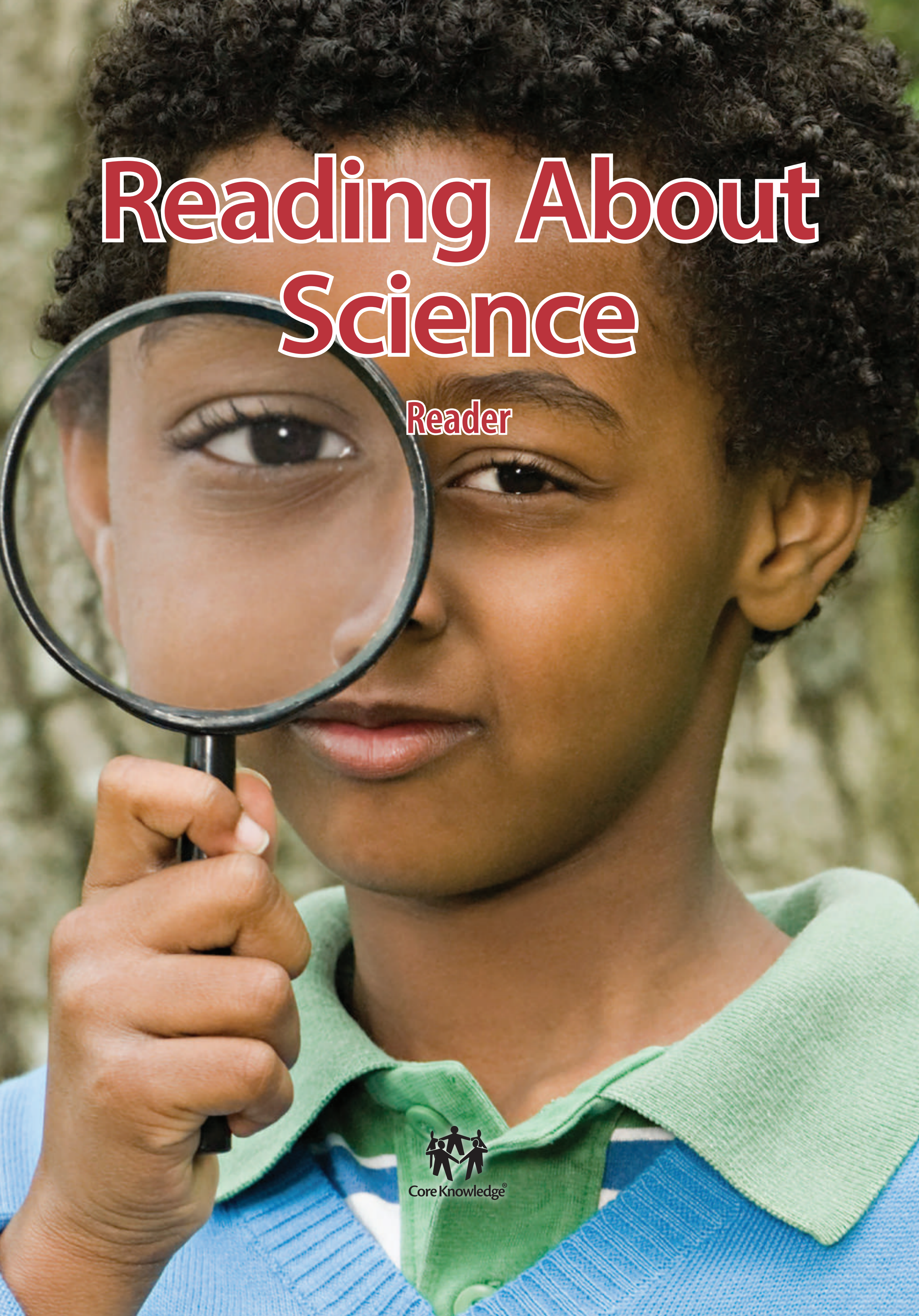

Core Knowledge®

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Reading About Science

Table of Contents

Is It Science?

Atlantic haddock

Chapter 1

This reading passage is a mock dialogue. A dialogue tells what different speakers say during a conversation. Reading a dialogue is like listening to a discussion. This dialogue does not quote a real conversation. It is lifelike fiction, written to help you learn about science ideas.

 **Host:** Welcome to today's meeting about rules for fishing in the Gulf of Maine. Haddock is one of the most abundant fish species in the region. Many people who are involved in this fishery are here today. Some are scientists. Others are fishery managers from the government. Some are fishers, dock workers, and fish sellers. And some of you are simply concerned citizens.

Our first speaker today is John D'Almeida. He operates the fishing vessel *Bluebird* out of Provincetown. John represents a fishing association from Cape Cod.

Words to Know

A *fishery* is an area where fish are raised for conservation or caught for business.

A *hearing* is a public meeting where people can tell their community leaders about issues that concern them.

Mr. D'Almeida: Thank you for that introduction. I have been a fisher all my life. My dad was a fisher, and so was his dad before him back on a small island off Portugal. I have probably been at sea for as many days as I've been on land. I don't have a college degree, and I don't remember much about my science classes in middle school or high school. But I know the sea, and I know fish. I believe I know fish and fishing better than the folks on the other side of the room who want to shut down our fisheries and change our way of life.

I will have a lot more to say later. But I'd like to start by saying that the ideas to cut the amount of haddock we can harvest from the Gulf of Maine are just plain wrong. I speak on behalf of most fishing families here as well as the seafood companies.

Mr. D'Almeida's crew member mends the net he uses to catch haddock and other fish from the Gulf of Maine.

Host: Thank you for your opening statement, Mr. D'Almeida. Next, we will hear an opening statement from Dr. Evan Cho. Dr. Cho is a senior scientist at the Marine Fisheries Service.

Dr. Cho: Good morning. On behalf of the Marine Fisheries Service, or MFS, I thank you all for coming to this hearing. I would like to explain what fisheries scientists like me do. I'd also like to talk a bit more broadly about what science is.

Science is a way of knowing, specifically knowing about nature. There are other ways of knowing. For example, John knows a lot about fishing and the sea from making a living as a harvester of wild fish populations. Wild fish populations—including Gulf of Maine haddock—are among our great natural resources. Sometimes John's work and the way fisheries scientists work is not that different. For example, he adjusts the type of net he uses to catch different fish. MFS experiments with nets, too. Here's a photo from one of our investigations of net mesh size.

Dr. Cho, continued: So, what makes John's work different from mine?

Scientists observe and collect data. We even collect data from John's boat and John's gear.

While John is focused on catching fish, an MFS at-sea observer is also on the boat. The observer records many things, such as:

- exactly what is caught,
- where it's caught,
- how deep the net was set,
- the time of day,
- how many minutes the net was towed across the seafloor,
- and many other data.

Virtually all the data recorded are quantitative, meaning they're based on something we can count or measure. Here's an example: *This haddock was 67 centimeters and weighed 2.2 kilograms, and a sample of its scales was taken.* Those are data. When you combine a bunch of data from lots of different fish, you generate other data, like the average length and weight of haddock caught in one tow of the net, or in one day, a year, and so on.

Dr. Cho's team samples the catch on a fishing boat.

Dr. Cho, continued: What do we do with all that data? We look for patterns. Maybe the data tell us fewer haddock are being caught despite steady fishing. Or maybe the data show that the average size of haddock has gotten smaller. Then we might draw the conclusion that the haddock population has declined. We could conclude that the haddock are being harvested faster than they can be replaced. That's when we start using the term *overfished*. If *more* haddock are being caught than in the past, then we could conclude that the population is doing well and is not overfished.

We follow the data, and we use what we have learned from many years of research to shape our conclusions.

Host: Thank you, Dr. Cho. I think Mr. D'Almeida would like a moment to respond. He's also asked me to project a new photo . . .

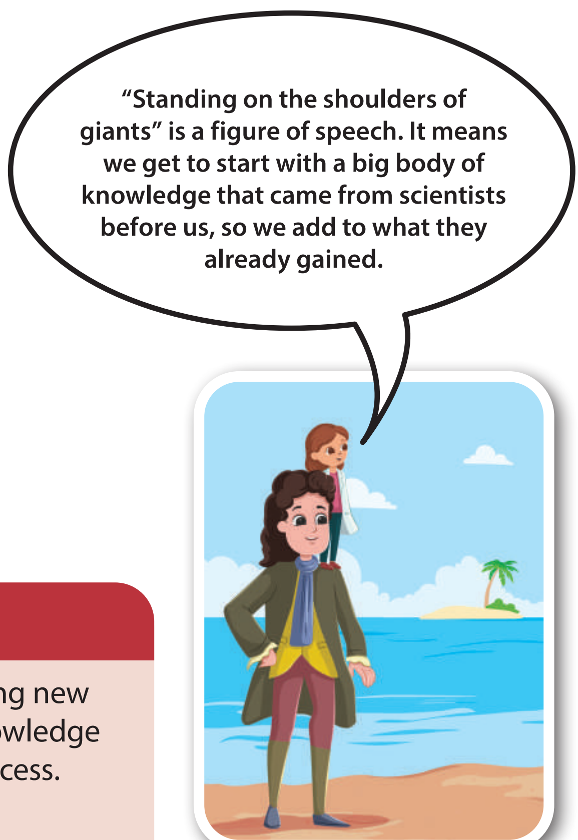
Mr. D'Almeida: I collect data, too, by taking notes about the fish we catch. I write down what we catch and where and when. And then I keep those data in my wheelhouse so I, too, can look for patterns in where the fish are. I don't see why Evan's data are better than mine.

A crew member works with a loaded net on the fishing vessel *Bluebird.*

Dr. Cho: John is one of the best fishers in the Gulf of Maine. There is no denying that! But I think what he just described as data is different from what science defines as data. John collects data about his catch and keeps those data mostly to himself. Those data are surely useful to him, but they are not useful to anyone else unless he decides to share them.

As fisheries scientists, we collect lots of data from many sources. We sort and organize data in different ways. We look at them from many angles, often with help from computers. Then we share our data in some way, such as in a scientific report.

Sharing data and communicating are essential. Working together as a scientific community helps humankind figure stuff out about nature. By sharing, scientists can test each other's work, argue about things—kind of like John and I probably will today—and keep building on what's been learned. In that way, we are all "standing on the shoulders of giants," as the physicist Isaac Newton once wrote.



Main Science Idea

Science is both a process for learning new information and a collection of knowledge obtained through a disciplined process. Scientists share what they learn.

Testing a Hypothesis

Chapter 2

Word to Know

A *hypothesis* is an explanation for an event in nature that is the basis for observation and experiment. It is a guess that can be tested.

Sunflower Growth in Two Soil Types

By Rachel Greene, Ms. Burke's Science Class

Introduction

My report is about my sunflower investigation. Sunflowers (*Helianthus annuus*) are cheerful, tall garden flowers. They are also important sources of seeds. The seeds are used as food for humans. They are used for birdseed, too. The seeds are also processed into cooking oil. Nearly 21 million tons of sunflower seeds are harvested every year. The sunflower is hardy. It can grow in different types of soil. My investigation was designed to test which type of soil is best.

In this investigation, I tested a hypothesis:

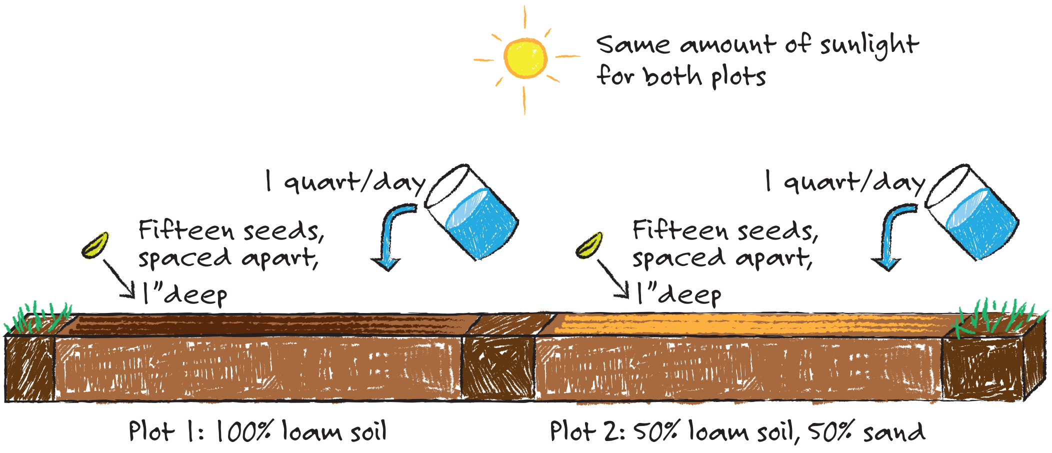
Sunflowers grow better in soil that is loamy and worse in soil that is sandy.

Methods and Materials

To test my hypothesis, I set up two square, three-foot plots of soil. Each one had a liner made of coconut husk. Each liner was placed in my family's backyard garden, so they had the same soil mix underneath them. The coconut husk liners allow water in and out as well as small soil organisms such as earthworms. The purpose of the liner was to help me put the exact same amount of test soil in each plot—one plot with loamy garden soil, the other with sandy soil.

In each plot, I planted 15 sunflower seeds from the same seed packet. Each seed was planted under one inch of soil. And each plot had the same total depth of soil: three inches. The seeds were spread out evenly across each three-foot plot.

At 7:00 each morning, I gave one quart of water to each plot. However, if it had rained overnight, or if rain was forecast for the day, I did not water the seeds. I did this for 22 consecutive days. I made observations and recorded measurements of sunflower plant growth from Day 15 through Day 22.



Assumptions

The design of my investigation was based on these facts:

- Sunflowers grow upward.
- Sunflowers bend toward a source of light, such as the sun.
- Sunflowers need water, air, and light to grow.
- Water moves downhill and sinks through soil until it can sink no farther.
- Loamy soil absorbs water better than sandy soil.
- The two plots received the same amount of sun.

Plants grow up and toward light.

Variable

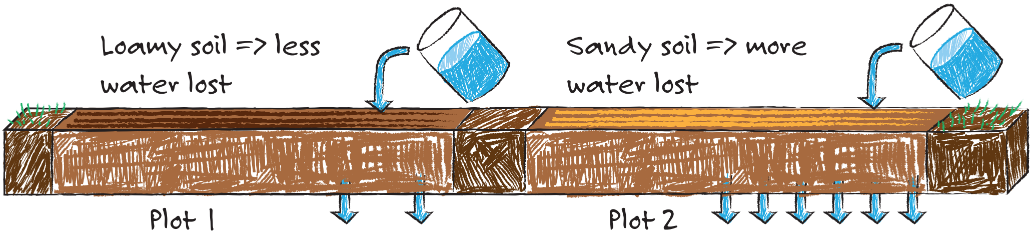
My two plots and their seeds were all kept under the same conditions: sun, air, water, temperature, organisms in the surrounding garden soil, coconut husk liners, and amount of soil.

Only one variable was different:

Plot 1 contained 100% loam soil.

Plot 2 contained 50% loam soil and 50% sand mixed together.

My theory that the loam soil would be better for sunflower growth was based on how quickly water tends to sink through sand versus loam. I thought Plot 2 would probably lose more water per day than Plot 1. I also thought that less water would mean fewer seeds would sprout or grow.



Observations and Results

For the first 15 days, I only noted if seeds had germinated, or sprouted. The seedling at the nearest end of a plot was called "1," the seedling at the far end was "15," and seedlings in between were named in a similar way. If a spot with a seed didn't produce a plant, it got an "N" for "no" in the table. After seedlings emerged and 15 days had passed, I recorded the seedling stem heights in centimeters.

These data tables summarize my observations.

Plants in Plot 1 (loamy soil)
12 of 15 seeds sprouted. Average plant height on Day 22: 18.8 cm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seed Sprouted?	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N
Stem Height on Day 15	5	4		4	4	6	5	5	5		4	5	5	4	
Day 16	6	5		5	5	7	7	7	6		6	6	6	5	
Day 17	7	7		7	7	8	8	9	8		8	8	7	7	
Day 18	9	8		9	8	10	10	11	10		10	10	9	10	
Day 19	12	10		11	10	12	12	13	12		12	12	12	12	
Day 20	14	13		13	12	14	14	15	13		15	14	15	14	
Day 21	16	15		14	14	16	16	17	15		17	16	18	17	
Day 22	21	19		17	17	18	19	19	19		18	18	21	20	

Plants in Plot 2 (sandy soil)
8 of 15 seeds sprouted. Average plant height on Day 22: 15.9 cm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Seed Sprouted?	Y	Y	N	Y	N	Y	Y	N	Y	N	N	Y	N	Y	N
Stem Height on Day 15	2	3		3		3	4		4			4		3	
Day 16	4	4		5		5	5		6			5		4	
Day 17	5	6		7		6	7		7			7		6	
Day 18	7	7		9		8	9		9			9		8	
Day 19	8	9		11		10	11		11			10		10	
Day 20	11	12		13		12	12		12			11		12	
Day 21	14	14		15		14	14		13			13		15	
Day 22	17	16		16		16	15		15			14		18	

Conclusions

Based on my investigation, loamy soil is better than sandy soil for both sunflower seed sprouting and growth. More seeds sprouted in Plot 1 than in Plot 2. The seedlings in Plot 1 also grew to taller heights overall than the seedlings in Plot 2.

These tests seem to show that my hypothesis was correct, but to test my hypothesis further, I would like to do more investigations based on this one. For example:

- My study could be repeated but with more plots and more seeds. This could help confirm my theory by having more data to analyze.
- Many of my seeds did not sprout at all, so I couldn't collect as much data about plant growth as I wanted. An investigation could focus more on plant growth rather than sprouting by starting with seedlings already sprouted in wet paper towels and plastic containers. Young plants of the same size can then be transplanted, half to sandy soil and the other half to loamy soil.

Main Science Idea

Testing ideas about how nature works helps us figure out things that are always true.

Science Tools

Chapter 3

Measurement and experimenting are important parts of science. You can measure some things with a ruler but not all things. Many investigations require more specialized equipment. This picture gallery features tools that are often used in scientific investigations.

Calipers measure relatively short distances very precisely. They are especially handy when you need to measure the length of something that isn't a flat, straight line. For example, you can use calipers to measure the size of an organism or part of it. Calipers often have two sets of jaws. One set of jaws is placed around the outside of the thing being measured.

Many calipers have a second set of jaws designed to measure inside a space, such as the width of the hole.

The simplest method of measuring straight distances is to use a ruler. These are usually sized to measure a foot (12 inches) or 30 centimeters or both. A meterstick is basically a large ruler designed to measure things that are one meter or less in size.

When a distance to be measured is not a straight line, a soft tape measure is a better tool than a ruler or meterstick. Another benefit of tape measures is that the flexible material allows them to be spooled up by a relatively small device.

Flasks are glass or plastic containers. They can be used to measure, mix, heat, and store fluids. Flasks often have marks for measuring the volume of a liquid. The wide base of the flask helps makes it stable on a table or lab bench.

A graduated cylinder is a glass or plastic container designed for measuring fluids more precisely. Graduated cylinders come in different sizes and have precise marks for measuring fluids by millimeter.

A balance is a type of scale that helps determine the mass of objects. It uses small metal weights with known masses to measure the unknown mass of something placed on the opposite pan. When the two sides balance, you can conclude that they have the same mass. You know they weigh the same.

A spring scale is a tool that measures the force of a pull. In this case, the pull is the force of gravity pulling the object down toward the ground. The pull stretches the spring and causes a metal pointer to move down along a marked scale. The scale could have marks for a measure of weight, such as pounds or kilograms, or a measure of force called newtons.

A hand lens is a small, portable, simple lens that magnifies images. The magnification power of a hand lens is not very great, but it can provide a closer look at something, such as a fossil in a piece of rock.

To see very small things in detail, a microscope is a better tool. Light microscopes can magnify subjects to appear up to one thousand times larger than actual size. You could never see the beautiful amoeba without a light microscope.

A telescope is a useful tool to get close-up looks at objects that are far away. Some telescopes are designed for seeing things that are meters or kilometers away. Others are used to view objects in space, such as the moon.

A tool for measuring temperature is called a thermometer. Some thermometers are placed outside to measure air temperature. Air temperature can range from below freezing to well above 100 degrees Fahrenheit. Other thermometers are designed to be placed in liquids or stuck into more-solid objects.

Sometimes you don't just want to measure temperature; you want to change it. A hot plate is a handy tool for increasing the temperature of a substance for an experiment. This is a way to heat things without using a flame.

There are many more science tools, as well. Can you think of any?

Main Science Idea

Many devices help with making observations and measurements in science.

Sneaker Testing

Chapter 4

Cedric and his childhood friend Elijah had a dream for many years. They wanted to become basketball sneaker designers. They spent hours sketching their own shoe designs. They even dissected used sneakers to see how they were made.

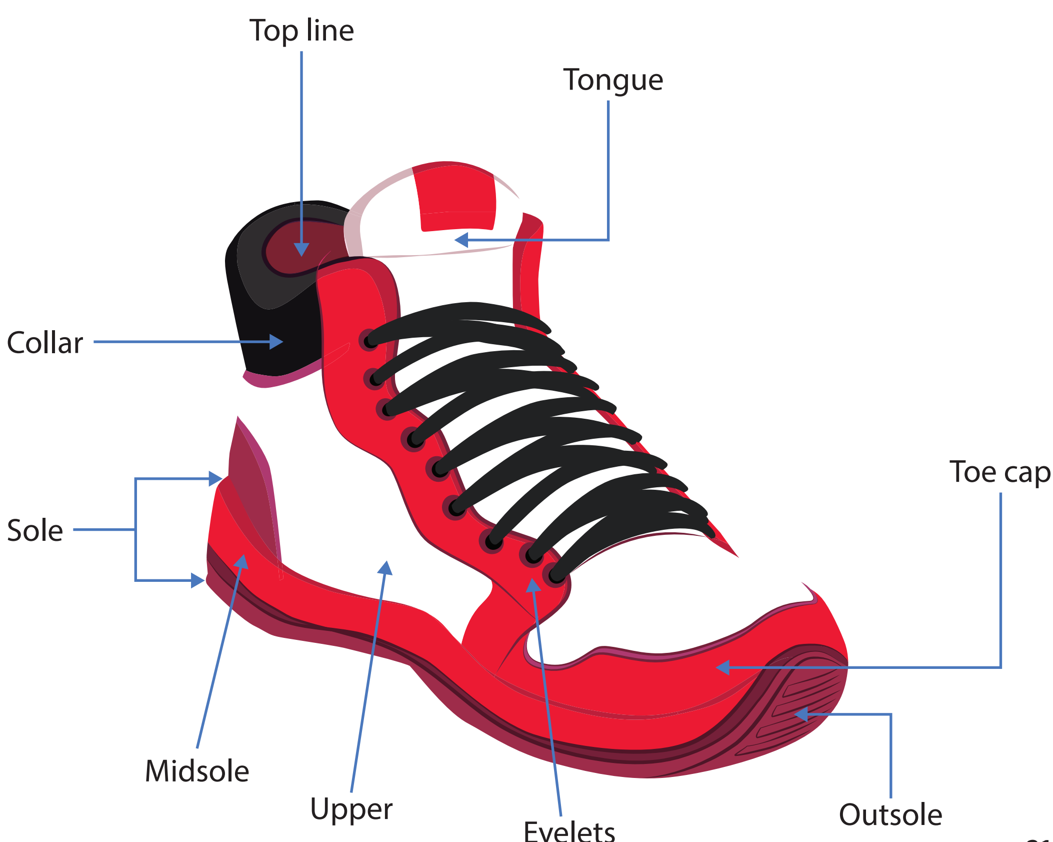
Toward the end of high school, they came up with a plan to make their dream come true. Cedric would study materials science in college, while Elijah would go to a design school. After earning their degrees, they would bring together what they learned and work as a team. Both graduated from college. Then they raised some money to begin developing new sneaker designs.

Now, they hope to invent new technologies to make high-performance sneakers that will give players an edge on the court.

Cedric and Elijah know there are lots of different ways to stitch materials together to make the "upper" of a shoe. The upper is the part that covers the top of the foot and secures the shoe to the foot and ankle. They know that the colors and look of the upper could make their shoe a hit or a flop.

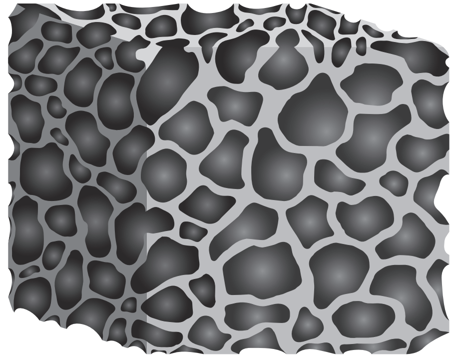
Elijah's training as a designer is most useful in designing the upper. And to really make their mark on the high-money industry of basketball sneakers, Cedric focuses on the sole.

- The outsole needs to be very durable and "grippy" to help basketball players run, jump, and change direction on a basketball court.
- The insole, which is a removable part that sits directly under the foot, must be comfortable and formfitting.
- The midsole needs to offer some cushioning, especially in the heel.

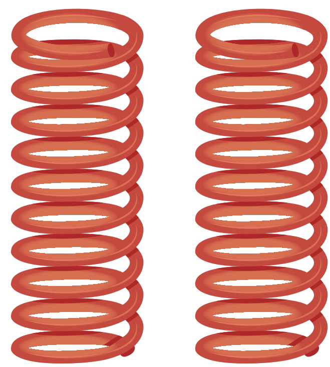


Cedric and Elijah think they can make a name for themselves by developing a midsole that gives basketball players extra bounce. Instead of a cushioning midsole that just absorbs force, they want to make a midsole that acts more like a trampoline.

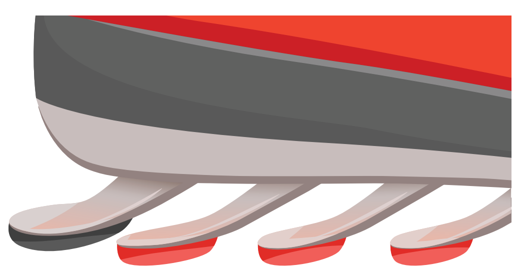
Cedric has experience working with different foams that compress and then bounce back. He has also experimented with coiled springs made of metal or carbon fiber and leaf springs made of plastic. He and Elijah have agreed to experiment with these three technologies.



Foam technology



Coiled spring technology



Leaf spring technology

By focusing only on the performance of the three midsole technologies, they can test just one variable at a time.

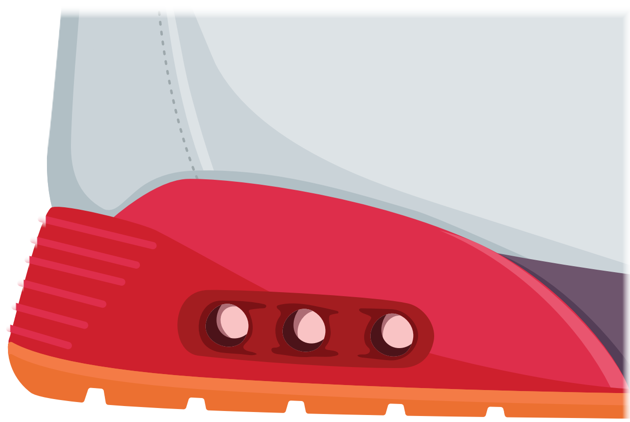
To compare their midsole options to what's currently available in sneakers, they buy two popular basketball shoes and take the soles off.

One sole has a midsole with a plastic bubble full of air. The other has a midsole of simply spongy foam. Together, these two midsoles will be the controls. The ability of the controls to provide bounce will be compared to Cedric's three midsole models. If Cedric and Elijah find that any of their midsoles perform better than the controls, then they will know they are onto something new.

Words to Know

A *variable* is a detail that is changed or changes in an investigation to see what happens.

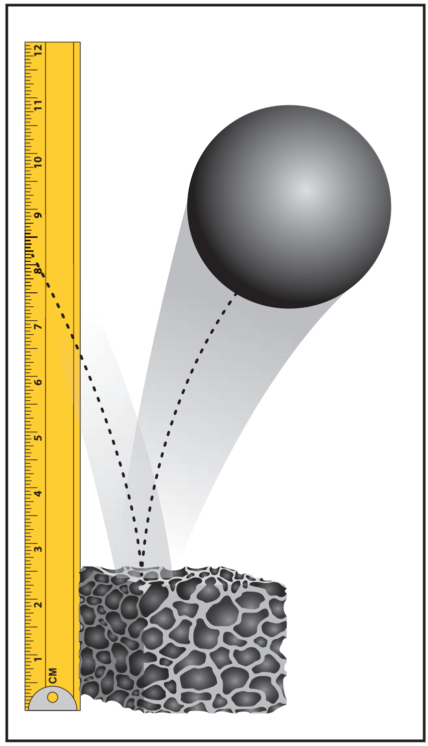
A *control* is a group or individual in an investigation for which nothing is changed. The control is used for comparison.



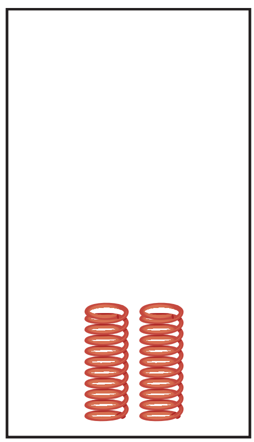
Air bubble midsole

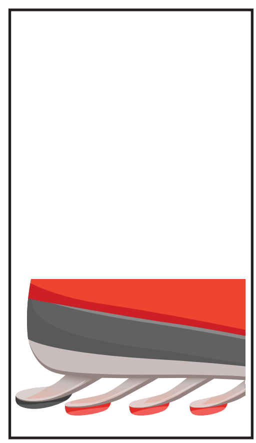
Spongy foam midsole

Later, people will test the prototypes of basketball shoes that Cedric and Elijah make. But for their early experiment, they need to use a test subject that only reveals clear data without opinions or feelings. So, instead of asking people to jump up and down on each of the five midsole models, they use a five-pound metal ball.

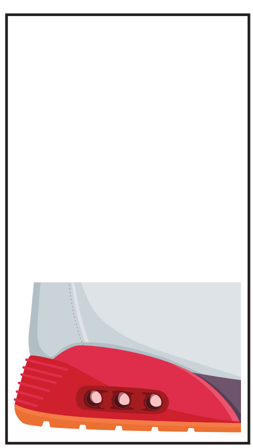


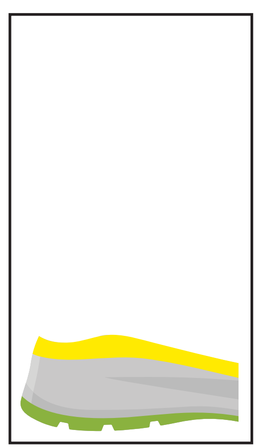
Cedric and Elijah test five midsoles: three of their own design, the air bubble midsole, and the spongy foam midsole.





They drop the ball from a height of three feet onto each of the five midsoles. A meterstick is mounted on the wall behind the midsoles. They record it all with a digital video camera. The video computer program lets them slow down the video and measure exactly how high the metal ball bounces up from each midsole.

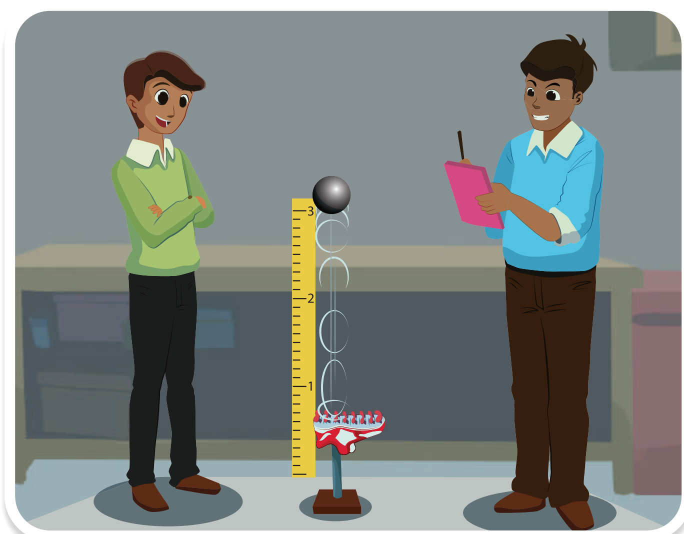




Cedric and Elijah test each sole fifty times. They calculate the average bounce height of the metal ball for each midsole model. Their findings are in the table below.

Midsole		Average Bounce Height (cm)
Control group	EVA foam	9
	Plastic air bubble	9.5
Experimental group	"Cedrijah"-foam	12
	Coil springs	11
	Leaf spring	15

The young shoe designers are excited! Why? Because it looks like all three of their midsole options provide more bounce than the types already on the market. Their next investigation will use heavier balls to see how well the midsoles hold up in tests for weights that are closer to what human beings weigh. In that case, the variables will be the three different midsoles, but they would require multiple tests using different weights.



Main Science Idea

In a scientific test, changing a variable and looking for different outcomes can help answer a question. But only one variable at a time should be studied.

Many a Model

Chapter 5

In Los Angeles, California, at the Griffith Observatory, visitors can walk around the grounds and see a scale model of the solar system. At the center of the model is a half-inch sun. The orbits of the inner planets are marked in bronze. These orbits are set within a few steps of the sun. The bronze bands marking the orbits of the outer planets are farther out. Uranus's orbit overlaps with the observatory building. So does Neptune's. The orbit of Pluto, which may or may not be a planet, is so wide and oval-shaped that it runs off into the sandy hillside around the observatory.

Models are helpful for understanding things that are very large or small. The solar system is an example. The solar system is too large to see directly. A smaller model of it makes it easier to visualize.

As scale models go, the Griffith's model is actually very big. But the actual solar system it is about 110 billion times larger!

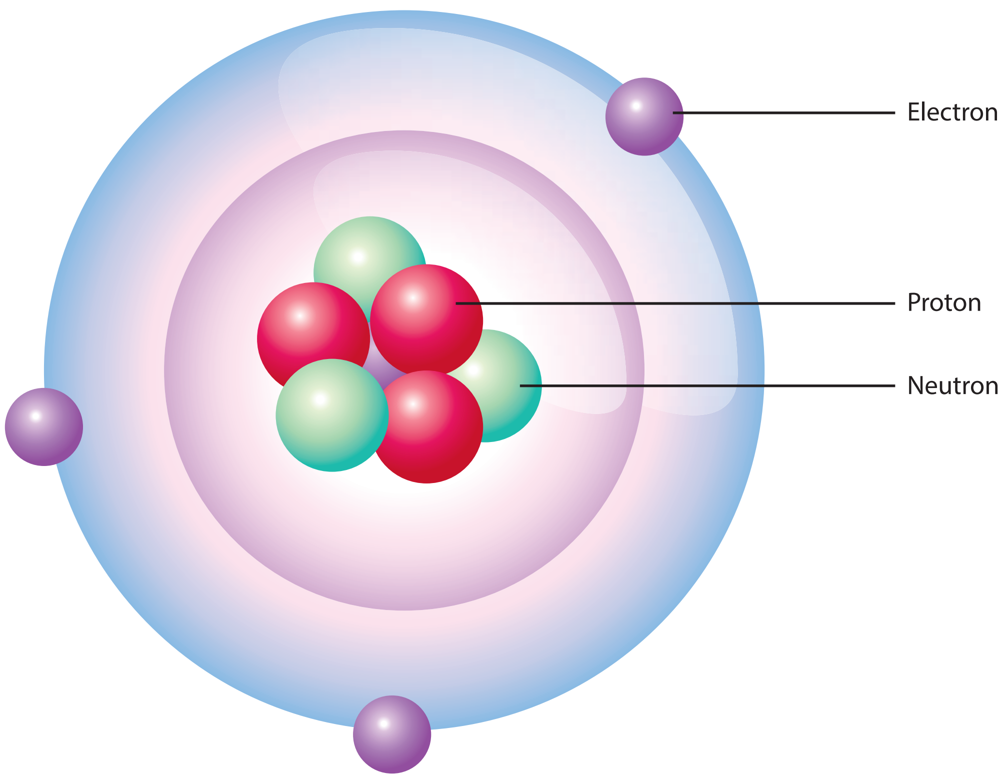
Word to Know

To *visualize* something means to imagine what it looks like.

Twelve inches on the grounds of the Griffith Observatory's solar system model represents twenty million miles of space!

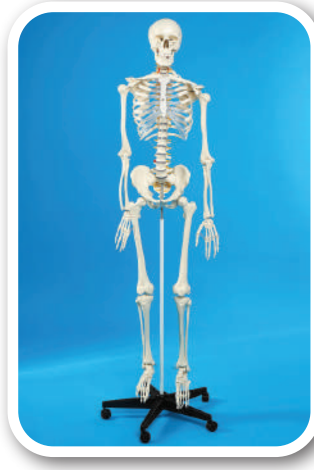
Models of very tiny things can also come in handy. Atoms are very tiny particles that make up all matter. It's impossible to see these particles with your own eyes. So, scientists have developed models to imagine them. These particle models can be pictures like this one, or they can be built as objects you can handle.

Atom Model



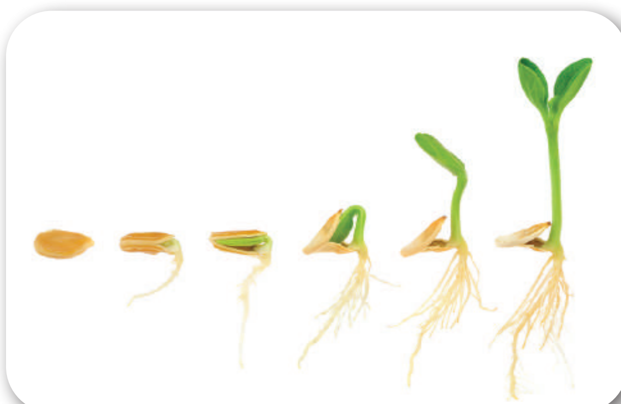
This model helps us imagine what a tiny particle of matter is made of. It looks a little bit like the planets orbiting the sun in the model on the previous pages. In actual atoms, the outer parts called electrons would be much farther from the middle part than they appear here, and none of the particles would have colors. Also, electrons don't move around the center in neat orbits like planets do. Their behavior is much more complicated than that.

Models can help us understand living things. Some models of living things help us understand the inside parts that we can't see. For example, a model of a human skeleton shows the different bones that make up the body.



This model shows a baby sea turtle developing inside its egg before it has grown enough to hatch.

A series of pictures models the process of a plant sprouting.



A model of a dinosaur skeleton helps us know how that animal was shaped and how it moved.

Models are also useful for understanding processes or events. For example, you can shape a mound of dirt or clay with a crater at the top to model a volcano. You can use basic household ingredients to model the eruption of a volcano, too!

Make a Model Volcano

Ingredients:

- modeling clay, dirt, or cake mix
- spoon
- baking soda
- white vinegar
- red food coloring
- baking dish
- measuring spoon
- cup

Steps:

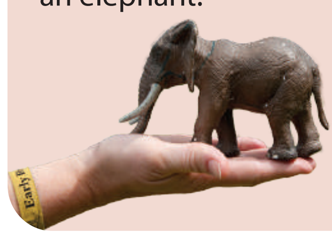
1. Shape damp soil or modeling clay into a volcano shape. Alternatively, bake a chocolate cake in the shape of a volcano. Set up the volcano on a baking dish or sheet with a lip.
2. Use a spoon or other tools to dig a crater about four inches deep at the top of the model volcano.
3. Pour about six tablespoons of baking soda into the crater.
4. In a bottle or flask, mix a cup of white vinegar with a teaspoon of red food coloring.
5. When ready for the eruption, carefully pour the colored vinegar into the crater, and stand back.

Models don't always have to represent an object or process exactly. The numbered steps printed here are also a model. The sentences model the process of building the physical volcano model.

The vinegar and baking soda foam up and pour over the edges of the volcano crater. It models the way lava flows out of a volcano crater.

Word to Know

A *scale model* is one that shows all the parts of a thing either the same amount bigger or the same amount smaller than the real thing. Here's a miniature scale model of an elephant.



Main Science Idea

A model is a representation of an object, idea, or process. Models can help us understand things that are too large or too small to be seen. Models can also help us understand processes.

Nailed It!

Chapter 6

The Griffin Tool Company makes hammers with wood handles and heads of high-carbon steel. Each hammer must meet the following criteria:

- The hammer's head must weigh enough to drive nails into wood. But it can't be so heavy that the hammer is difficult to use.
- The handle must be narrow enough to grip easily. But it must still be strong enough to withstand the head striking nails hundreds or thousands of times a day. The wood must be very durable.

Each Griffin hammer goes through the following inspection test:

- Five different people take turns swinging the same hammer.
- They hit fifteen nails of three different sizes.
- They drive the nails into similar pine logs.

Each hammer goes through about 375 test strikes before the company decides the wooden handle and steel head are worthy of being sold. If a hammer doesn't pass the test, they don't sell it.

Phil Fried is a blacksmith, a person who forges objects out of metal. Blacksmiths are very good at swinging hammers. Like the Griffin Tool Company, Phil also makes hammers. When he's making a hammer, he thinks about the same criteria that a good hammer must meet. He also tries to make his hammers look like works of art. They have polished steel heads, handles with beautiful wood grain, and handcrafted leather grips. However, Phil works by himself, which constrains how much time he can spend testing his hammers. When he thinks a hammer is done, he tests it on just one type of nail, and he is the only tester. He can't afford to buy lots of wood for hammer testing, either. So, he drives the nail into the same old tree trunk that he's had in his shop for years.

Phil Fried's hammers sell for three times what a Griffin hammer sells for, yet in online reviews, many more people complain that Phil's hammer handles tend to break after just a few weeks of use or that his hammers' heads are too heavy.

The case of the two hammer makers and the way their products are tested is an example of how experiments or trials can be done well . . . and not so well.

By using multiple testers, the Griffin Tool Company includes variables that imitate what happens in the real world when lots of different people use hammers. Not everyone who buys and uses a hammer is a professional.

The Griffin approach to hammer testing also involves different types of nails and many different swings of each hammer. All these factors mean each hammer goes through several hundred trials. Multiple trials are a feature of a good experiment and the development of a product. The more something is tested, the more chances there are for flaws to be found. Conducting multiple trials also helps people confirm what someone else may have already done or discovered.

If a hammer maker tests hammers with only strong testers, they might not realize that the hammer is too heavy for the average person to use.

If a hammer isn't tested on lots of nails, it might be hard to figure out if the hammer has the right weight to be used many times a day on a variety of nails.

Tests and experiments can also be made stronger by making some part of the process blind. This means the testers do not know information about the thing being tested. For example, if someone is comparing the Griffin hammer with one made by Phil Fried, along with several hammers made by other companies, it is best if the tester does not know who made which hammer. Knowing the maker of each hammer might affect the way the tester uses it. And that can affect the test results.

This tester doesn't know who made which hammer because the labels are covered with tape. This will help him give unbiased opinions about the hammers. If the tester has heard about Phil Fried's hammers for years and knows he is swinging a Phil Fried hammer, he might say that hammer feels better or strikes nails better, despite how it performs.

Imagine you need to test a new type of clothespin. Its design is like the type that's been around for a long time—two pieces of wood held together with a wire clip. The wire acts as a spring, giving the clothespin its pinching power. The new pin design features a toothlike texture where the clothespin "bites" the clothing.

Here is an experimental design you could follow to test the new design and compare it with the old design:

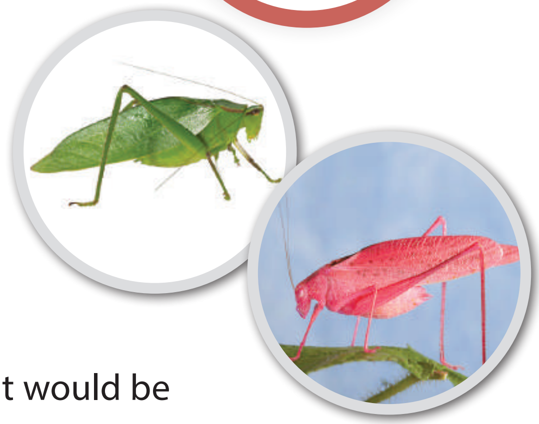
1. Gather two T-shirts of identical size and weight. Use two of each type of clothespin.
2. Label the new clothespin as the variable. The older version is the control.
3. Wet the shirts, and wring out most of the water. Make sure the shirts still have the same weight.
4. Hang one shirt on a clothesline with the variable (new) pins. Hang the other shirt with the control (traditional) pins. Make sure the shirts are hung in the same way.
5. Record video of the shirts as they dry. Review the video to see whether either pair of clothespins did a better job holding the shirt on the line.
6. Repeat the same test multiple times, and record your observations.
7. Test both pins again under different real-world conditions, such as on a windier day or using heavier items, such as wet beach towels.

Main Science Idea

Testing and investigations use an organized process. Repeating the process helps the results be more trustworthy.

How Much Data?

Chapter 7



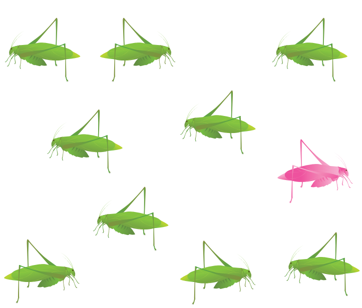
Here's a way to think about data and data collection. Traits vary within populations. Oblong-winged katydids vary in color. Most are green, but a few are bright pink. You wonder, "What percentage of katydids are pink?"

How could you answer this question? It would be difficult to observe each and every katydid in the United States. There are probably millions!

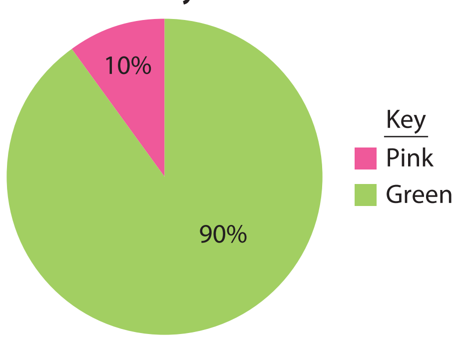
The next best thing is to gather data from a smaller sample in the field. Perhaps you count how many there are in one square meter. You then can use data from your sample to infer something about the entire katydid population being studied.

You collect a sample of ten katydids in one square meter and record their colors. You get the data shown.

Katydid Sample

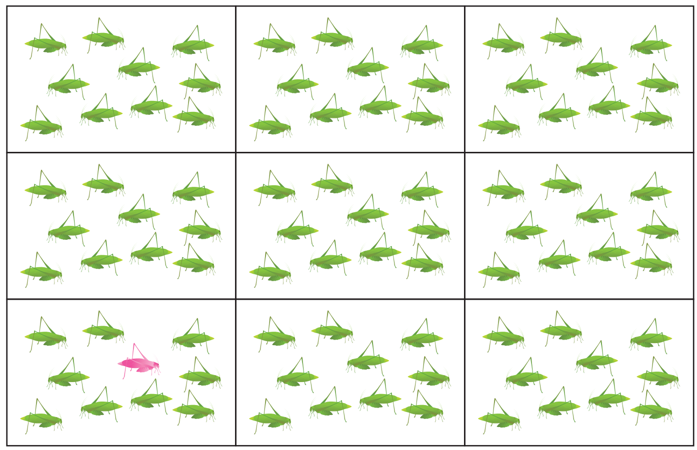


Katydid Colors



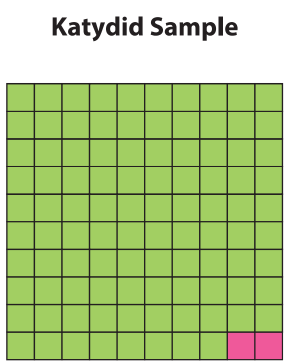
Then, you draw a conclusion: 10 percent of katydids in the field are pink.

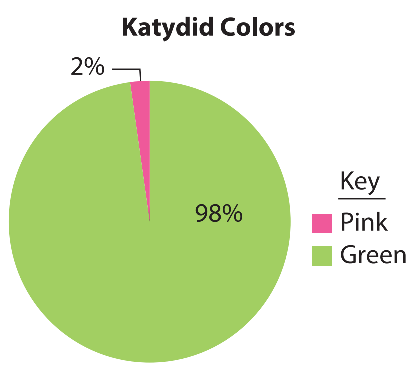
But is this answer reliable? *Reliable* means that the data give you about the same answer each time. But the size of your data set is too small to be certain. Maybe you just happened to be lucky when you found that one pink katydid. Or maybe there were more pink katydids, but you didn't see them.



So, you ask nine of your friends to collect data. They each collect ten katydids, each from one square meter. They get the results shown.

Did your first single data set of ten katydids give you a reliable answer? It did not. You needed a larger data set to get a more reliable answer. You get better information by combining *all* the data you and your friends collected, making a bigger data set of 100.





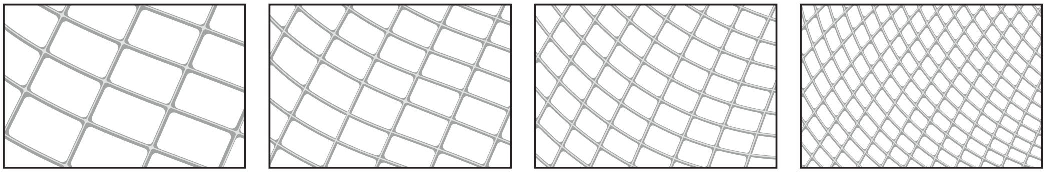
This data set tells you that 2 percent of katydids are pink. Because the data set is bigger, this answer is more reliable. You can't know the exact numbers, but you can be *more certain* that close to 2 percent of katydids in the population are pink.

Here's another data story. This one is about collecting data correctly.

Last year, your school's vegetable garden had some trouble. The leaves of the onion plants were floppy and brownish. Some of the onions didn't grow at all!

The problem was caused by the onion fly. A fly that eats onions? Yes, but only when it is a larva. Adult flies lay eggs on the onion's leaves. When the eggs hatch, the larvae (called maggots) burrow into the onion and feed on it. This makes the plant sick.

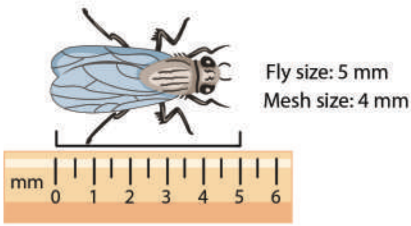
To keep the flies from laying their eggs on the onions, your class will cover the plants with mesh netting. First, you must choose the right size mesh! If the openings are too big, the flies will be able to fit through it. But mesh with smaller openings is heavier and traps more heat. The openings should be small enough to keep out the flies but no smaller.



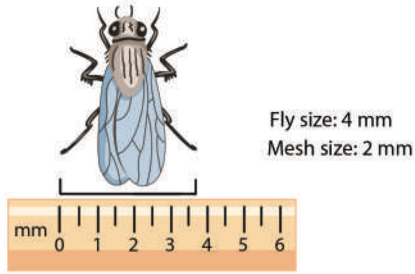
4 mm **2 mm** **1 mm** **1/4 mm**

Your classmates catch some adult onion flies. Carefully measuring the flies will help them choose the best mesh netting. They should measure the width of each fly's body, from one side of the wings to the other. Four students each measured a fly and recorded their results. Which student's data do you agree with? Did they measure carefully?

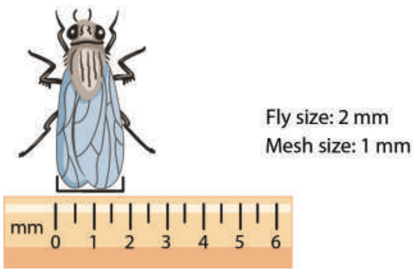
Student A



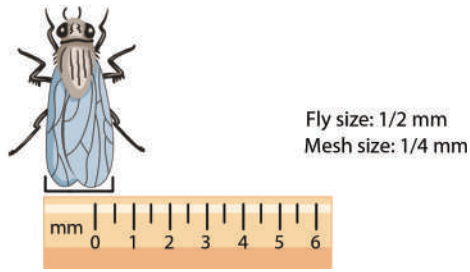
Student B



Student C

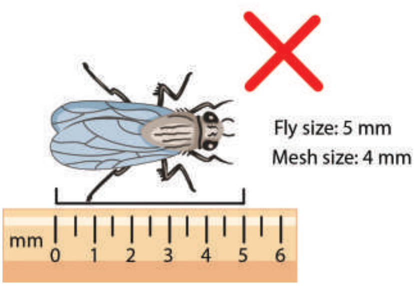


Student D

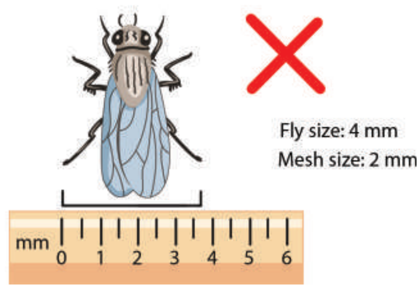


Student A measured the length of the fly instead of the width. Student B measured the width across the fly's legs, not across its wings. Both students chose a mesh size that is too big.

Student A

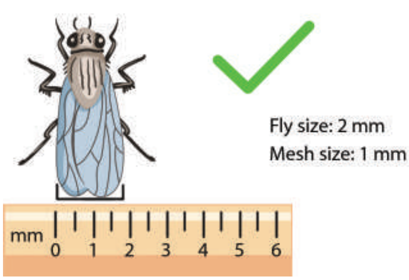


Student B

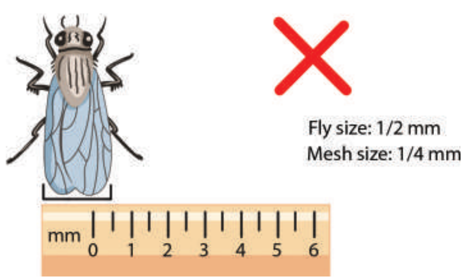


Student D measured from side to side across the wings. This is correct, but it should be measured from the zero mark instead of the end of the ruler. Student D chose a mesh size that is too small.

Student C



Student D



Only Student C measured correctly. By measuring carefully, you can get more helpful information. This can help you to make better choices!

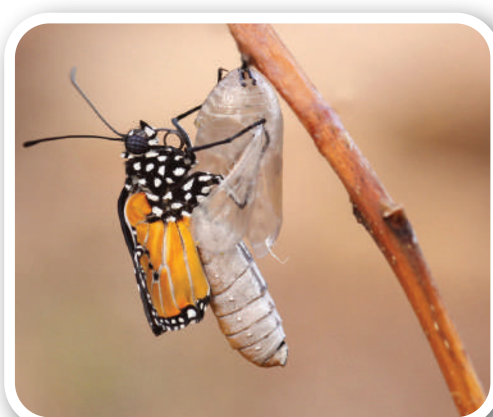
Here's one more example to help you think about data.

Spring arrives, and leaves start to bud in your school's garden. You notice small caterpillars munching on the leaves of some of the plants. It's only a matter of time until they transform into butterflies.

You wonder *how much* time. You ask, "How long does the pupa stage of a butterfly last?"

To find out, you set up a tank with a caterpillar and some plants. You observe it every day. Finally, it starts to form a pupa. You record what it looks like.

Fourteen days later, the adult butterfly emerges from the pupa. You conclude, "The pupa stage of an this butterfly lasts fourteen days."



You share this news with a friend . . . who disagrees! Your friend did the same experiment last year and came to a different conclusion. The pupa stage lasted only six days!

You and your friend did the same investigation but got different answers. What would happen if you each did the same experiment again?

You each agree to repeat the investigation four more times. Each repeated investigation is called a trial. Your data from all five trials are shown in the table.

You		Your Friend	
Trial	**Days**	**Trial**	**Days**
1	14	1	6
2	8	2	10
3	7	3	13
4	10	4	9
5	11	5	12
Average:	**10**	**Average:**	**10**

Notice that your data are more similar to your friend's in this bigger collection. For both of you, the average length of the pupa stage is ten days. The pupa stage is never shorter than six days or longer than fourteen days.

When you repeat an investigation multiple times, you get data that is more reliable. You can be more and more certain that it will give you the same answer. You both conclude, "The pupa stage of this type of butterfly lasts, on average, ten days."

Main Science Idea

More data, and data collected carefully, provide better information in science.

About to Exactly

Chapter 8

Sizes and amounts can be difficult to determine exactly. But, you can describe by estimating.

When you estimate, you carefully guess how much or how many. Estimating uses your five senses. You don't need any tools to estimate.

Quantity

When people estimate, they often choose a round number, or a number that ends in zero.

Height

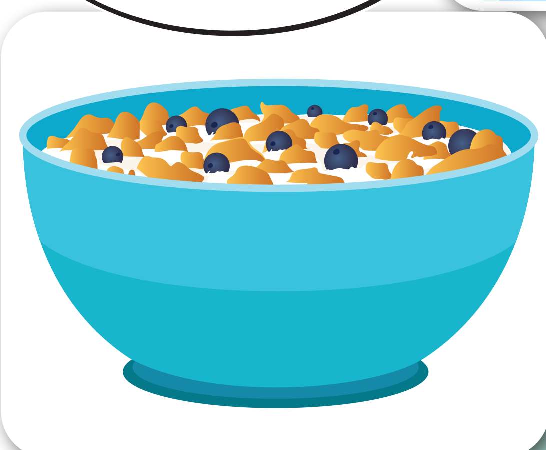
You can estimate by comparing something to a measurement that you already know.

Temperature

Know some common measurements to help you estimate. Room temperature is about 70°F. The inside of a refrigerator is about 40°F.

Weight

You can estimate weight by comparing something to things you know.



Volume

The volume of cereal and milk in the bowl is about the same as a large bottle of water.

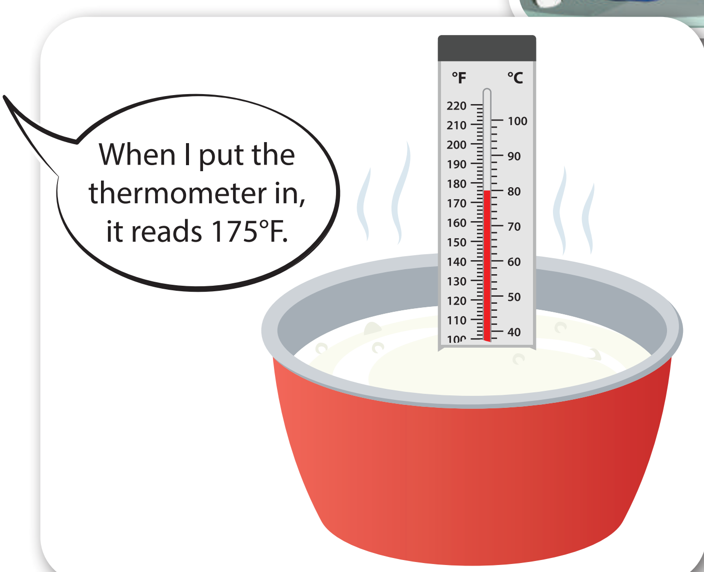
Time

Pay attention to how long it takes you to do everyday activities. It will help you estimate time.

Measuring is not estimating. When you measure, you find an exact number. Measuring uses tools as well as your senses.

Quantity

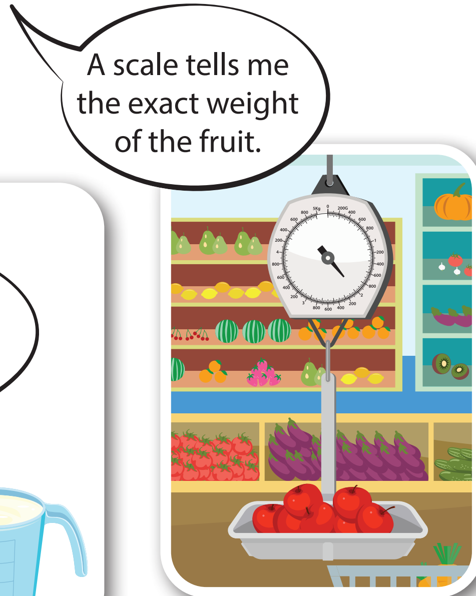
Height

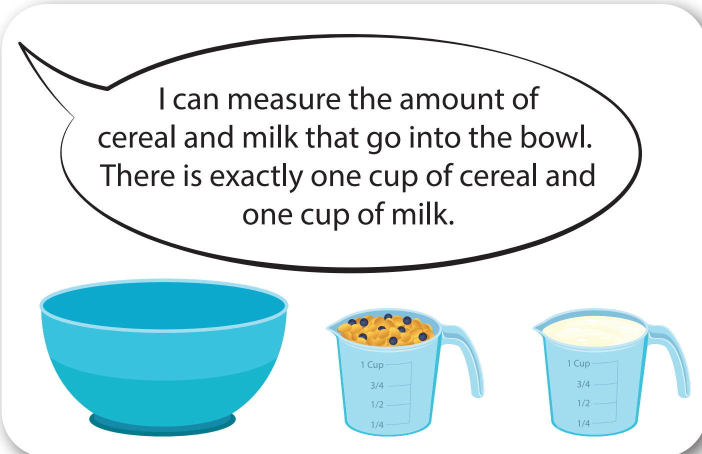


Temperature

Thermometers can measure in degrees Fahrenheit (ºF) or degrees Celsius (ºC).

Weight





Volume

Measuring cups measure volume, or the amount of space things take up.

Time

A clock or stopwatch helps you measure time.

Main Science Idea

Sizes and quantities of things can be loosely described or estimated, or they can be counted or measured precisely.

Relationships

Chapter 9

A dialogue is a conversation between two people. This is a dialogue between a student named Prentis and his teacher, Ms. Sophos.

Prentis: Change?

Ms. Sophos: Yes. If two things are related, a scientist may mean that one changes along with the other.

Prentis: What kinds of things?

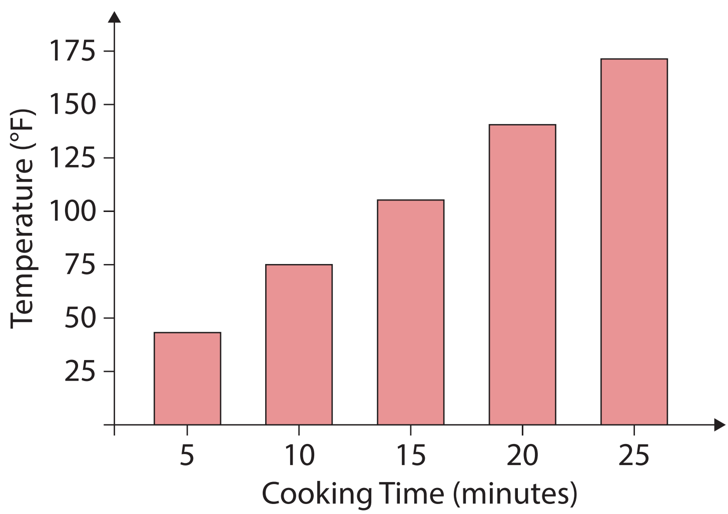
Ms. Sophos: Anything that can be counted or measured. It could be temperature, time, size, how many of something there are, or how often something happens.

Prentis: But the idea is things change *together*?

Ms. Sophos: Yep. I have a handy example. Say I'm cooking strawberries to make jam. I heat the pot and measure the temperature. What two things are both going up, or increasing?

Prentis: Well, time is passing, so the amount of cooking time is increasing. And temperature is changing, too. So, there is a relationship between cooking time and the temperature of the strawberries.

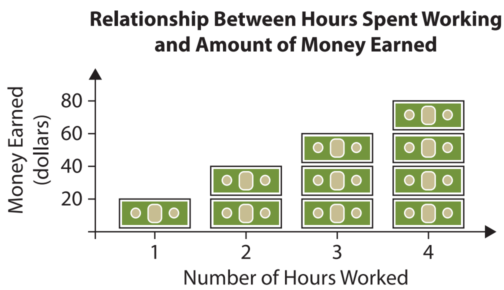
Relationship Between Cooking Time and the Temperature of Strawberry Jam

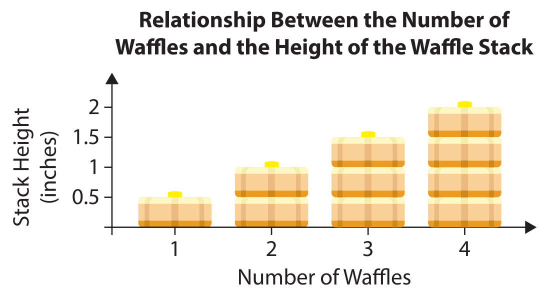


Ms. Sophos: Right. So, time and temperature are changing together. As cooking *time* increases, *temperature* also increases!

Prentis: That's what the graph is showing. The relationship between *time* and *temperature.*

Ms. Sophos: Let's think about other examples that are like that.





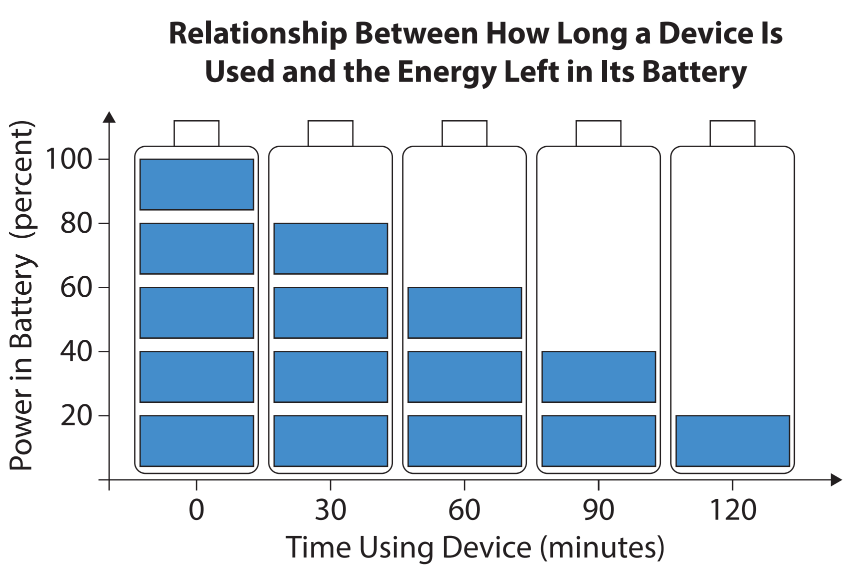
Ms. Sophos: But that isn't the only kind of relationship. Two things can also change in *opposite* ways.

Prentis: Does that mean one goes up while the other goes down?

Ms. Sophos: Exactly.

Prentis: That makes sense. Using a device takes energy. The more it's used, the less energy is left in the battery.

Ms. Sophos: Good thinking. One thing is the cause; the other is the effect. Noticing relationships can help us figure out explanations.

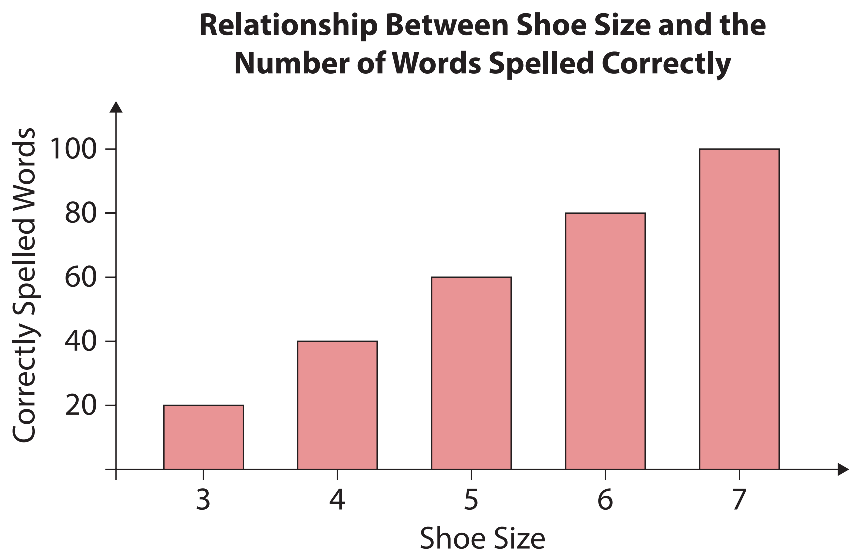


Prentis: So, if two things change together, that means that one thing is *causing* the other to change, right?

Ms. Sophos: Maybe. But maybe not.

Prentis: How could it *not*?

Ms. Sophos: Let's look at an example.



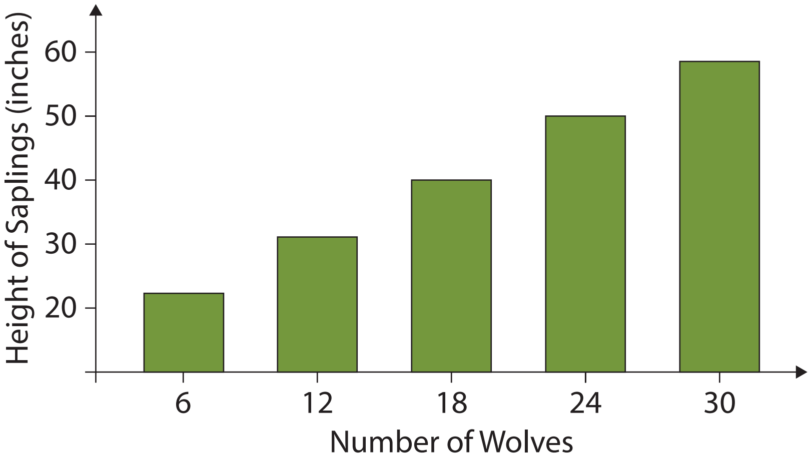
Prentis: Why would these things be related? Bigger feet don't make me a better speller.

Ms. Sophos: No, but maybe *something else* causes both to change.

Prentis: I know! *Time!* As kids get older, their feet get bigger. And the older they are, the more time they've spent in school. So, they learned how to spell more words!

Ms. Sophos: Exactly! Let's look at another relationship and try to figure out an explanation for it.

Relationship Between Number of Wolves and Sapling Height in Edge Nature Preserve



Prentis: Why would the saplings get bigger when there are more wolves around?

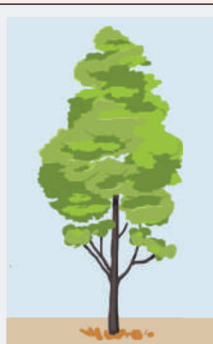
Ms. Sophos: We need to know a little more to figure it out. Let's look at more evidence.

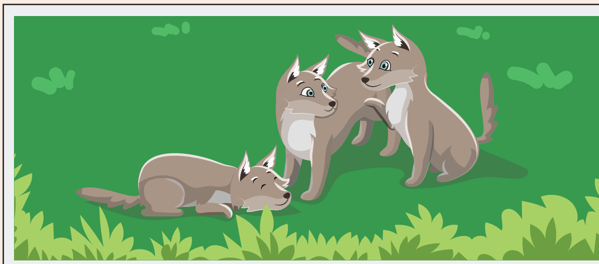
Bulletin of the

Rosalie Barrow Edge Nature Preserve

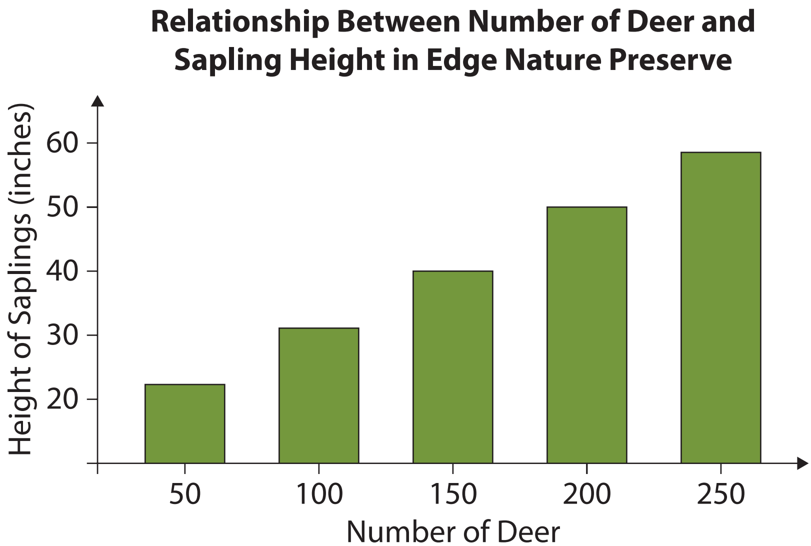
Aspen trees are an important part of the Edge ecosystem. But deer can damage the young saplings. Deer like to eat the tender leaves of young trees.

Because saplings are short, they are just the right height for deer.





Wolves are doing better at Edge! Recently, a wolf pack added three cubs, bringing its size up to twelve. Please send us your ideas for names!



Prentis: As the number of deer *increases*, the sapling height *decreases*. Deer eat plants, so that explains why having more deer around causes the saplings to be shorter.

Ms. Sophos: Yes. The deer are munching on them before they can get very tall.

Prentis: Wolves hunt deer. So, it makes sense that more wolves lead to fewer deer. They're eating them!

Ms. Sophos: Or just scaring them away. Now, can you put it all together?

Prentis: I think so. Wolves scare away or eat the deer. Fewer deer eat the tops of the saplings. So, the saplings can grow taller!

Ms. Sophos: You looked at evidence and explained the relationship!

Main Science Idea

When two things are related, it means there is some sort of connection between them. Close observation can help us figure out the nature of the relationship.

Believing Versus Knowing

Chapter 10

Broccoli: Love It or Hate It?

People have strong opinions about it. “Broccoli tastes wonderful” is an opinion. An opinion is a feeling or belief about something. You might love broccoli, but your cousin might not like it.

Broccoli: Green or Red?

Looking at broccoli tells you that it is green and not red. “Broccoli is green” is a fact. A fact is a statement that can be verified.

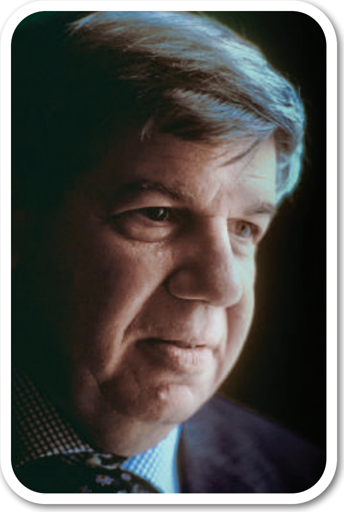
To verify means to use evidence to tell whether something is true or false. You can verify a fact by observing or measuring. If you look at broccoli, you can observe that it is green. Others who look at broccoli will observe the same thing.

If you believe that broccoli tastes great, nothing will change how it tastes *to you*. There is no such thing as a true opinion or a false opinion. It is important to be able to tell facts from opinions. When you read, you will come across both. People have all sorts of opinions, but they don't *always* have their facts right.

But not everything is either a fact or an opinion. Sometimes, you might get a hunch about something. For example, you might have a hunch that your little sister ate most of the jellybeans. Is this an opinion or a fact?

A hunch is a little bit like an opinion. It is based on a feeling or a guess. A hunch is a little bit like a fact, too. You can figure out whether a hunch is true or false. You do this by looking at evidence. You can see that most of the jellybeans are gone, but you need to verify who ate them!

Read the biography on the next page. As you read, try to spot opinions, facts, and hunches.



Remembering Stephen J. Gould

Stephen J. Gould was a scientist who studied how life on Earth changed over time. Gould was born in New York City on September 10, 1941. As a child, he loved exploring nature. His favorite animals were dinosaurs, and he wanted to know all about them.

He remembers visiting the American Museum of Natural History. A huge skeleton of a *T. rex* stood in the lobby. It was awesome and a little scary! Gould decided right then that he would study dinosaurs.

He went to college to study paleontology. Paleontology is the study of fossils. Palentologists learn how living things and their environments have changed. They thought that living things are always slowly changing. However, there was a problem: fossils don't change at a steady rate.

Gould had a new idea: For very long periods, organisms change very little, but there are also short periods when they change a whole lot.

Gould tested his idea by comparing fossils of snail shells. He found that they changed slowly sometimes and quickly at other times.

At first, some scientists hated this new idea. It was very different from what they had been taught. Eventually, they began to accept it.

Gould wrote books and articles that made science easy for people to understand. He wanted to share the things he studied with people who weren't scientists. He also loved baseball and wrote about it, too. Gould won awards for both his work in science and his writing.

Stephen J. Gould passed away on May 20, 2002. It was a great loss for the world. Even though he is gone, his work lives on. Many people are inspired by the things he wrote.

Did you find facts, opinions, and a hunch in the biography of Stephen J. Gould? Let's review!

> Stephen J. Gould was a scientist who studied how life on Earth changed over time. Gould was born in New York City on September 10, 1941. As a child, he loved exploring nature. His favorite animals were dinosaurs, and he wanted to know all about them.

Who Stephen J. Gould was and when he was born are **facts**. They can be verified. Gould's love of nature and dinosaurs are his **opinions**. They are his feelings.

> He remembers visiting the American Museum of Natural History. A huge skeleton of a *T. rex* stood in the lobby. It was awesome and a little scary! Gould decided right then that he would study dinosaurs.

It is a **fact** that the museum had a *T. rex* skeleton. It is his **opinion** that the *T. rex* was awesome and scary. Others might not agree.

> He went to college to study paleontology. Paleontology is the study of fossils. Paleontologists learn how living things and their environments have changed. They thought that living things are always slowly changing.

A science idea is only a fact if it can be verified. The idea that living things are always slowly changing is a **hunch**, or a guess that can be verified.

> However, there was a problem: fossils don't change at a steady rate.

No matter how people *think* fossils should change, it is a **fact** that they don't change at a steady rate. This can be verified by observing fossils.

> Gould had a new idea: For very long periods, organisms change very little. There are also short periods when they change a whole lot.

This idea sounds like another **hunch**. The next paragraph states that Gould verified his idea by looking at evidence. These are **facts**.

> Gould tested his idea by comparing fossils of snail shells. He found that they changed slowly sometimes and quickly at other times. . . .

> . . . Stephen J. Gould passed away on May 20, 2002.

The date that Gould passed away is a **fact**.

> It was a great loss for the world. Even though he is gone, his work lives on. Many people are inspired by the things he wrote.

The writer of this biography has an **opinion** about Gould: that the world was better off when he was in it. People who read Gould's writing can develop opinions about it, too.

Main Science Idea

Facts are verifiable as true. Opinions or beliefs are what a person thinks or feels. Opinions and beliefs might not be true.

Spotting Evidence

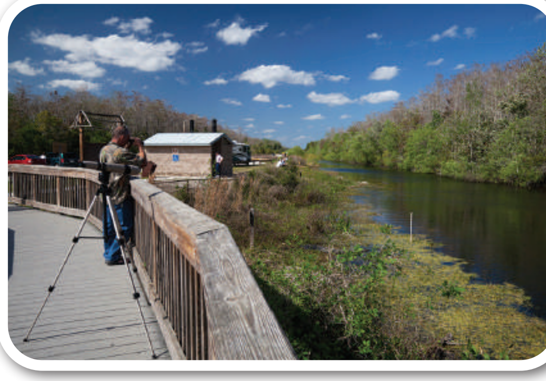
Chapter
11

Your teacher asks you to give a presentation about how to protect animal habitats. You will need to learn more about them first! To do this, you need to find books, articles, and web pages with good evidence.

What is good evidence? Good evidence is facts, not opinions. You want to learn a lot of facts about protecting animal habitats. You need to be sure these facts are true and accurate, too.

Compare the two passages on the Florida Wildlife Corridor. Think about which one you would choose and why. Do you think that both of them will help you with your presentation?

Passage 1: The Florida Wildlife Corridor



In 2021, Florida passed a law to protect its wildlife corridor. The law was the best way to protect animal habitats. Millions of acres of spectacular forests, lakes, estuaries, and swamps make up the corridor. It is a state treasure.

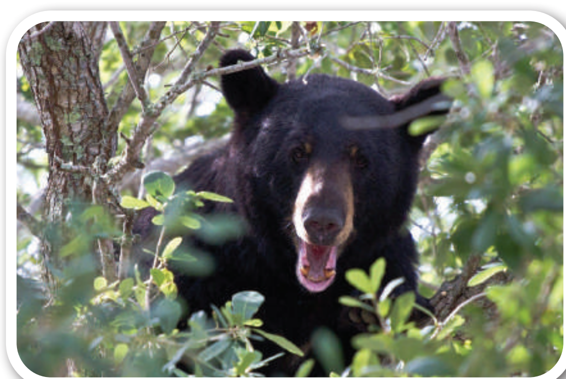
The Florida Wildlife Corridor is a boon to birds, mammals, and reptiles. The Florida panther especially benefits from the corridor. This majestic animal is endangered. It would be a great loss to Florida if it were to become extinct. Black bears and gopher tortoises also depend on the corridor.

With more people moving to Florida, protecting habitats is more important than ever. Habitats are necessary for the survival of plants and animals. The plants, animals, and landscapes of Florida are what make it a great place. The Florida Wildlife Corridor is the right way to keep Florida excellent.

Passage 2: The Florida Wildlife Corridor

The Florida Wildlife Corridor has millions of acres of natural areas, but they are not all in one place. Instead, many smaller areas across the state make up the corridor. These areas are all connected. In fact, *corridor* means "passageway."

The connections are important. They allow animals to move around in a larger area. Black bears, panthers, and other animals have more places to find food and shelter. If there were no connections, animals would have to cross busy highways.



Bears and panthers once lived across Florida. Then, people began to build towns and roads. Before the corridor, animals avoided these areas and could not travel like they normally would. Scientists learned this when they tracked one bear, called M34. The bear took a journey of hundreds of miles just to get to a place thirty miles away.

Good job getting ready for your presentation. But you don't have a lot of time. You can't read everything! The things you read must not only have facts. Those facts also must be relevant! Something is *relevant* if it has to do with the topic you want to learn about.

Compare the two passages on the following pages about orangutan habitats. Which one would you choose? Why?

Passage 1: Orangutans in Their Habitat

You can spot an orangutan right away by the reddish hair all over its body. Orangutans are three different species. There are Sumatran, Bornean, and Tapanuli orangutans.

Orangutans live in only a few places in the world. They are found in Borneo and Sumatra, two islands in Southeast Asia. Orangutans live in trees. They swing from tree branches and sleep in nests they build in the trees. Orangutans eat fruit from trees. They also eat leaves, tree bark, bird eggs, insects, and other small animals.

All three types of orangutans are in danger of becoming extinct. There are only about 100,000 Bornean orangutans, 14,000 Sumatran orangutans, and fewer than 800 Tapanuli orangutans.

Orangutans have less habitat space than they did a century ago. People cut down the trees in the orangutans' forests and use the land to grow palm trees. They can make money by selling palm oil.

Poachers also take orangutans from the forests. Even though it is illegal, some people try to sell orangutans as pets. They take baby orangutans away from their mothers.

Passage 2: Orangutans in Their Habitat

You can spot an orangutan right away by the reddish hair all over its body. Orangutans are three different species. There are Sumatran, Bornean, and Tapanuli orangutans. They look similar, but Sumatran orangutans have longer hair around their faces. Tapanuli orangutans have flatter faces than the other two species.

Orangutan means "man of the forest." Trees are very important to orangutans. They get most of the food they eat from trees. Over half of an orangutan's diet is fruit, such as mangoes, figs, and lychees. They also eat leaves, tree bark, bird eggs, insects, and other small animals.

Orangutans have long arms that are good at gripping tree branches and feet that can grab. They sleep in trees, too. If you see an orangutan out of a tree, it is most likely a Bornean orangutan.

Orangutans are usually solitary, living alone. The exception is mothers and their offspring. Young orangutans stay with their mothers until they are eight years old.

Main Science Idea

When we read about science topics, we should look for facts that matter to the topic. Opinions, or even facts that are true but not related to the topic, are red flags that should make us consider whether or not what we are reading is good information.

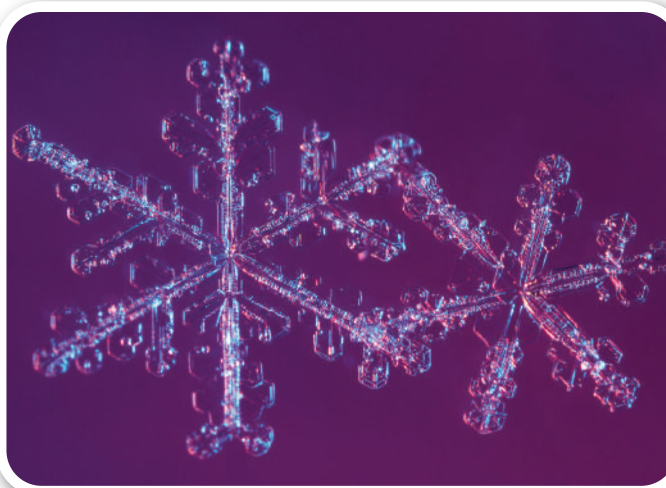
Patterns as Evidence

Chapter 12

A pattern is something that repeats. Patterns can be easy to spot. Every rainbow has colors in the same order. This is a pattern.

A pattern can be something that happens in the same way every time. When you look at close-up images of snowflakes, what do you notice?

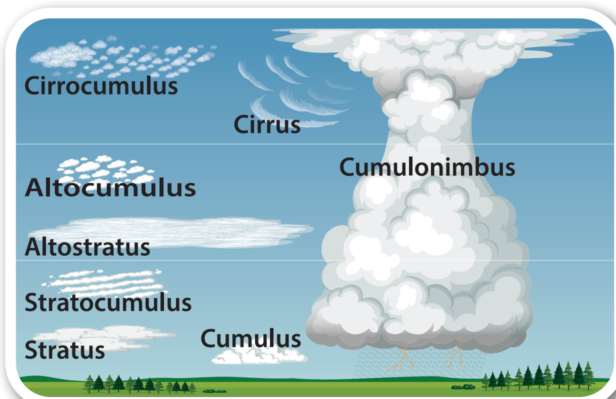
Every snowflake has six sides. This is a pattern. It repeats for every snowflake.



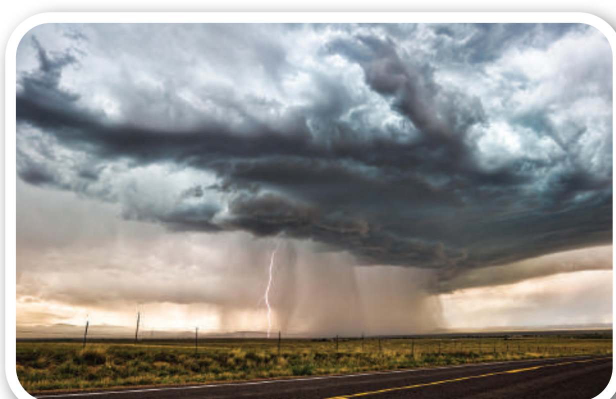
Patterns can help us explain what we observe. Water in clouds freezes to form snowflakes. Scientists notice that water forms a six-sided crystal when it freezes. They use the six-sided pattern of snowflakes as evidence to support this explanation.

Some patterns can be harder to notice. Have you ever really looked at clouds? It might not seem like there is any pattern to them at all.

Clouds come in just a few basic types. There is a pattern to cloud shapes. There is also a pattern to where they form above Earth's surface.



Different cloud types form at different heights. Cirrus clouds form high in the sky, above 14,000 feet. Stratus clouds form lower, below 4,000 feet.

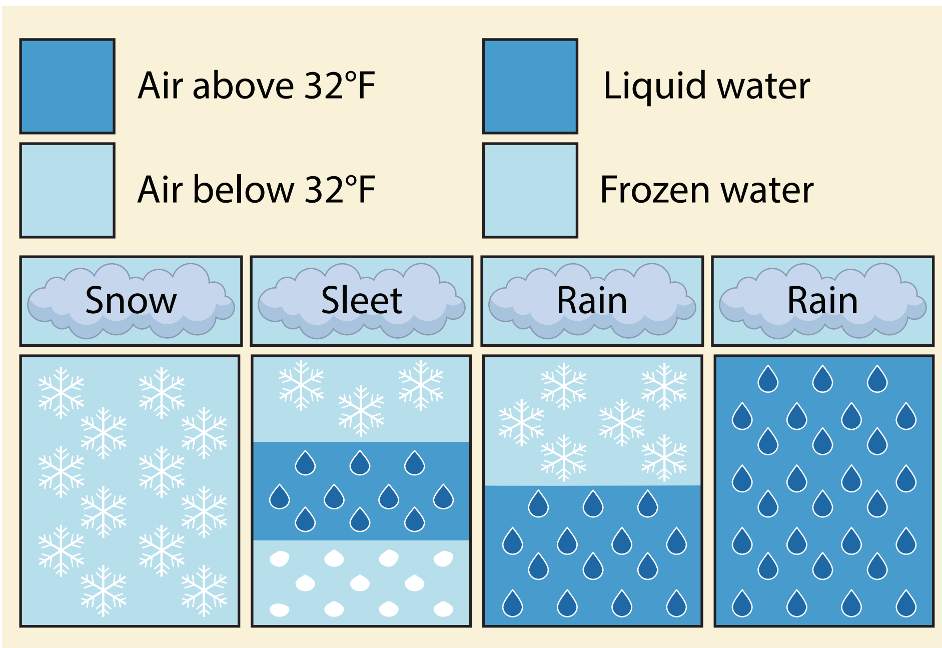


Rain, thunder, and lightning come with cumulonimbus clouds. When things happen together, this is another kind of pattern.

Rain, snow, and sleet are different kinds of precipitation. They fall from cumulonimbus clouds.

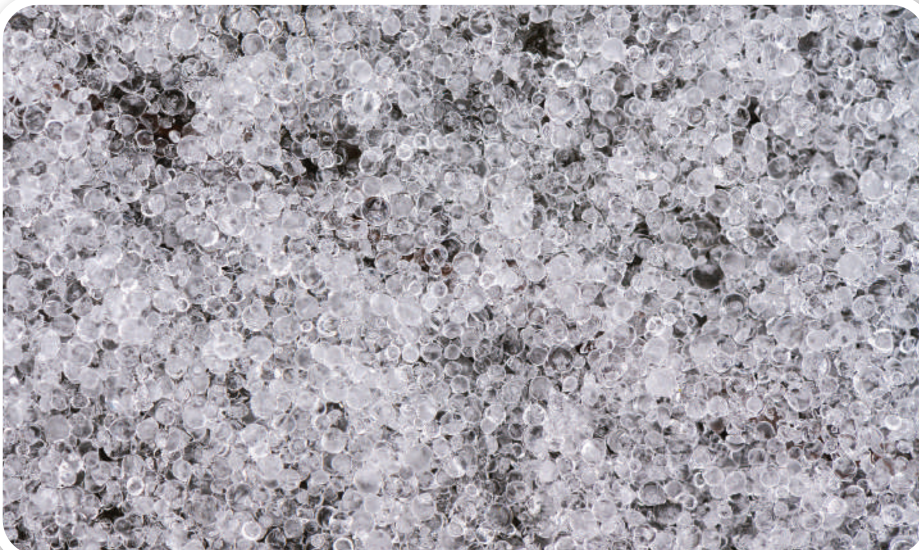
Examine the diagram. Look for patterns. Try to explain how the different kinds of precipitation form. Remember that water freezes at 32°F. Use these details as evidence.

A pattern may not be obvious at first, but it might be there!



When the air is below 32°F, it is cold enough for water to freeze and form snowflakes. If the air temperature is below freezing, it snows.

Sleet starts out as snow high in the sky, where the air is freezing cold. As it falls to the ground, it passes through a warmer layer of air. The snowflakes melt into raindrops. Closer to the ground, the air becomes colder again. The raindrops freeze and turn to sleet.

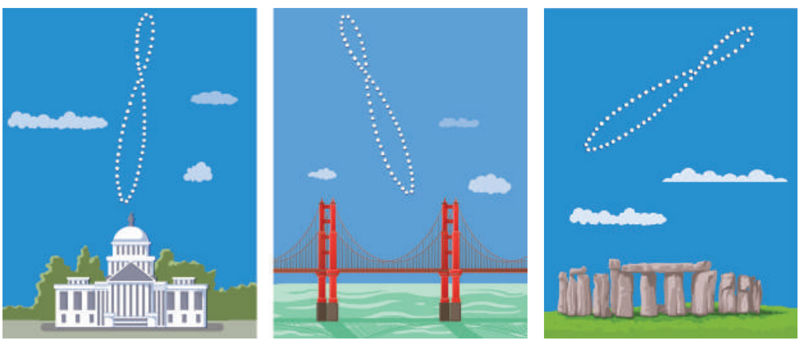


It rains when the air is above 32°F. Water does not freeze. Rain can also start out as snow if it is very cold high in the sky. If the air closer to the ground is warmer, the snowflakes melt into raindrops.

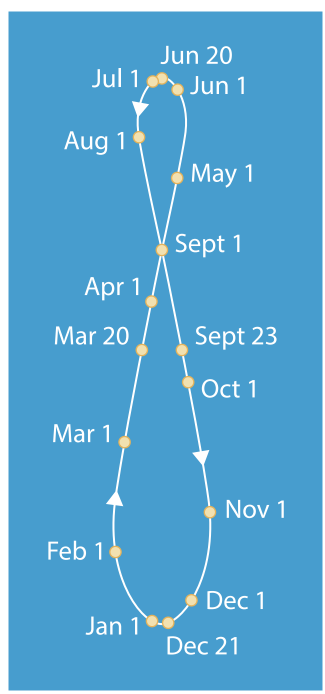
Let’s look at another pattern in nature.

Where is the sun when it is highest in the sky? Is it always in the same place?

Using special equipment to protect his eyes, a photographer took a picture of the sun at noon. He did this once about every thirty days with the camera in the same spot. He made one image by putting all the photographs together. Notice how the position of the noon sun changes.

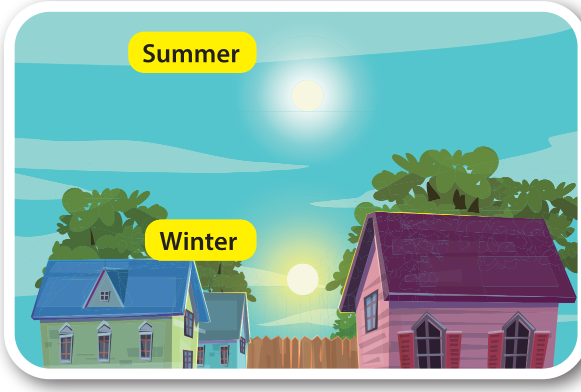


No matter where in the world people take pictures like this, the shape is the same. It is called the analemma. The same pattern appears in sets of photos taken at other times of day, too.

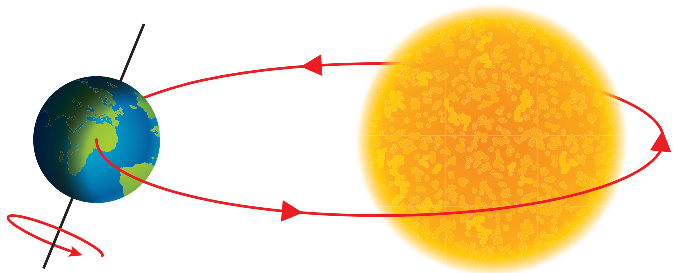


What causes the analemma shape? Look at the dates that the sun is highest and lowest in the sky. Do they remind you of another pattern? The patterns are evidence.

Close to the summer solstice, the sun is high in the sky. Close to the winter solstice, it is low in the sky. Between the solstices, the noon sun's position gradually changes. On each equinox, it is close to the middle of the analemma.



You might be thinking that the pattern has something to do with the seasons. You're right! They are caused by the same thing.



Earth's tilted position as it moves around the sun causes the analemma. (A few other things affect its shape, too.)

Patterns help us explain things we observe. When one thing causes another, they will often have the same pattern. It will repeat in the same amount of time.

A pattern that repeats over time is called a cycle. What other cycles can you think of?

Words to Know

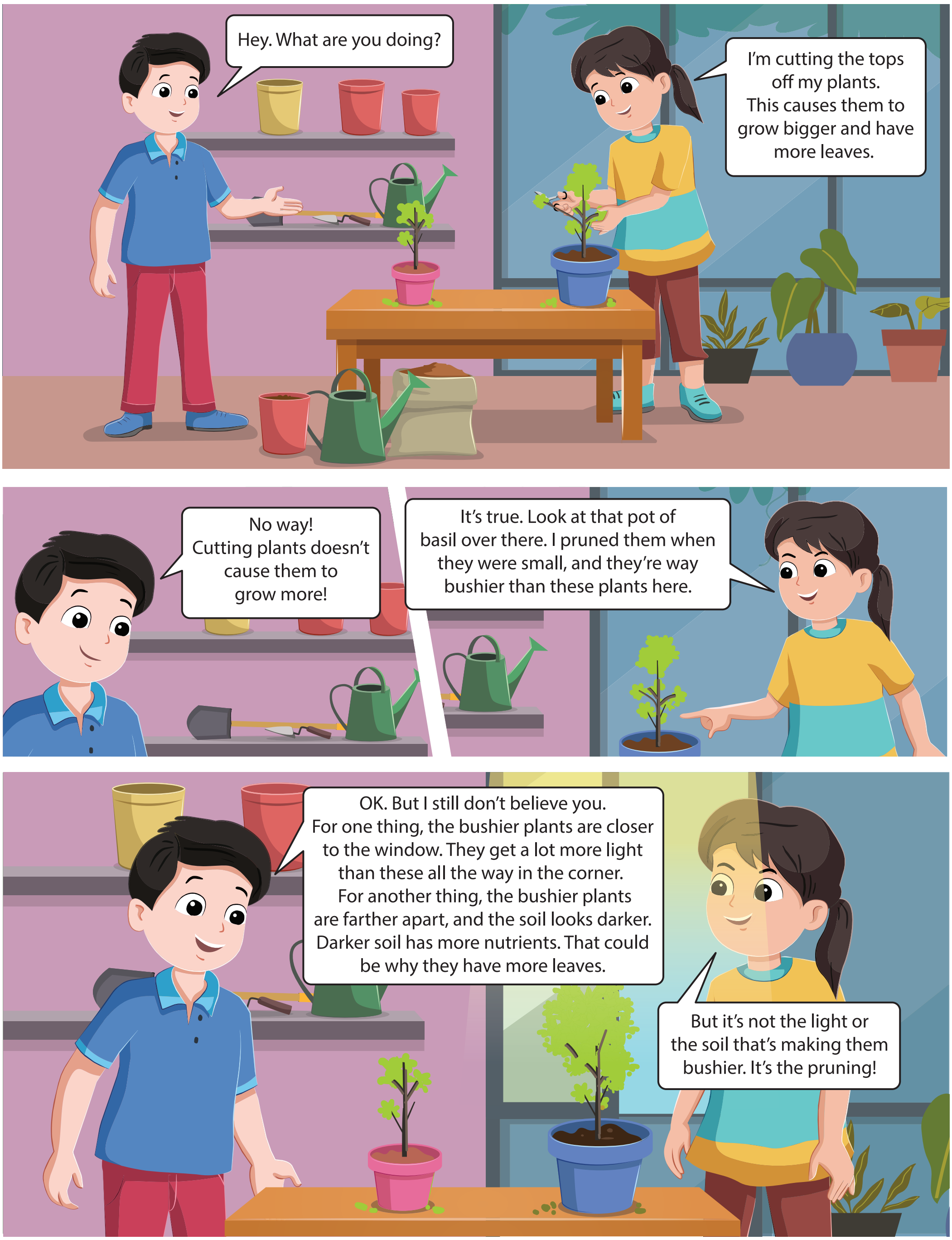
The first day of summer and the first day of winter are each called a *solstice*. The first day of spring and the first day of fall are each called an *equinox*.

Main Science Idea

Some patterns can help us describe how predictable things happen. They can also help us figure out and explain why some things happen.

Cause-and-Effect Detectives

Chapter 13




Are they even the same type of basil? Some grow better than others, you know.
OK. I give up. What will it take to convince you that pruning is the cause of one pot of basil growing bushier than the other?
How would you prove that pruning the basil is what causes it to grow differently?

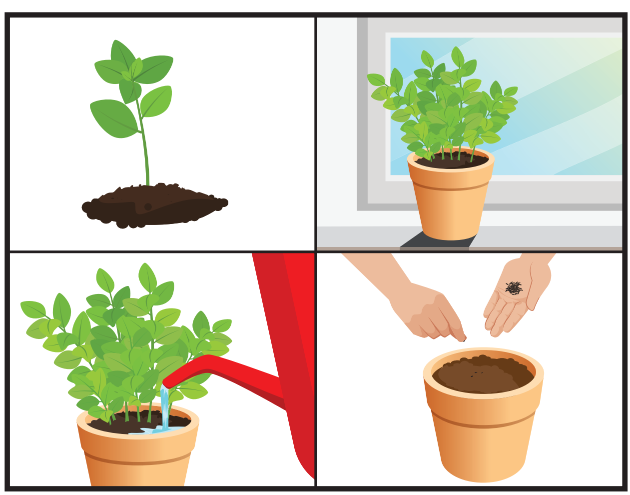

I have an idea! You can help me grow two pots of basil. We'll keep everything the same.
Same-size pots, same soil, same packet of seeds. We'll put the pots in the same place so that they get equal amounts of sunlight.
We can even give them the same amount of water! Then we can prune the basil in one pot and leave the other uncut.
That way, if there is any difference in how the basil grows, we can be sure that it was the pruning that made the difference. Everything else was the same!
BASIL
SEEDS

Scientists look for cause-and-effect relationships. This means that one thing causes another to happen. Causes come before effects. A **cause** is the reason for something happening. An **effect** is what happens.

A person pushes a child on a swing. The person pushing is the cause. The swing moving back and forth is the effect. The swing moves up *because* of the pushing force. The swing moves down because of the force of gravity.

It is not always easy to know what causes something to happen. More than one thing *might* be the cause. One basil plant grows bushier and has more leaves than another. Is it because it has better soil? More light? A different amount of water? Were the seeds different to begin with? Any of these could have been the causes.

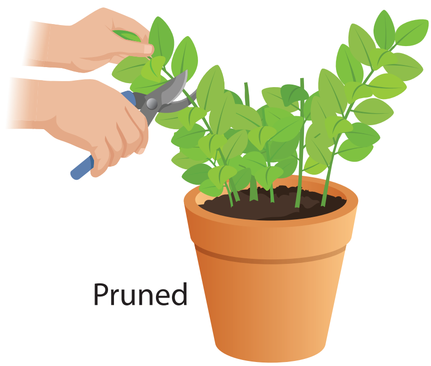
How can you tell? Do a fair test to isolate the cause. To *isolate* means to be sure one thing and one thing only is the cause of something.



To do this, test only one thing. Test the thing you think might be the cause. Keep everything else the same.

A fair test uses a **control**. To find out whether pruning basil makes it grow bushier, you need a pot of basil that is *not* pruned. This is the control. But *do* prune a second pot of basil. These are the test plants.

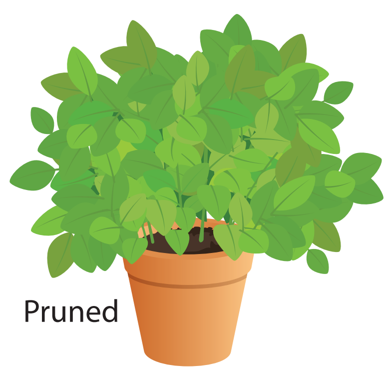
No pruning



Pruned

In a fair test, you **compare** the control with the test plants. Is there a difference? If there is, you can be sure that it was caused by the one thing that you changed—whether you pruned. By changing only one thing, you can isolate what causes the difference.

No pruning



Pruned

Understanding causes and effects can help explain how things work. Can you think of other causes and effects?

Spiny madwort is a plant that grows in France and Spain. It is bushy and grows low to the ground. Madwort is a favorite food of goats and sheep. These animals munch on madwort plants.

Spiny madwort has spines. Animals do not like to eat the spines. Spines protect the plants from being eaten by animals.

Some spiny madwort plants have many spines. Others have just a few. What could *cause* some plants to have more spines than others? Do the plants grow more spines when they are eaten by animals?

How could you do a fair test to find out?

These two butterflies might look like they belong to different species, but they are both European map butterflies.

Spring

Summer

Map butterflies that hatch in the spring have orange wings with brown spots. Map butterflies that hatch in the summer have dark wings with white stripes.

What could *cause* the map butterflies to look so different? (*Hint:* what are some things that are different between spring and summer?) How could you do a fair test to find out?

Main Science Idea

If you have a hunch about what causes something to happen, you can test the cause and effect to see if one thing really causes the other.

Maria's Model

Chapter 14

Maria Escamilla is a high-school student in Manatee County, on Florida's Gulf Coast. On weekends, Maria volunteers with the sea turtle conservation project at a local marine laboratory. One of Maria's goals is to make people more aware of how human activities affect the loggerhead sea turtle, *Caretta caretta*. Important parts of the life cycle of this marine reptile take place on warm sandy beaches like those in Manatee County.

Mature female loggerhead turtles crawl onto sandy beaches to lay eggs. Once a female finds dry sand, she digs a hole with her flippers. This hole becomes the nest for several dozen white, leathery eggs. She buries her eggs under sand and heads back out to sea. A female can nest multiple times in one nesting season.

If the eggs incubate properly, sea turtles hatch and dig themselves out of the nest—often all at once—after about sixty days. The hatchlings scramble for the ocean and begin independent lives. Female hatchlings that manage to survive another thirty years and reach adulthood will try to find their way back to the same beach to lay their own eggs.

Maria is assembling a scale model of a span of coastline in Manatee County. She wants the model to show people how coastal development and other human activities threaten loggerhead sea turtles. It especially affects nesting females, buried eggs, and newly hatched young.

The model will be useful because it will be portable. Maria will be able to use it in schools, town meetings, retirement communities, and more. Her goal is to encourage people of all ages to think about how they can help the loggerhead sea turtle survive as a species and continue to nest on Florida's Gulf Coast beaches.

Before Maria builds her model, she must pick a good shape and the right scale for it. She envisions a rectangular shape that models a span of beach 100 yards wide, and she wants the model to be no wider than 30 inches so she can easily carry it through standard doorways by herself.

- Maria determines that her 30-inch-wide scale model should represent a 90-foot stretch of beachfront.
- This translates to a scale of 1 inch in the model representing 3 feet in the real world.
- There are 12 inches in a foot, so the scale is 1 inch in the model to 36 inches in the real world, or 1:36.

Maria now has a scale to work with for all the physical parts of her model. The scale is 1:36. If something is 36 feet tall in reality, then it can be one foot tall in the model.

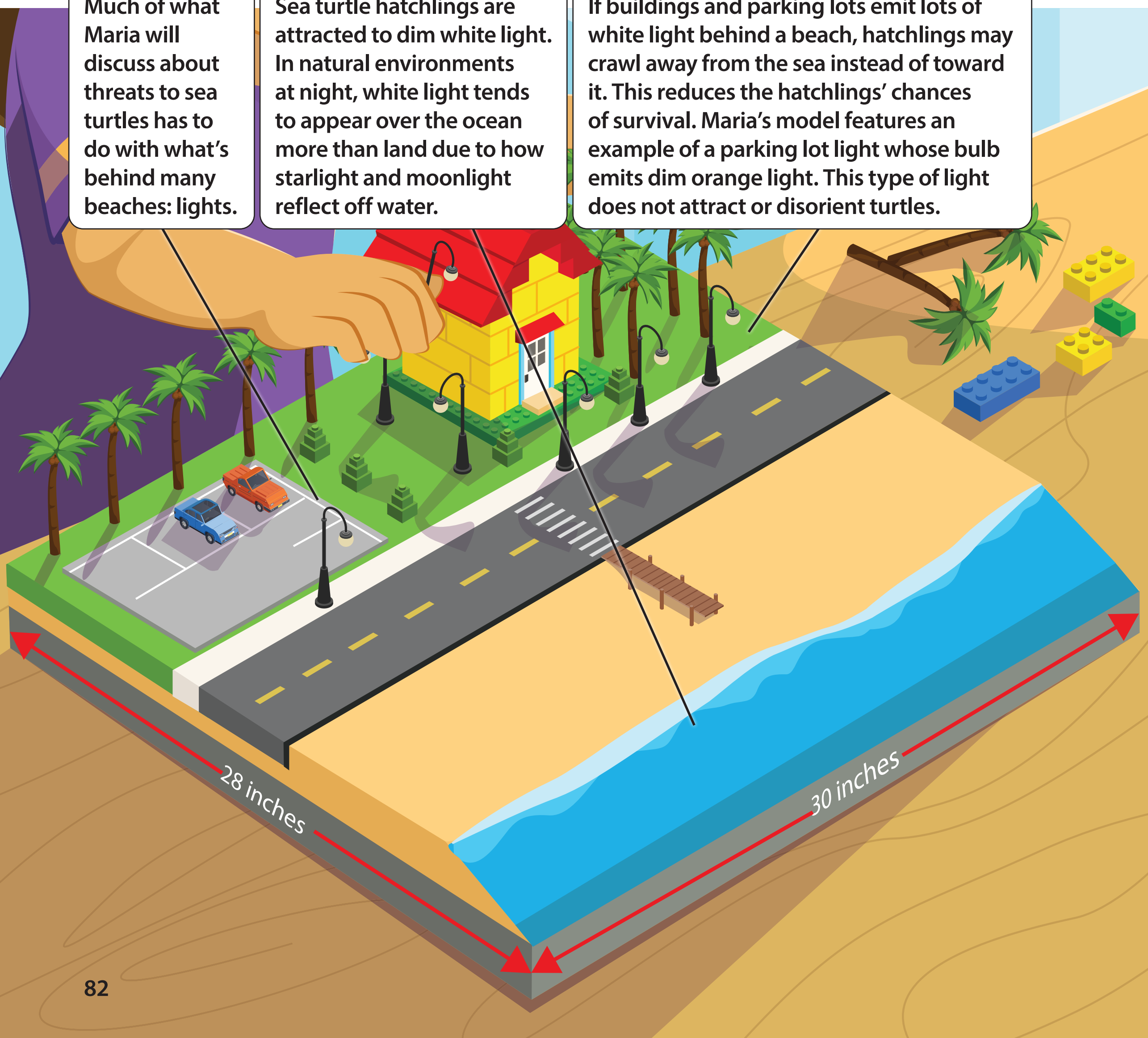
If something on a real sea turtle nesting beach is about three feet tall, then Maria knows she needs to make the scale model version of that thing about 1 inch tall. That is also a scale of 1:36.

She decides to work first on the features that will be at higher elevations at the back of the model: buildings, a parking lot, walkways, palm trees, and tall lamps.

Much of what Maria will discuss about threats to sea turtles has to do with what's behind many beaches: lights.

Sea turtle hatchlings are attracted to dim white light. In natural environments at night, white light tends to appear over the ocean more than land due to how starlight and moonlight reflect off water.

If buildings and parking lots emit lots of white light behind a beach, hatchlings may crawl away from the sea instead of toward it. This reduces the hatchlings' chances of survival. Maria's model features an example of a parking lot light whose bulb emits dim orange light. This type of light does not attract or disorient turtles.



The next part of the model Maria needs to fill in is the upper part of the beach. This is where sea turtles dig nests and lay their eggs. If nests are too close to the ocean, they can be flooded with seawater or swept away by a storm. The warmth of dry sand also incubates the eggs at the correct temperature. In the upper part of her model, Maria uses plastic figures to model some of the threats to sea turtle nests on the upper beach.

Raccoons eat a wide variety of organisms. When raccoons find sea turtle nests, they will dig up the eggs and eat them.

Vehicles that come onto the beach can disturb and destroy sea turtle nests. Even something as simple as a child digging in the sand can harm a nest. Maria's model should show similar threats.

If sea turtle eggs safely incubate for about two months and hatchlings dig themselves out of the sand, the next challenge they face is making it from the upper beach to the ocean. Depending on the width of the beach, this could be a long journey for hatchlings that are just inches long. If there are obstacles in the way, the hatchlings can get stuck or trapped. If this occurs while the sun is high and the air is hot, the hatchlings can overheat and die. They are also vulnerable to other beach predators, such as seagulls. Seagulls are often attracted to the beach by food discarded by humans.

Finally, if loggerhead hatchlings survive the long crawl to the ocean, they must get past the surf zone and the shallows. Predatory fish and birds hunt for bite-sized prey where the water is shallow. If hatchlings make it to the open ocean, they spend years living among large rafts of floating sargassum, a type of seaweed, far out at sea. After that, they migrate through the ocean in search of food and, eventually, mates.

When mature nesting turtles return to their homeplace to lay their own eggs, they haul themselves up onto the sand. They crawl to the upper area where the sand is warm and dry, and the life cycle begins again. Fishing gear, fast-moving boats, tiger sharks, pollution, and other things threaten large, mature turtles in coastal waters. Maria completes her scale model by adding these details.

Main Science Idea

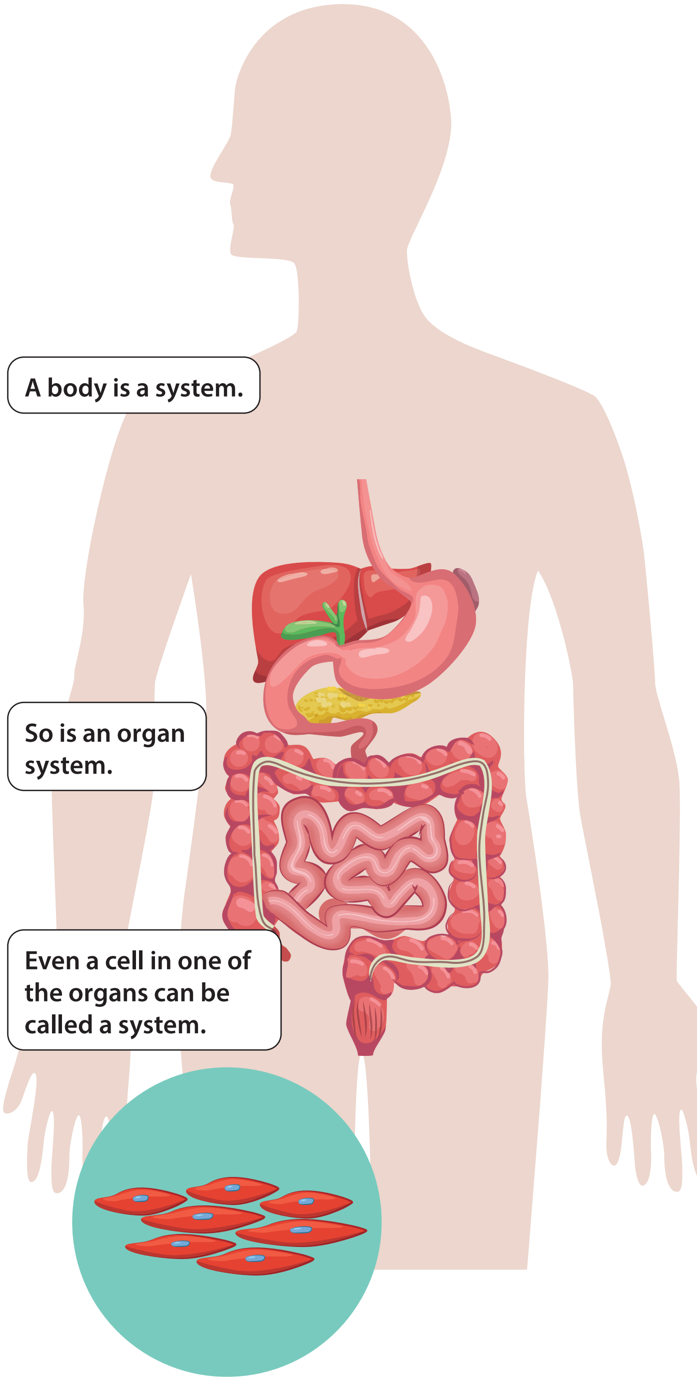
Scale models are useful tools for teaching and learning. They can help us figure out solutions and explain concepts and processes to others.

Open and Closed Systems

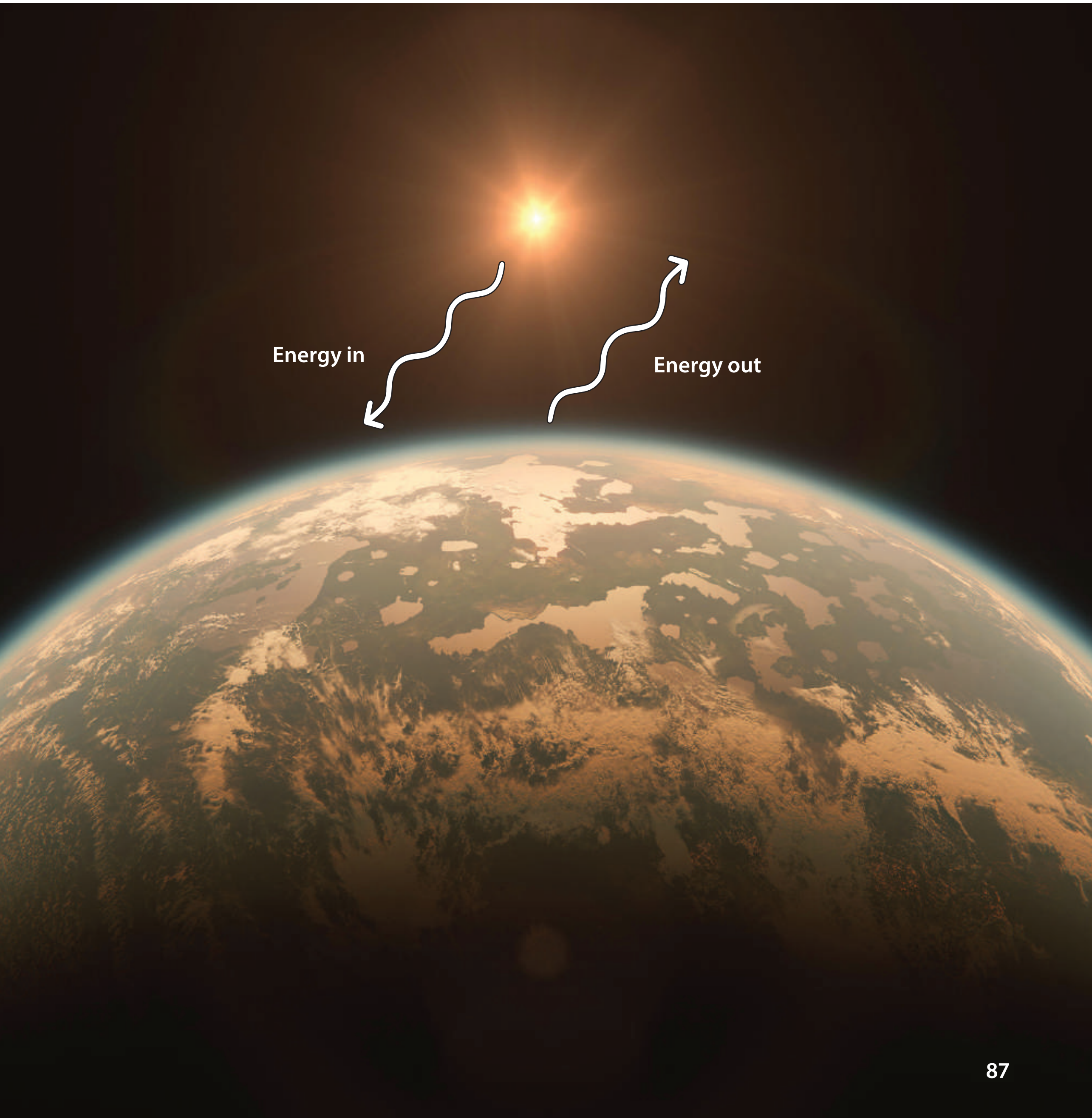
Chapter 15

A system is a set of things that work together. In science, there are lots of systems to investigate. In life science, a living thing's body can be considered a system, and so can the different organ groups within that body. Even the different parts functioning inside a cell make up a system. In physical science or engineering, a system might consist of a car engine or an airplane.

A system that interacts with other systems is called an open system. An open system is like something with an open door: it lets things in or out. Sometimes matter or light passes into or out of an open system. Sometimes energy passes in or out.



In terms of matter, Earth might be thought of as a closed system. Virtually nothing enters or leaves Earth, aside from some meteorites crashing down and some space probes heading out. In terms of energy, however, Earth is an open system. The sun gives Earth a tremendous amount of energy, and a lot of that energy ends up being radiated back out to space.



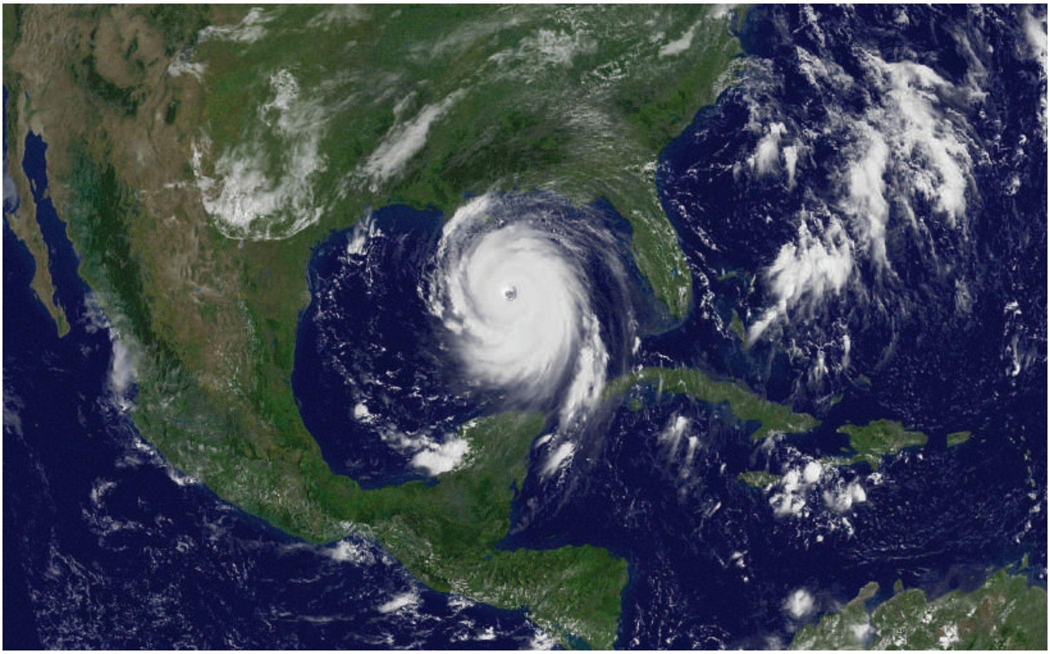
In nature, it's unusual for a system to be closed in terms of energy, because energy has ways of moving around. These items are all designed to prevent energy from getting into or out of what's inside them. But it's very hard to make them completely effective. A cooler for sodas in the summer might be a closed system, but heat will always move in over time.

This insulated container is designed to prevent heat from moving into or out of the liquid inside. But after a few hours, the temperature of whatever's inside will start to get closer to the temperature of the surroundings. Heat moves from the warmer thing to the cooler thing. This is an open system.

There are a few systems shown here. The diver's wetsuit is meant to prevent the movement of body heat, but the diver's body is an open system exposed to the environment. Their body loses heat to the cooler water. The scuba gear is a system that provides air to the diver's lungs, but the exhaled air goes into the environment. It's another open system once the tank's valve is opened and the diver starts to breathe. The ocean water is another open system. Things move into and out of it.

This lava lamp is an example of a system that is both open and closed. It's closed in terms of matter because matter cannot get in or out. But it's open in terms of energy. Light energy can enter the system through the glass. Electricity flows through a bulb inside the base of the lamp. The bulb emits light and heat. The heat causes the up-and-down movement of wax bubbles inside the lamp oil. The heat also spreads out into the room where the lamp is. The flows of electrical and thermal energy show the system is open in terms of energy.

This salt marsh is a system. A lot of matter and energy move in and out of this system. The salt marsh is found where the ocean meets low-lying coastal land. Saltier water from the ocean mixes with fresh water flowing downhill from the land. Sunlight gives the marsh grass the energy it needs. Wildlife migrate in and out of the marsh, sometimes several times a day. This is a very open system.



The satellite image shows a major hurricane approaching a coastline. A hurricane is a type of weather system that moves across the ocean. It has strong winds blowing in an enormous circular flow. The hurricane gets energy from warm ocean water. It also gains matter in the form of water. Eventually, the hurricane loses its energy, and the water it contains falls back to Earth's surface. This is an open system.

An engine is a system that converts energy from fuel into motion energy. In the case of a car engine, the mechanical energy turns the car's wheels, making the car move. The engine releases heat and exhaust gases to the environment. It's an open system.

When a lid is on tight, a pan and water can be considered a closed system in terms of matter. Heat from the stove warms the system, and heat leaves the system, too. If the lid stays on, the water inside should remain there even when it becomes steam. Realistically, steam will come out though.

A chemical cold pack is a good example of a closed system in terms of matter. When squeezed, two chemicals in the pack react, making the pack cold. This allows it to draw in heat from something it touches, such as a sore elbow or knee. But the matter inside the pack stays there, and matter from the environment doesn't get inside. The only thing moving into the system is thermal energy.

An egg might look like a closed system in terms of matter. It has a hard shell, it doesn't move on its own, and it doesn't appear to do much at all. But it is exchanging gases with the air around it. Oxygen goes in, keeping the embryo alive, and carbon dioxide goes out, which also helps keep the embryo alive. The egg is an open system.

A sewing machine can be thought of as a type of closed system, at least in terms of matter. Electricity powers the motor inside, which makes different mechanical parts move so a needle, thread, and fabric interact to stitch things together. Some of the energy is lost to the environment as sound and heat. But no matter needs to be added to the machine to make it work, and the machine doesn't release any matter.

Main Science Idea

A system of parts that work together can be closed or open. If matter or energy can get into or out of the system, it is open. If matter or energy cannot get in or out, the system is closed.

Water: One Matter Cycle

Chapter 16

I am water—well, the tiniest particle of water. I am made of two atoms of hydrogen and one atom of oxygen. Atoms bind with one another to form a molecule. I'm a molecule, and my nickname is H_2O. As you will find out, I am part of one of nature's cycles. I move around in the water cycle.

I sometimes hang out in the air. Sometimes I get together with other water molecules and form a droplet of water. If enough of us get together, we can form a drop of rain. If we get cold enough, we can form an ice crystal and then a snowflake. Then we fall from the sky to Earth's surface. This is the part of the water cycle known as precipitation. On average, I only spend about nine days in the air until I become precipitation and end up on the ground or in a lake or ocean. In those nine days, I might travel hundreds or thousands of miles through Earth's atmosphere. It's quite an adventure!

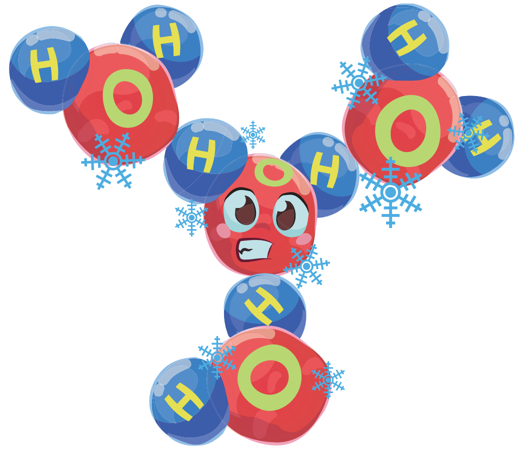
I was part of this storm. That was a wild ride!

When I fall back to Earth’s surface, there are different places I can end up. Sometimes I stay for quite a while, and sometimes for not much time at all.

If I become part of a shallow puddle on a warm sidewalk, I will probably head back into the atmosphere in a few hours through evaporation—when water changes from liquid to gas.

If I fall into a deep body of water, such as an ocean or a lake, I might stay there for many years, especially if the climate is cool and the rate of evaporation is slow. This lake was in a warm place. Evaporation happened fast here. I was only in the lake for a few months.

If I fall to Earth as a part of an ice crystal, like in a snowflake, my friends and I might melt after a short time and flow into a stream. Or we might be stuck in a glacier for a million years.



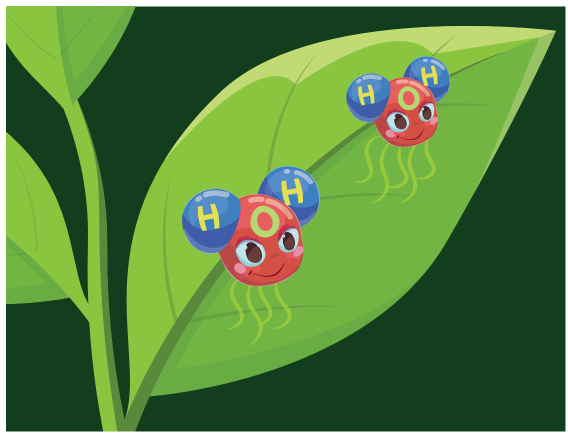
Sometimes the snow I'm part of melts very quickly. I'm cycled into the liquid part of the water cycle like when I was part of this mountain stream.

Multiple times, I've become part of a glacier or an ice cap at one of Earth's poles. Eventually I get out when the ice melts. This can take thousands of years!

I cycle through the atmosphere and bodies of water, soil, and even deep layers of rock. I also cycle through the biosphere—all the living organisms, like trees, animals, and fungi. I've passed through plenty of plants, mushrooms, animals, and other organisms over millions of years.

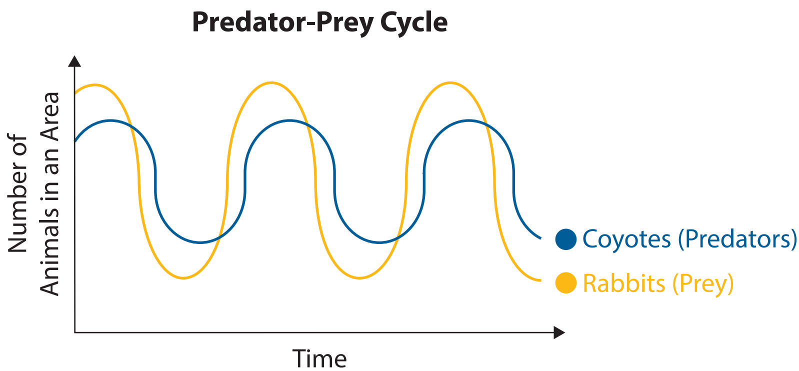
I've passed through fishes, whales, algae, and many other organisms. I recently was breathed out by a deer.

When plants release me into the air, it's called transpiration. Animals release me as sweat, exhaled air, or waste.

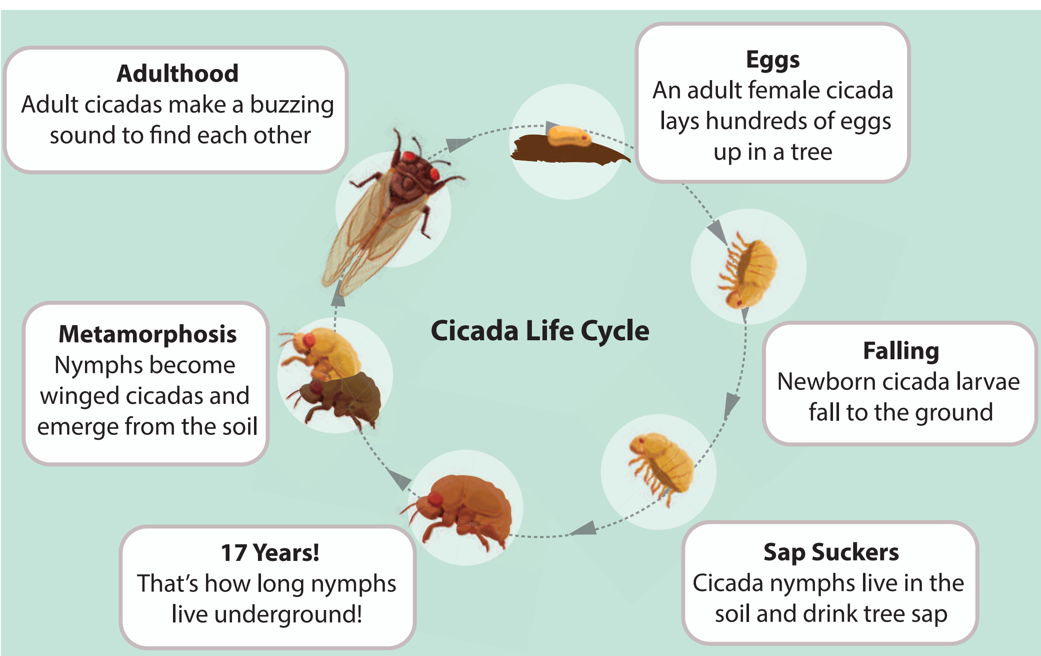


I'm usually in the ocean for about 3,000 years at a time. Last year, I got to evaporate from the shallow water over a coral reef and join up with other water molecules to form a cloud. We were a beautiful sight!

The water cycle is just one of many cycles in nature. There are other cycles in nature and in our everyday lives, too. Here are some examples:

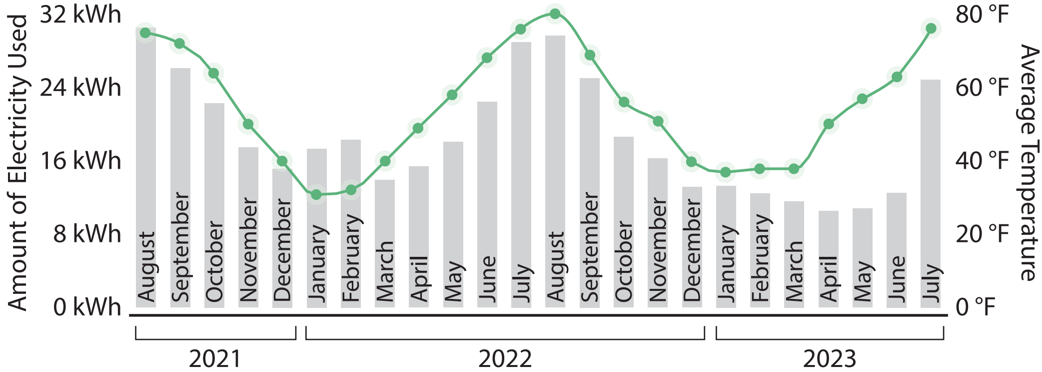


This graph shows a predator-prey cycle. When the population of the prey—like rabbits—is up, predators like coyotes have more to eat. Coyotes thrive, and their numbers increase. When the coyotes reduce the rabbit population, fewer coyotes can be supported, so the coyote population declines. That lets the rabbit population grow again.



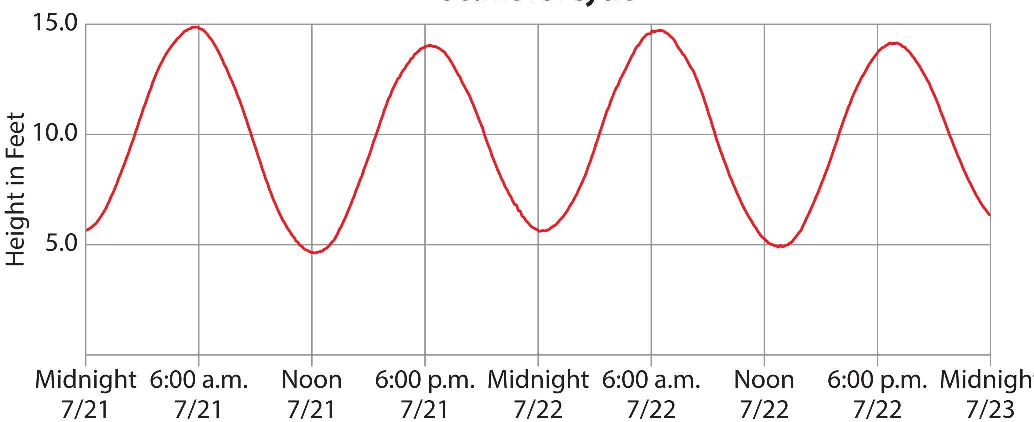
This diagram shows the life cycle of a cicada. All living things go through a life cycle that is the same for all their type of organism.

Cycle of Home Electricity Use



The bar graph shows how much electricity a home used over two years. A lot of electricity in this home is used to power the air conditioning system. There is a clear up-and-down cycle of temperature and electricity usage. When it's hot outside, electricity is used a lot more. When it's cooler out, less is used.

Sea Level Cycle



The rise and fall of the sea level is a natural cycle. We call this the tides. The tides measured by a sea-level monitor in Maine are shown here. There is a high tide and a low tide every six hours or so.

Main Science Idea

Matter moves around on Earth. Water is one example of a type of matter that moves around in a big and complex cycle. A cycle is a repeating process.

A Closer Look!

Chapter 17

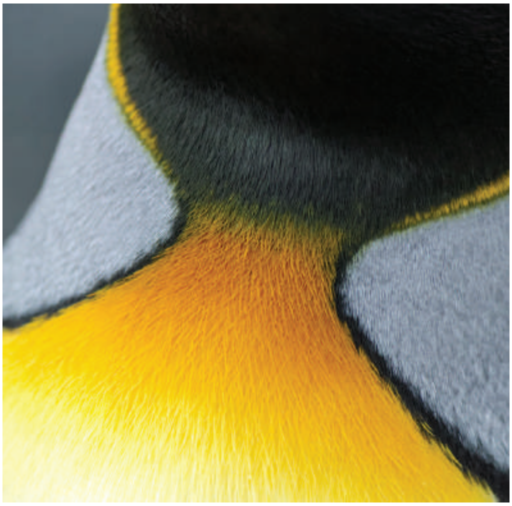
Everything you see is made of smaller structures. If you look closer, those structures are made of even smaller structures!

Feathers are often different from one species to another. In fact, feathers from one part of a bird to another part of the same bird can be very different.

Flight feathers, which are found on the wings of many birds, are long and firm. They catch the air and move it around, like the blades of a fan.

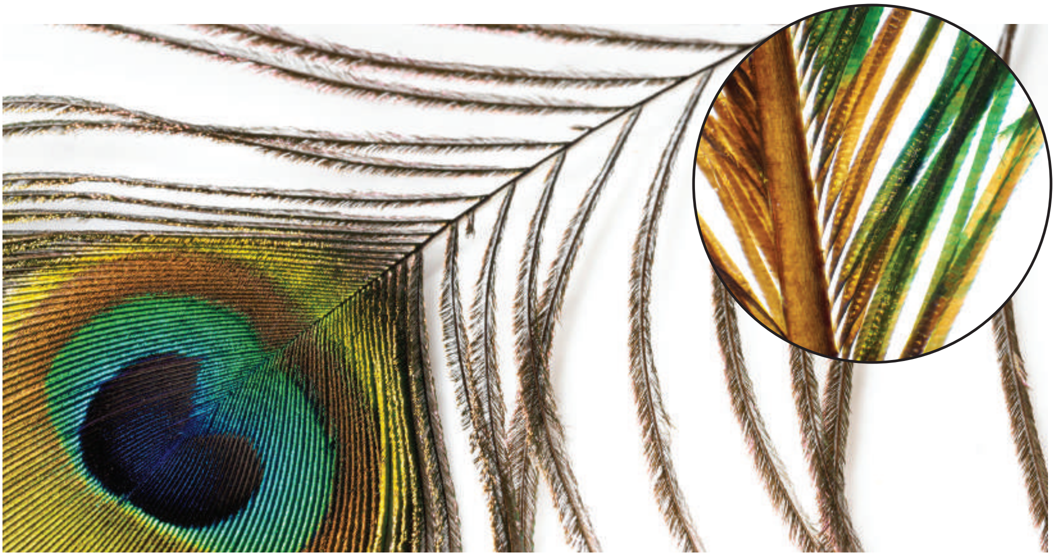
The fluffy body feathers, or "down," are shorter and softer, and they work to keep a bird warm. They provide insulation.

Penguin feathers are for high-speed swimming that looks a lot like flying. When penguins dive into water to hunt for food, tiny pockets of air trapped in their fine feathers are squeezed. Small air bubbles are released around the penguin's body. These bubbles form a layer of air that makes the penguin's body move through the water more easily.



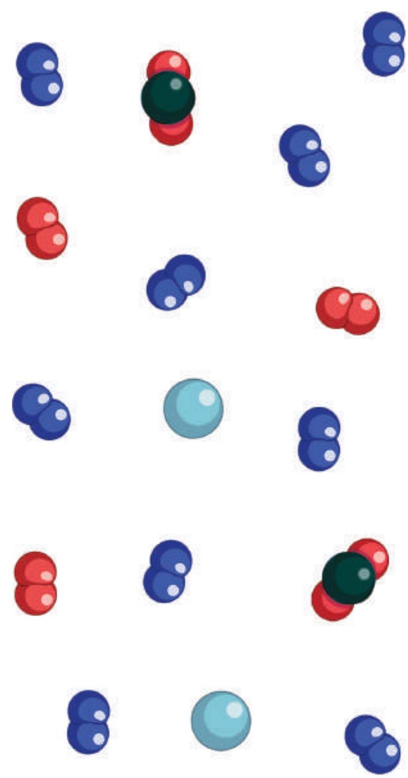
Eventually the air gets squeezed out, and the penguin must get back on land and re-fluff its feathers to prepare for another dive. The fluffed feathers also provide insulation against frigid air when the penguin is on land. This is essential for survival in the cold, dark winters of Antarctica.

You can see the smaller structures of feathers by looking closely with just your eyes. If you take an even closer look through a microscope, you can see that feathers consist of thin strands.



This peacock feather has long barbs that branch off to either side of the feather's shaft. Each barb has short barbules. All these structures help bird feathers make lots of contact with air.

So, feathers are made of smaller parts. Let's consider another example. How about air? What is air, anyhow? Does it have structures? Yes. Air is made of different particles, including molecules of oxygen, carbon dioxide, nitrogen, and a few other elements. Air can also hold water vapor. All that stuff in air gives feathers something to push or pull against.



Air is made up of tiny particles.

If you look closely at other swiftly moving animals, you can see how they are made up of different parts. Some move through water in a similar way to other animals that flap, soar, and glide through air.

Sharks, rays, and other finned fishes use winglike fins to steer and propel themselves through water. The fins on their backs, called dorsal fins, help provide stability.

Shark fins are thicker at their front edges and thinner at their rear edges, like the wings of an airplane.

If you take a close look at shark skin, you will see millions of tiny sharp structures. These are called dermal denticles, which means "skin teeth." These give shark skin a tough, protective layer, but there's more to it than that. Water flows over the dermal denticles very easily. The structure of shark skin allows sharks to easily glide through water.

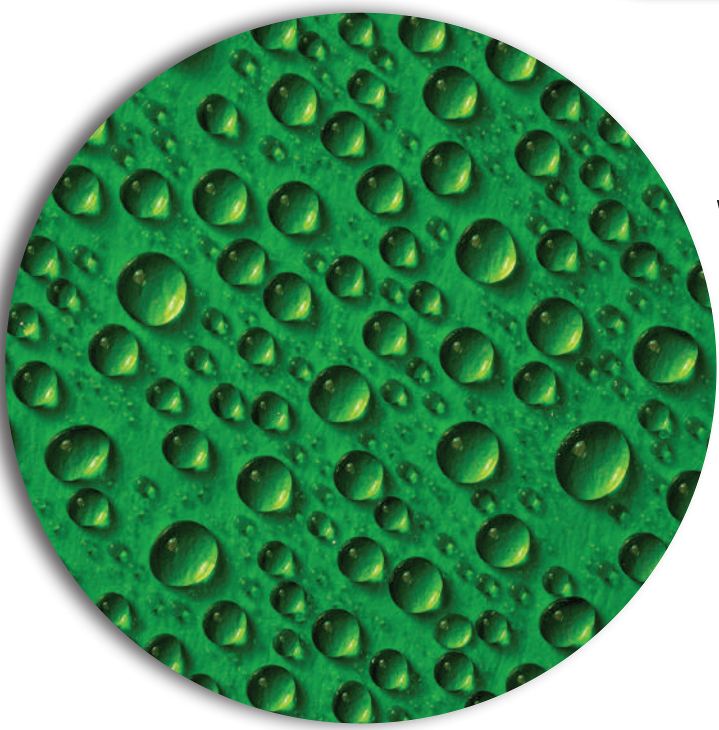
Looking closely at sharks helped people design airplanes. The design of airplane wings is inspired by observations of wings and fins in nature.

The advantage that dermal denticles give sharks inspired the development of textured surfaces for airplanes. Modern airplane surfaces reduce the "drag" that a plane has to deal with as it flies through air. Less drag means faster speeds and less fuel needed.

In the future, the surfaces of airplanes could be textured like a shark's skin to make them travel through air more easily.

Looking closely at plant structures has also helped people. For example, surface products such as paints are influenced by a type of plant that lives in ponds.

These lily pads are the surface leaves of an aquatic plant. The surface of the leaves repels the water and causes it to form drops. These drops tend to roll off the leaves, dragging dust and dirt with them. This cleans the leaves and allows them to absorb more sunlight.



When scientists looked closely at the surface of lily pads, they saw tiny bumps. These bumps force water droplets up and away from the surface, making the droplets cling together and roll away. Paint makers develop coatings that have the same ability to repel water.

Some plants have structures for moving through air. Floating or gliding through the air helps fruits or seeds spread out so new plants can sprout where they have room to grow.

Main Science Idea

A structure is something that is built or arranged in a way that enables it to serve a particular purpose. Each structure is made up of smaller structures with characteristics that make the structures work the way they do.

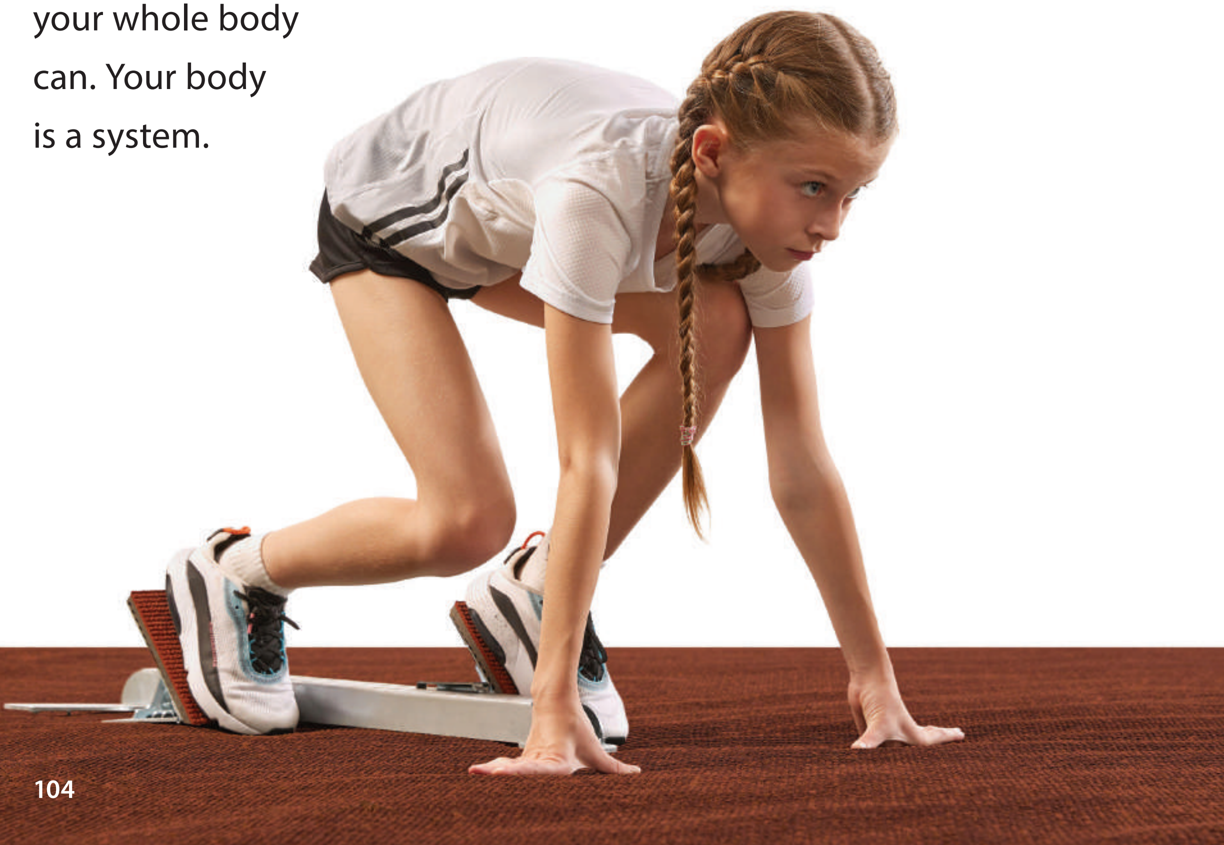
Dynamic!

Chapter 18

Are *you* a system? Think about what a system is.
A system is made up of different parts. The parts all work together. The system can do things that any one part cannot do alone.

Think about your body. It is made up of different organs. It has muscles and bones. It has a brain, ears, eyes, a heart, lungs, and a stomach. Your body's parts work together. Your heart pumps blood to your muscles. Your brain tells your muscles how to move. It might use information from your eyes to figure out where to go.

You are ready for a race. Your muscles are tense. You wait for the starting horn—and then you are off! None of your organs could do this on their own, but your whole body can. Your body is a system.

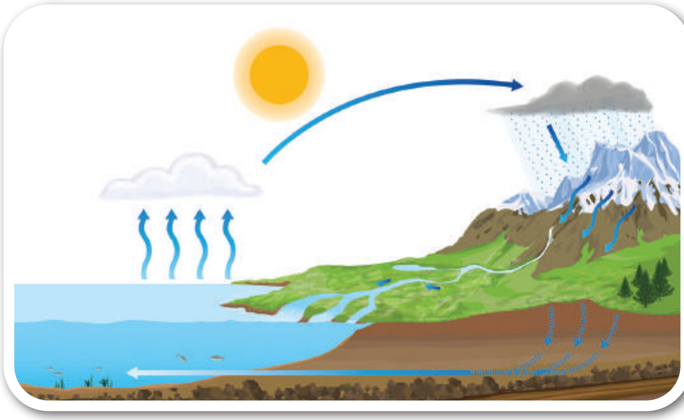


A forest is also a system. It is made up of soil, trees, animals, air, and water. The trees could not grow without soil, air, and water. The animals need the trees for food and shelter.

Your body and a forest are dynamic systems. This means that they are constantly changing.

A forest does not always have the same number of owls or bears. Trees in a forest might have leaves in summer and bare branches in winter. Heavy rain might bring a lot more water than usual to the forest. Since the forest is always changing, it is a dynamic system.

Earth's climate is also a dynamic system. It is made up of parts that change and affect each other. The air around Earth, called the *atmosphere*, is one part of the system. The atmosphere traps some of the sun's heat. The sun's energy is an input to the system.



The sun heats some parts of the atmosphere more than others. The unequal temperature causes winds to blow. Earth's water and ice are also part of the climate system. The sun's heat changes liquid water to a gas. The water vapor forms clouds and precipitation. Cold air changes the water vapor to snow, sleet, or hail.

Everywhere on Earth, the weather changes daily, but the climate patterns stay generally the same. Deserts are usually dry, even though it might rain sometimes. Rainforests are usually wet. In places that have changing seasons, those seasons repeat every year. A dynamic system always changes, but it also has stability.

A desert may get rain, but it remains a stable, dry desert over time.

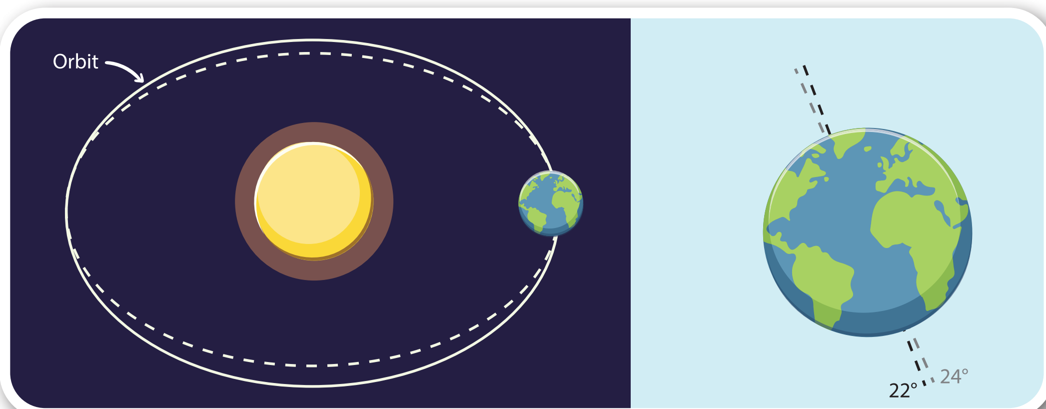
Some changes to the climate system happen in cycles. The seasons have a yearly cycle. Seasons can bring cold weather during winter and hot weather during summer. Some places have a rainy season and a dry season.

Some cycles take longer. A climate change called El Niño happens every three to seven years, when part of the Pacific Ocean becomes warmer than usual. In a dynamic system, the parts work together. The warmer ocean water causes a low-pressure system over the Pacific Ocean.

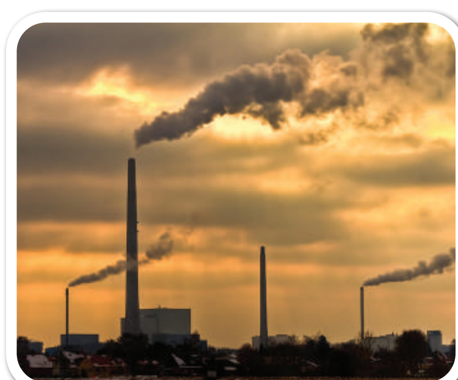
This change affects the other parts of the climate system all over the world. El Niño causes drier weather in Australia but more rain in South America. The northwestern United States is usually rainy, but El Niño makes it warmer and dryer. El Niño brings rain to other parts of the United States. In Death Valley, California, the rain causes flowers to bloom all over the desert floor.

Climate cycles can take many thousands of years. At times in Earth's past, the climate was much colder. Huge sheets of ice called *glaciers* covered the land where people now live. In between these *ice ages*, the climate is warmer. Glaciers are only found near the North and South Poles.

Ice ages are caused by changes in the shape of Earth's orbit and the tilt of Earth's axis. These changes are very small. They cause Earth to get a tiny bit more or less of the sun's energy. A small change in the amount of energy going into the climate system makes a big difference.



Humans can also change the climate system. For the past few hundred years, people have burned fossil fuels. Burning coal produces electricity. Cars and trucks burn gasoline. Using these fossil fuels releases gases into the air.



Climates are dynamic over time—they change. Sometimes a dynamic system can produce extremes of climate or weather. *Extreme* means further away from the average. It can mean that some places have much colder winters than usual. A *record high* or *record low* temperature is one that has never been measured before. Record-breaking heat can result in more fires.

A hurricane is an example of an extreme change in a system. These storms get their power from warm ocean water. Warmer oceans cause stronger hurricanes that do more damage.

Main Science Idea

Dynamic means "constantly changing."

Wants, Needs, and Limits

Chapter 19

Weather hazards put people in danger. Engineers come up with solutions. For example, drivers are not able to see the road when it rains. Windshield wipers solve this problem. Problems might have more than one solution. How can people decide which to use?

To evaluate means to judge something. You may decide that something is useful or not so useful. You might judge an item as very important or not important at all. The middle of the word *evaluate* looks like the word *value*. When you evaluate something, you decide how much value it has.

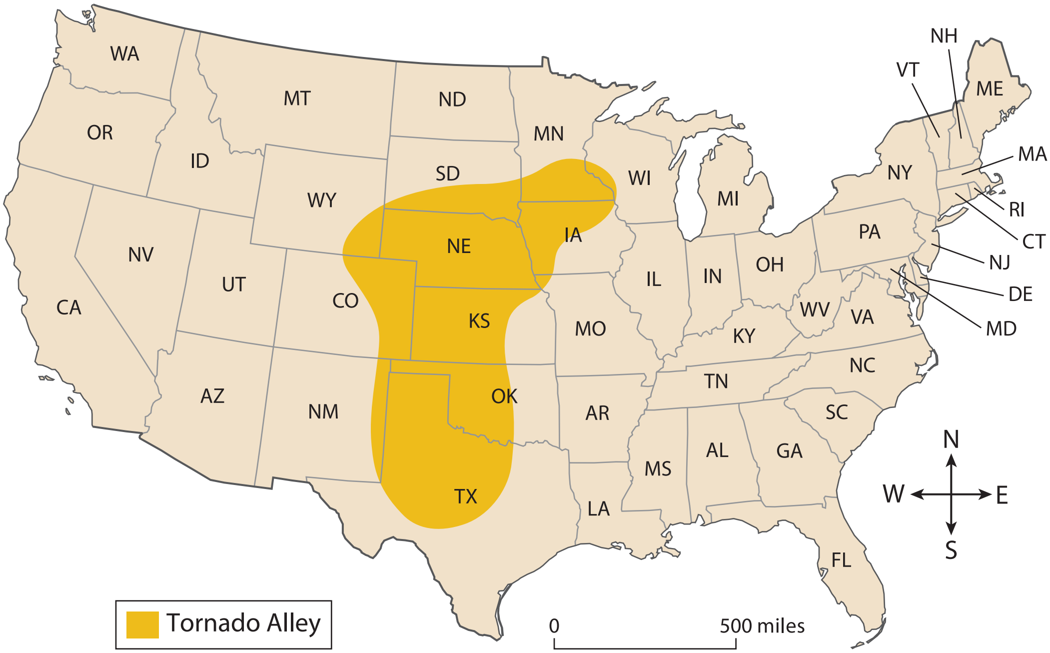
The goals or conditions that a solution must meet are criteria (or a *criterion* if there is only one). Criteria are like a checklist. They state what makes a solution a good one. Having clear criteria helps when we evaluate solutions.

Some Criteria for a Solution

PROBLEM: Tornado winds can destroy buildings. People need a way to be safe during tornadoes. The safest place to be is underground, such as in a basement.

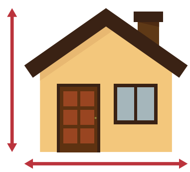
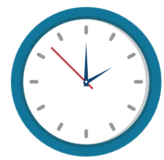
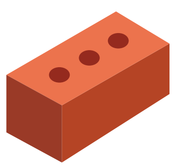
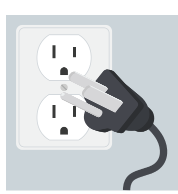
SOME CRITERIA: People have to get there quickly. The structure must be structurally solid.

SOLUTION: Everyone needs a way to quickly get underground when a tornado forms. Some building rules in "Tornado Alley" state that all homes must have basements. Apartment buildings must have tornado shelters in their basements that everyone living there can use.



A problem might have many possible solutions. However, some solutions will be too big, too small, too heavy, or too light. Some solutions will be too expensive or need materials you do not have. These are constraints, or limits. Constraints sometimes keep a solution from being the best it can be.

Types of Constraints

Size or weight  Examples: • Light enough to move around • Too heavy for strong wind to blow away	**Time**  Examples: • Can be built quickly • Needs to last a long time
Materials  Examples: • Easy to get in time • Needs to work in wet weather • Needs to insulate	**Cost**  Examples: • Need enough money to build it • Need to find materials that are affordable
Power  Examples: • Needs to work at night or in the dark • Does not need electricity	**Users**  Examples: • Easy for anyone to use • Can be used by elderly people

What Were the Constraints for These Solutions?

PROBLEM: Severe weather can damage electric power lines. People need to listen to radio updates during severe weather. Every home needs a cheap, easy way to do this.

SOLUTION: An emergency radio is useful in severe weather. It can be stored easily and moved to any room in a home. The radio can be powered by turning a hand crank.

SOME CONSTRAINTS: It must be affordable. It needs to be lightweight enough to carry. It must have a sturdy hand crank.

PROBLEM: People need to keep floodwater away from homes and businesses. Flooding does not happen often, but it can ruin buildings.

SOLUTION: A dam holds back water. Portable plastic dams are lightweight and come in many sizes. They can be rolled up when not needed and do not cost a lot of money.

SOME CONSTRAINTS: It needs to be affordable.
It should be easy to store.
It must be made of a reliable material.

Read about some problems caused by weather hazards. Think about solutions. Try to identify one criterion each solution must meet. Try to think of two constraints for each solution.

PROBLEM 1

Tumbleweeds are the dried parts of a Russian thistle. Bushy parts of the plant dry and fall off the stem. There are more tumbleweeds when the land becomes very dry.

Wind moves tumbleweeds, and they can be dangerous and annoying. They have sharp thorns that hurt animals. They stick together and can block roads and houses. In dry weather, they easily catch fire and spread it around. Tumbleweeds are a hazard in places where a drought is happening.

A county in a southwestern state has tumbleweeds in every area. It wants to get rid of tumbleweeds before the next drought.

PROBLEM 2

In winter, the temperature can drop so low that water freezes. Wet roads can become icy. Moving cars cannot stop quickly over ice.

A town sends out trucks to put rock salt on roads. The rock salt keeps water from freezing. But rock salt only works when it is a few degrees below freezing. It does not work at colder temperatures. It does not work as well on bridges.

Bridges are made of metal. When the temperature is below freezing, ice forms on bridges before it does on roads. Drivers might not expect a bridge to be icy. This can cause car accidents.

The town wants to make bridges safer in winter. The town does not have a lot of money. The solution must work with the trucks the town already uses. It cannot damage the bridges.

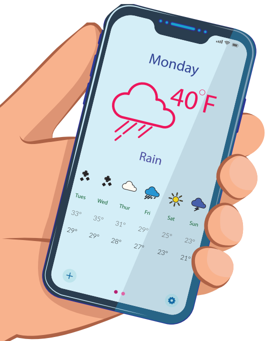
Main Science Idea

To solve a problem, we must identify everything that the solution needs to do. These are criteria. Some things limit our ability to solve a problem. These are constraints.

Science or Technology? Both!

Chapter 20

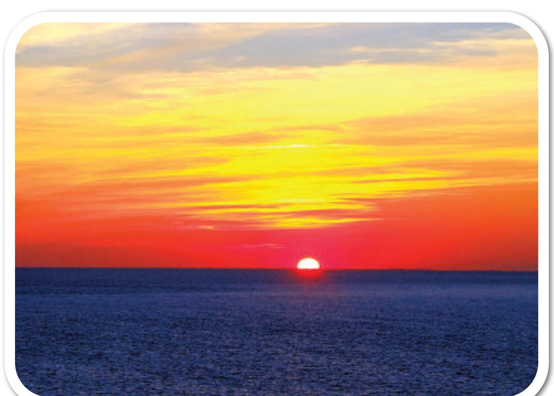
As Sara got ready for work, she could see a bright, clear sky from her sunny window. She grabbed her lunch bag, her jacket, and an umbrella. She also planned to pick up some groceries on her way home. A blizzard was coming, and she might be stuck in the house for a few days.



But how did she know all this?

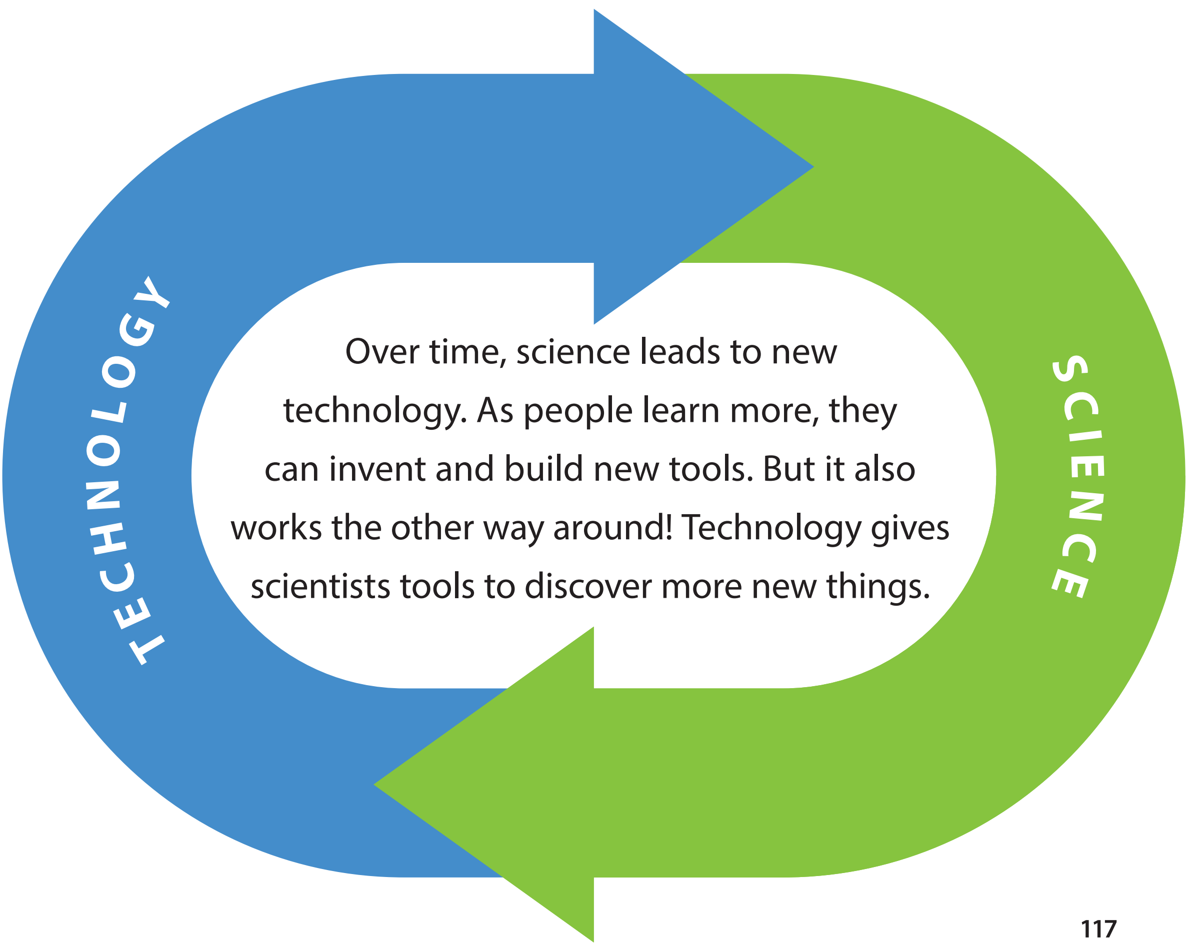
Sara had checked the weather forecast. She did this every day. How amazing it was that she could know the day, or even the hour, when rain would fall. She thought of the coming storm and was glad she had a warning.

But it wasn't always like this. Sara remembered her great-grandfather saying, "Red sky at night, sailor's delight. Red sky in the morning, sailors take warning." In his day, people looked at the sky for signs of changing weather. But predicting the weather even a few days ahead would have seemed like telling the future with a crystal ball.



Science and technology change what people can do in everyday life. Let's investigate how Sara gets a reliable weather forecast.

- **Technology** includes tools, such as thermometers and barometers. Technology can also be a process, or way of doing things, such as making weather forecasts and storm warnings.
- **Science** is how we understand the natural world. Knowing what air pressure and temperature make a blizzard likely is science.



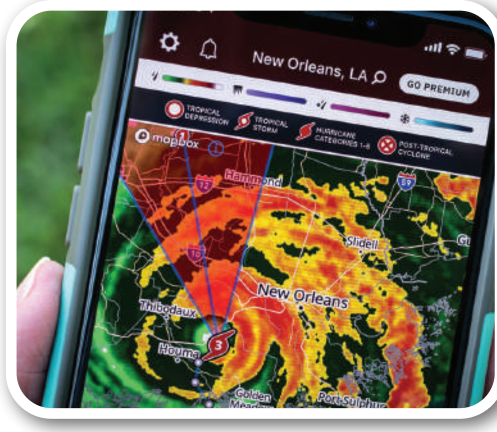
Nearly every building has a lightning rod. If it is struck by lightning, the metal rod carries the energy into the ground. Without it, lightning could damage the building. Benjamin Franklin invented the lightning rod in the 1700s.

Lightning rods are technology. They are simple to build. Why didn't people use lightning rods earlier? A lightning rod made sense only after people understood that lightning is electricity and then studied how electricity behaves. Benjamin Franklin first had to discover facts about lightning. His discoveries in science led to a new kind of technology. Science and technology go hand in hand.

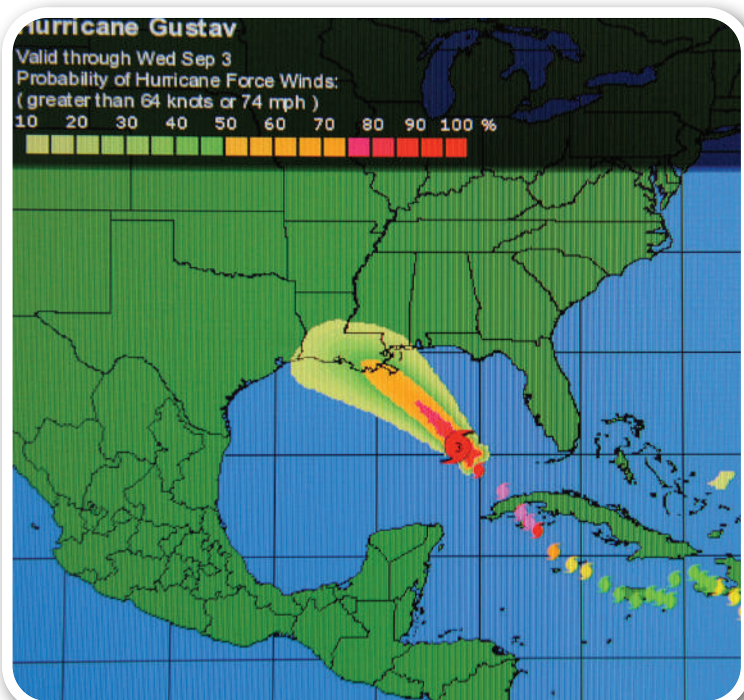
In the early 1800s, Christian Doppler discovered how waves change when they travel. In fact, the discovery is named after him. It is called the Doppler effect.

The Doppler effect is used in Doppler radar. This weather forecasting tool sends out waves, which bounce back. It measures the returning waves and compares them to the original waves.

Doppler radar creates images of things that are too far away to see. Meteorologists use Doppler radar to observe weather. It lets them make images to map precipitation that is happening far away. If you watch a weather report on TV, you will probably see a Doppler map.



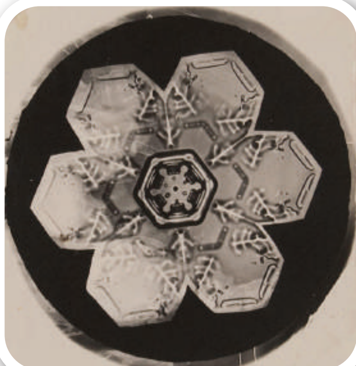
Meteorologists can also see how weather is moving. Doppler radar shows the paths of clouds and storms. This lets us predict where a storm is heading so we can forecast the weather.



How are science and technology related in these examples? To invent the lightning rod, someone had to first understand that lightning is electricity. What science had to come before the technology of Doppler radar?

Maybe the word *technology* makes you think of computers or smartphones. But any tool, even a pencil, is technology.

Wilson Bentley used microscopes and cameras to take pictures of snowflakes. This technology helped scientists figure out how snowflakes form. In this example, technology came first and supported science.



Weather satellites take pictures of clouds and precipitation and send the data back to Earth. This technology helps scientists get data and understand weather and climate.

How do weather satellites reach their orbits? Rockets launch them thousands of miles high! In the 1900s, NASA raced to send people into space. Scientists worked hard to make rocket technology better.

Satellites let people in different parts of the world communicate quickly. Before satellites, scientists needed to board ships to study the oceans and atmosphere. They would stay aboard for weeks or even months. Now, satellites let them control a research ship from far away. Technology makes science easier.

Every day, hundreds of weather balloons all rise into the atmosphere. Each one has a device called a *radiosonde*. It measures air pressure, temperature, and humidity. It sends data to scientists, who use it to make forecasts and study climate.

Léon Teisserenc de Bort first built weather balloons in the 1800s. He built them to study the atmosphere. He discovered that the atmosphere is made up of layers. Most weather happens in the lowest layer.

Main Science Idea

Science is a process of studying. Technology is the use of knowledge. We use science knowledge to develop technology. We use technology to help with science activities. Science and technology support each other.

Glossary

B

balance, n. a device used to determine the mass of an object

C

caliper, n. a device used to measure the inside or outside dimension of a shape that is less easily measured by a ruler

cause, v. to make something happen (also n. the reason something occurs)

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

control, n. part of a test or experiment that is kept the same in all trials

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

cycle, n. a series of events that repeat in the same order

D

data, n. factual information collected from observations

describe, v. to tell the characteristics of something

dynamic, adj. describing something that is continuously changing

E

effect, n. the outcome produced by a cause

estimate, v. to guess at a quantity without taking a precise measurement

evaluate, v. to form a judgement based on evidence

evidence, n. information that helps prove or disprove a conclusion

experiment, n. a scientific process used to test an idea or determine something

explanation, n. the stated reason for something or about how something happens

F

fact, n. a thing that is proved to be true

fair test, n. a controlled investigation in which only one variable changes while all other factors remain constant

flask, n. a clear glass laboratory container for measuring and holding liquid

function, n. the way something works or its purpose

G

graduated cylinder, n. a narrow, round, glass laboratory container for measuring liquid

H

hunch, n. an idea not yet proven with facts

hypothesis, n. a statement of an idea that is the starting point for an investigation based on limited evidence

I

investigate, v. to systematically observe, examine, or study

investigation, n. an instance of investigating

M

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

measure, v. to quantify by time, distance, volume, or mass

model, n. a representation of a thing or idea

O

observation, n. a noted detail

opinion, n. a belief about something that cannot be proven with factual evidence

P

pattern, n. a reliable sample that enables predictability of characteristics or occurrences

R

relationship, n. the way in which two or more things are connected

relevant, adj. providing evidence that matters

reliable, adj. able to be trusted

S

sample, n. a small part that helps show that the whole is like

scale, n. an instrument for weighing; *or* a range of comparisons

scale model, n. a physical model in which all parts are equally smaller or larger than the real thing they represent

science, n. a system of knowledge and investigation to determine the truth and physical laws governing phenomena

spring scale, n. a device used to determine the weight of an object

stability, n. the tendency of something to remain undisrupted

structure, n. the pattern of organization of the materials that make something up

system, n. a set of parts that work together and affect each other

T

technology, n. the use of science in devices or processes to solve problems

test, n. to systematically observe outcomes from the manipulation of variables

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

V

variable, n. a factor in a test that is changed or changes so the outcome of the change can be observed

visualize, v. to form a mental image of something

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Jerome Wilson / Alamy Stock Photo: 118b
Joanne Dale / Alamy Stock Photo: 89b
Jodi Payne / Stockimo / Alamy Stock Photo: 103b
John Sirlin / Alamy Stock Photo: 69b, 92
John Trevor Platt / Alamy Stock Photo: 67b
Jonathan Larsen/Diadem Images / Alamy Stock Photo: 114
José María Barres Manuel / Alamy Stock Photo: 78a
Juris Teivans / Alamy Stock Photo: 109a
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