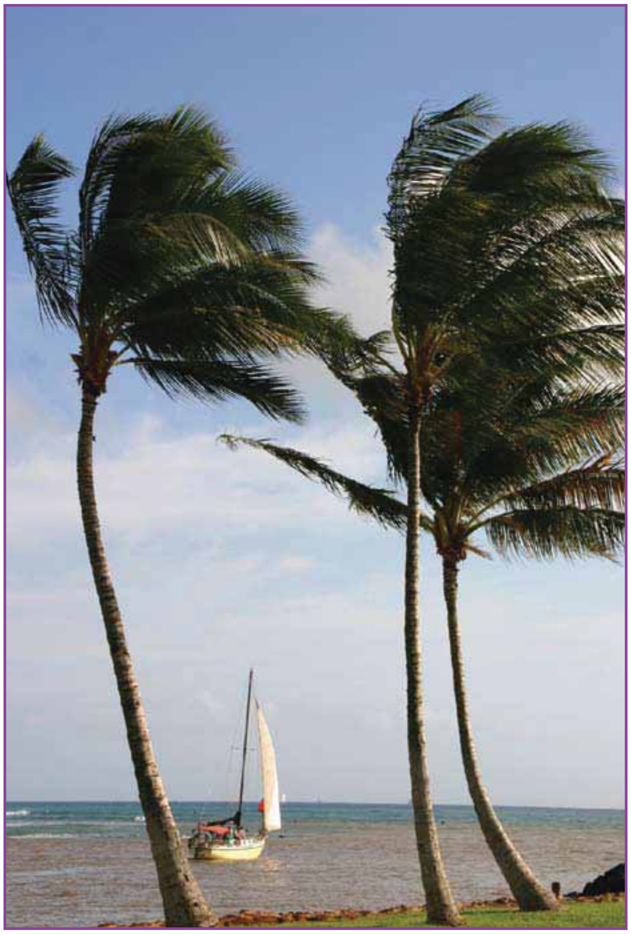
Learning Set 1

What Is Air?

In the parable about Malaire, you explored pollution. Before you can fully understand air pollution, you must first learn about air. You may not have thought much about air in the past, but you probably know something about it. You might tell people that you breathe air. You blow air into a balloon and pump air into your bike tires. How much do you really understand about air? It is important to think about what you know about air before you answer the *Big Question* for this Unit. The demonstrations in this section will help you learn more about air.



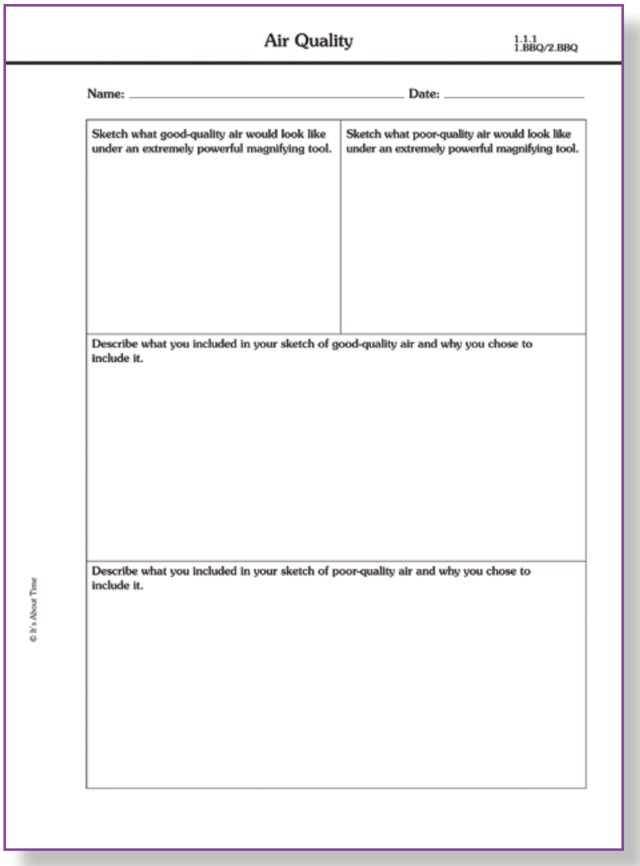
Wind is moving air that blows the leaves of trees and the sails of sailboats.

1.1 Understand the Question

What Is Air?

Imagine you could look at a sample of good-quality air through an extremely powerful magnifying tool, so powerful it could see the smallest parts that make up air. What do you think the air would look like? What would a sample of poor-quality air look like? How might good-quality air look different from poor-quality air?

Sketch two pictures. In one, sketch your idea of what clean (good-quality) air would look like if you could see it through the powerful tool. In the second picture, sketch what you think polluted (poor-quality) air would look like through the same tool. Put as much detail as you can into your pictures. Be prepared to present your sketches to your group. Do not worry if you do not know a lot now. You will add to your knowledge as you complete this Unit.


Air Quality

1.1.1
1.BBQ/2.BBQ

Name: ______________________ Date: __________

Sketch what good-quality air would look like under an extremely powerful magnifying tool.	Sketch what poor-quality air would look like under an extremely powerful magnifying tool.
Describe what you included in your sketch of good-quality air and why you chose to include it.	
Describe what you included in your sketch of poor-quality air and why you chose to include it.	

Conference

Share your sketches with your group members. When you present your sketches, be as clear as you can about what each item in your drawing represents and how any parts in your sketch are related to one another.

In your group, make one list of similarities and another of differences among the sketches. If you are not sure about the details of someone's sketch, ask questions to help you understand. For example, ask what the different parts of the sketch represent. How big are the parts shown in the sketch? What shape are they? Find out if the parts are moving or still.

Communicate

Investigation Expo

Make a poster with your sketches, and post it so others can examine it. On your poster, include your group members' sketches and the lists of similarities and differences you developed. Use the sketches that members of your group created to show examples of what your list items mean.

As you walk around and look at the other posters, compare your ideas about what air looks like with the other groups' ideas. Ask questions if you do not understand another group's sketches. Be sure to ask your questions respectfully. As you examine the other sketches, make lists of similarities and differences among the sketches. Then, as a class, answer the following questions:

1. What are common components of the sketches of good-quality air? What unique ideas do students have?
2. In the sketches, what are the most common components of poor-quality air? How are these sketches different from the sketches of good-quality air?

Reflect

It is difficult to draw air. Your class probably has many different ideas about what good-quality air and poor-quality air look like. Some students probably think clean air is empty space or is not made of anything. Some students probably described many different substances in clean air, and others described only one. Some of you sketched air with particles shown by dots, and in some of those sketches, the particles were moving. If scientists were arguing about whether air is empty space or made of particles, they would collect data and use it as evidence to find out what air is. Answering the questions below will help you identify evidence that will tell you if air is empty space or made of particles. Be prepared to discuss your answers to the questions with the class.

1. You cannot see air, and you cannot touch air. What evidence, then, could help you determine if clean air is made of particles or is just empty space?
2. If air is made of particles, what do you need to investigate to find out if the particles are moving or still?

Update the *Project Board*

In this section, you sketched and described what you think good-quality air and poor-quality air look like. Update the *Project Board* by adding ideas from your sketches and discussions in the *What do we think we know?* column. You have also discussed what makes up air. Some students may think it is empty space, and some students may think that substances make up air. Be sure to add the ideas your group agreed on and ideas you are not sure about to the *Project Board*. You may have questions about what air looks like, what it contains, and the relationship between air and pollution. You may have ideas for investigations to find out more about what air is. Record your questions and ideas for investigations in the *What do we need to investigate?* column.

What's the Point?

You imagined you were looking through an extremely powerful magnifying tool at samples of good-quality air and poor-quality air. Your ideas may have differed from the ideas of others. You may have thought air looks like dots, or you may have thought that air looks more like a cloud. Your sketch may have contained particles that were moving or particles that were still. Or, you may have thought that air looks like empty space. Before scientists can fully describe a new substance, they must gather evidence.

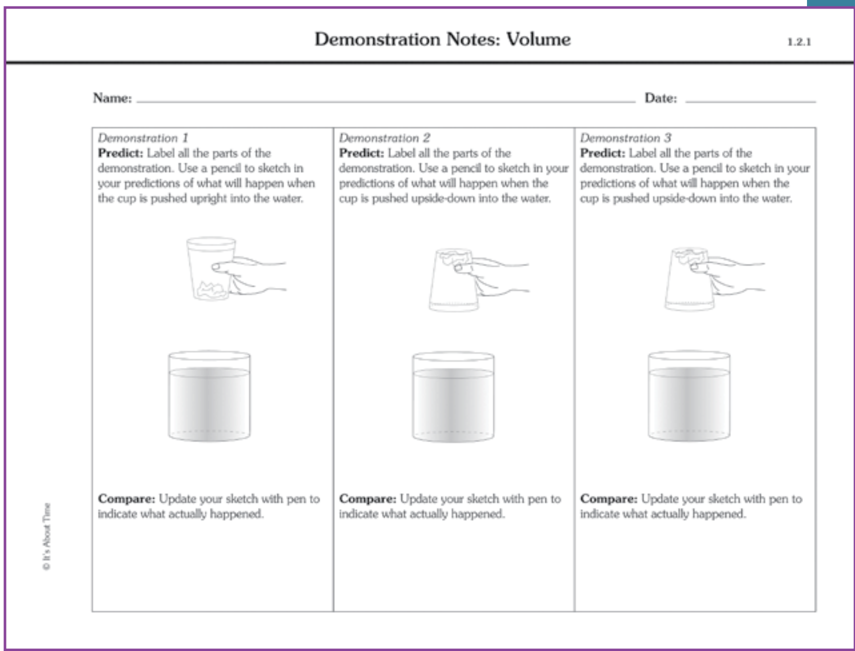
1.2 Investigate

Does Air Take Up Space?

When scientists examine a substance, they investigate its properties, or its characteristics. One property they might investigate is how much space it takes up. Investigating this property of air will help you understand more about what air is.

Demonstrations

You will observe three demonstrations to help you think about whether air takes up space. In each demonstration, a cup that contains a paper towel is pushed into a bowl of water. Pay attention to the paper towel and whether or not it gets wet. Look for evidence of the role air may play in whether the paper towel gets wet. In each demonstration, ask yourself where the air is in and around the cup, and what happens to the air as the cup enters the water.



Demonstration Notes: Volume 1.2.1

Name: Date:

Demonstration 1	Demonstration 2	Demonstration 3
Predict: Label all the parts of the demonstration. Use a pencil to sketch in your predictions of what will happen when the cup is pushed upright into the water.	**Predict:** Label all the parts of the demonstration. Use a pencil to sketch in your predictions of what will happen when the cup is pushed upside-down into the water.	**Predict:** Label all the parts of the demonstration. Use a pencil to sketch in your predictions of what will happen when the cup is pushed upside-down into the water.
Compare: Update your sketch with pen to indicate what actually happened.	**Compare:** Update your sketch with pen to indicate what actually happened.	**Compare:** Update your sketch with pen to indicate what actually happened.

During each demonstration, you will be asked to do three things:

Predict—Make a prediction about what will happen based on your ideas about whether air takes up space.

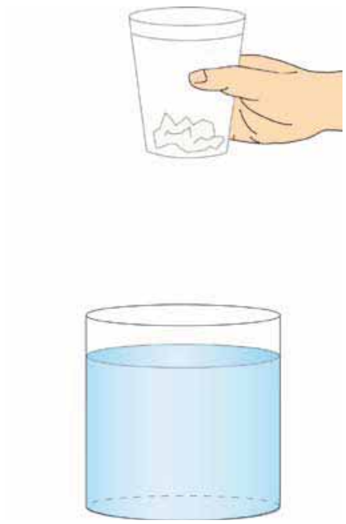
Observe—Observe the demonstration and record your observations.

Compare—After the demonstration, you will compare your predictions to what you observed. Note what you predicted correctly and what surprised you.

You will record all of your predictions, observations, and comparisons on a *Demonstration Notes: Volume* page. After you have seen all of the demonstrations, you will make a claim about whether air takes up space.

Demonstration 1: Upright Cup, Paper Towel, Water

In this demonstration, a cup with a paper towel taped inside will be pushed upright (open end up) into a bowl of water until the water is above the rim of the cup.



Demonstration 1

Predict—In the *Demonstration 1* sketch on your *Demonstration Notes: Volume* page, use a pencil to label all the parts of the demonstration: cup, paper towel, bowl of water, and where you think there is air in the cup.

- Sketch your prediction of what will happen to the air in the cup after the cup is pushed upright into the water.
- Label the drawing to show what will happen to the paper towel when the cup is pushed upright into the water.

Observe—Observe what happens when the upright cup is pushed into the water. Watch the level of the water in the bowl. Does it go up, down, or stay the same? If it changes, how much does it change? Pay special attention to what happens to the paper towel and what happens to the air in the cup.

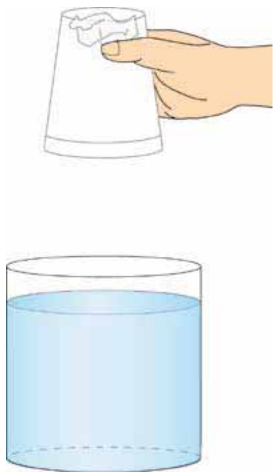
Compare—Update your original sketch under *Demonstration 1.* Use a pen to label the actual location of air and water in the cup. Think about how the results compare with your prediction. If your prediction differs from the actual results, record why you think the actual results were different.

Stop and Think

1. Describe what happened to the paper towel in the cup when the cup went into the water.
2. Describe what happened to the air when the cup was put into the water.
3. What happened to the level of the water in the bowl? If it changed, how much did it change? How did you observe this result?
4. How do you think what happened to the air affected the paper towel?

Demonstration 2: Upside-down Cup, Paper Towel, Water

In *Demonstration 2,* a dry cup with a dry paper towel taped inside will be pushed into the water upside down until the cup is completely below the water.



Demonstration 2

Predict—When you are making your predictions, begin by thinking about the results of the first demonstration and what you observed that might help you make a good prediction for this demonstration. Think about how the position of the cup (upright or upside down) affects the air in the cup.

In the *Demonstration 2* sketch on your *Demonstration Notes: Volume* page, label all of the parts of the demonstration: cup, paper towel, bowl of water, and where you think there is air in the cup.

- Use a pencil to sketch your prediction of what you think will happen to the air in the cup after the cup is pushed upside down into the water. Label the location of where air will be in the cup when the cup is underwater.
- Label the drawing to show what will happen to the paper towel when the cup is pushed upside down into the water.

Observe—Observe what happens when the cup is pushed upside down into the water. Watch the level of the water in the bowl. Does it go up, down, or stay the same? If it changes, how much does it change? Pay special attention to what happens to the paper towel and what happens to the air in the cup.

Compare—Update your original *Demonstration 2* sketch based on what you saw in the demonstration. Use a pen to label the actual location of air and water in the cup. How did the results compare with your prediction? If your prediction differed from the actual results, record why you think the actual results were different.

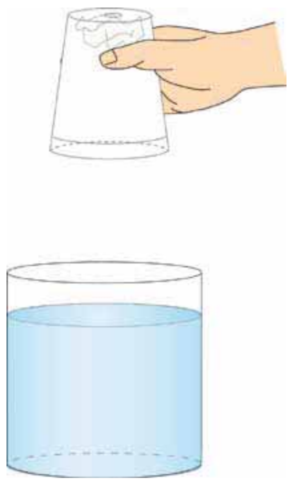
Stop and Think

1. Describe what happened to the paper towel in the cup when the cup went into the water.
2. Describe what happened to the air when the cup was put into the water. How did what happened to the air affect the paper towel?
3. What happened to the level of the water in the bowl? If it changed, how much did it change? How did you observe this result? Why did the result differ from *Demonstration 1*?
4. How did the results of *Demonstration 2* differ from the results of *Demonstration 1*? How did the position of the cup affect the results?

These demonstrations helped you think about whether air takes up space. Only if air takes up space would the paper towel in *Demonstration 2* stay dry. The results of *Demonstration 2* might have surprised you. These results should help you think about whether air takes up space.

Demonstration 3: Upside-down Cup With Hole, Paper Towel, Water

Demonstration 3 is the same as *Demonstration 2,* except the cup now has a hole in the bottom. This cup, with a paper towel taped inside to the bottom, will be pushed upside down into a bowl of water until the cup is completely below the water. Before you make your predictions, think about the other demonstrations. Think about how having a hole in the bottom of the cup will affect the paper towel and the air in the cup.



Demonstration 3

Predict—In the *Demonstration 3* sketch on your *Demonstration Notes: Volume* page, label all of the parts of the demonstration: cup, paper towel, bowl of water, and where you think there is air in the cup.

- Use a pencil to sketch your prediction of what will happen to the air in the cup after the cup is pushed upside down into the water. Label the location of air in the cup when the cup is under water. Indicate in your drawing how the hole in the cup affects the air in the cup.

Observe—Observe what happens when the cup with the hole is pushed upside down into the water. Watch the level of the water in the bowl. Does it go up, down, or stay the same? If it changes, how much does it change? Pay special attention to what happens to the paper towel and what happens to the air in the cup.

Compare—Update your original *Demonstration 3* sketch based on what you saw in the demonstration. Use a pen to label the actual location of air and water in the cup. How did the results compare with your prediction? If your prediction differed from the actual results, record why you think the actual results were different.

Stop and Think

1. Describe the results of *Demonstration 3*. What happened to the paper towel in the cup? What happened to the air in the cup?
2. What happened to the level of the water in the bowl? If it changed, how much did it change? How did you observe this result? Why did the result differ from *Demonstration 2*?
3. How did the results of this demonstration differ from the results of the other two demonstrations?
4. In the sketch for *Demonstration 3,* trace the path the air took during the demonstration.

Reflect

Discuss the answers to the following questions with the class.

1. What made the results of the three demonstrations so different?
2. You were looking for evidence that air takes up space. What did these three demonstrations tell you about whether or not air takes up space?

volume: a measure of how much space something takes up.

Volume

In the demonstrations, you were looking for evidence that air takes up space. You may have made some conclusions about this based on the demonstrations. Scientists call the amount of space a substance takes up **volume**. The cup and the water in the demonstrations took up space. The paper towel also took up space. It makes sense that all these parts of the system have volume. The question is whether air takes up space as well.

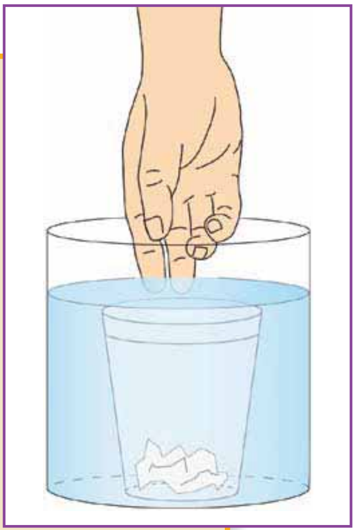
When an object takes up space, only that object can be in that space at any one time. For example, if you sit in a chair, another person cannot sit in that same chair at the same time. You are already taking up the space in the chair. You have volume. Does air have volume, too?

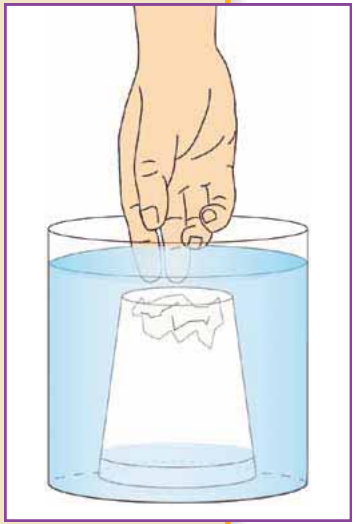
The three demonstrations you observed provide evidence that air takes up space, and therefore, has volume.

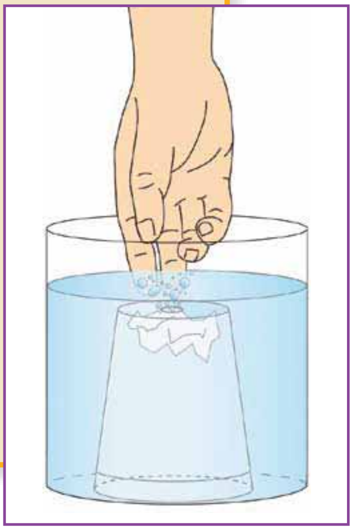
- When a cup containing air and a paper towel is pushed upright into a bowl of water, the water rushes into the cup and pushes out the air. Only one object can be in one place at a time. The water rushing into the cup takes the place of the air that was in the cup. As a result, the paper towel in the cup gets wet. The level of the water in the bowl rises a very small amount because the cup and paper towel take the place of some of the water.

- When a cup is pushed into the water upside down, the paper towel stays dry. In the upside-down cup, air takes up space in the cup and stays in the cup as it is lowered into the water. The water cannot push the air out. There is no way for the air to escape from the cup. The paper towel does not get wet because the water cannot reach it. In *Demonstration 2*, air takes up the space inside the cup. Because two things cannot occupy the same space, water cannot fill the space inside the cup if air is already there. The level of water in the bowl rises higher than in *Demonstration 1* because now the cup, the paper towel, *and* the air are taking the place of some of the water.

- The hole in the cup in *Demonstration 3* allowed the air in the upside-down cup a way to escape. The air in the space in the cup is pushed out of the hole by the water. The cup fills with water, and the paper towel gets wet. The level of the water in the bowl will rise the same distance as in *Demonstration 1*. The bubbles you saw are an indication of air escaping from the cup.


Demonstration 1


Demonstration 2

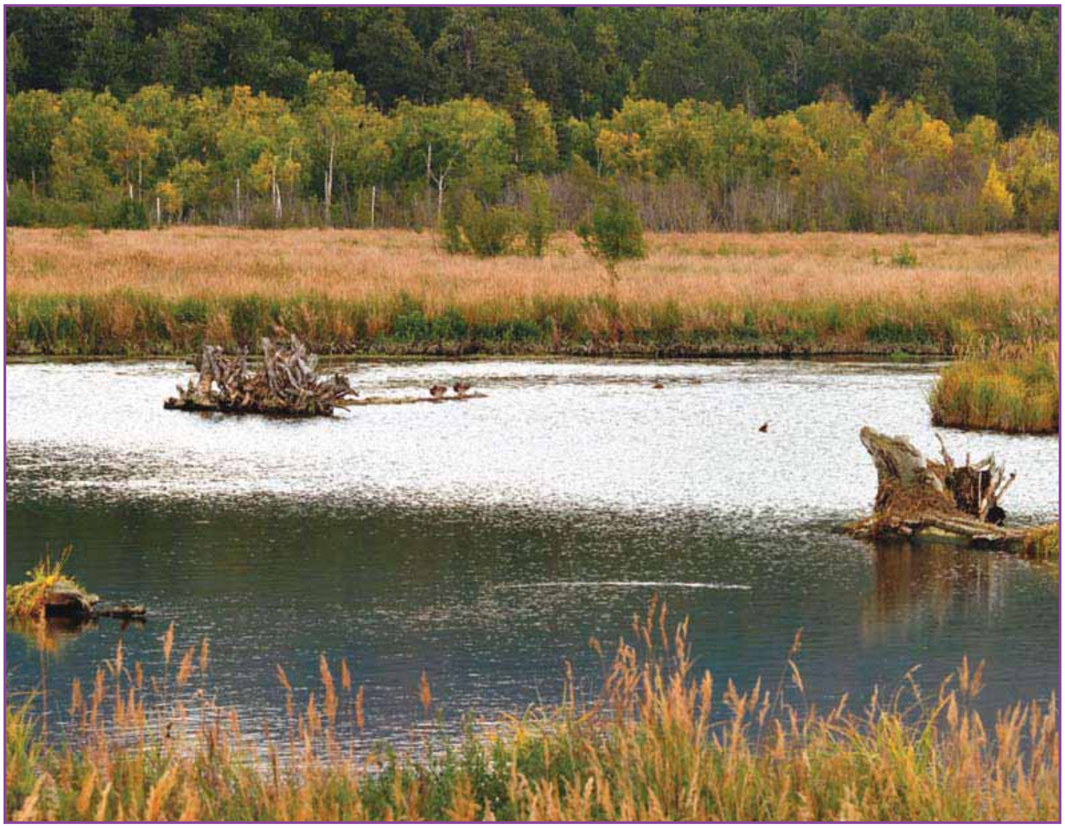

Demonstration 3

Reflect

1. Using the information from the demonstrations and from the reading, describe why you think air takes up space.
2. Describe another example that tells you that air has volume.

What's the Point?

To determine if air takes up space, you observed demonstrations involving water, a cup, and a paper towel. The demonstrations supported the idea that air takes up space. A measure of how much space something takes up is its volume. Volume is a property of any substance. The demonstrations provided evidence that air has volume.



You cannot see air with the unaided eye. Therefore, it is difficult to determine if air has volume.

1.3 Investigate

Does Air Have Mass?

A water bottle with no water in it is sitting on the table. Your friend says the bottle is empty. What would you tell your friend about the bottle? Would you describe the bottle as empty?

You know that one property of a substance is volume (how much space it takes up). Another property of a substance is how much "stuff" it contains. How much "stuff" something contains is its **mass**. Think about the "empty" bottle again. Do the contents of the "empty" bottle have mass? How would you find out?

Scientists measure mass using an instrument called a **balance**. In investigations of substances, scientists have discovered that some things have more mass than other things. A bowling ball has more mass than a golf ball. A golf ball has more mass than a table-tennis ball.

mass: the amount of "stuff" something contains.

balance: an instrument used by scientists to measure mass.

Is the bottle empty?

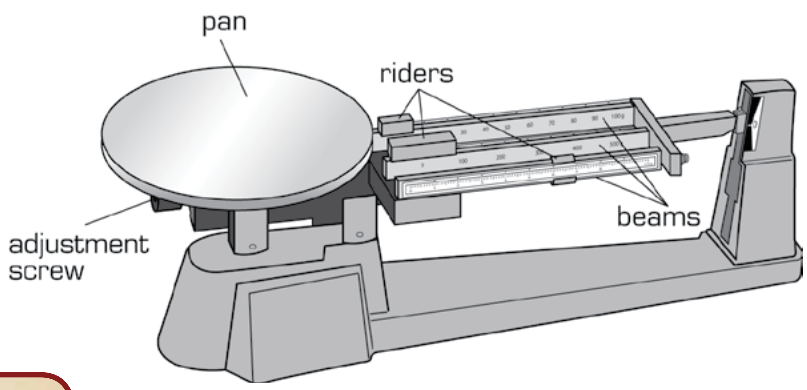
Be a Scientist

Using a Balance to Measure Mass

If you were a scientist and wanted to investigate a substance, you would probably measure its mass.

Scientists can use two types of balances to measure mass: a triple-beam balance or an electronic balance. A triple-beam balance acts like a scale in a doctor's office. In the doctor's office, you step onto the scale, and the nurse slides weights along beams until the scale is balanced.

Triple-Beam Balance

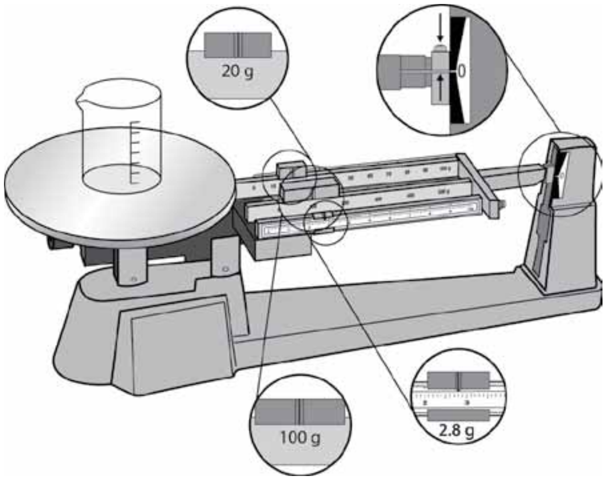


Most doctors use a triple-beam balance to determine a patient's weight.

The first step to measuring the mass of a solid object is to make certain the pointer is lined up with 0.00 g. The next step is to put the object on the pan. Once the object is on the pan, move the riders along the beams until the pointer again lines up with 0.00 g. Then you add the masses on each rider to find the total mass of the object.

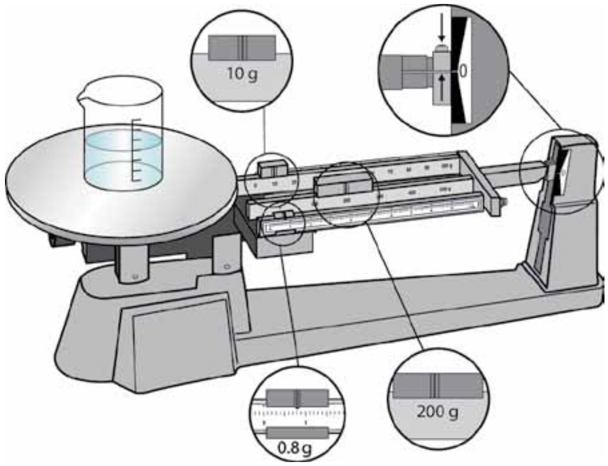
To measure the mass of a liquid such as water or a loose substance such as salt, you must put the substance in a container before measuring its mass. You do not want to include the mass of the container in your measurement. You must first measure the mass of the empty container. Then, measure the mass of the substance in the container. This is called "taring" the container.

Before and after measuring the mass of a substance, make sure the pointer of the balance is on 0.00 g.

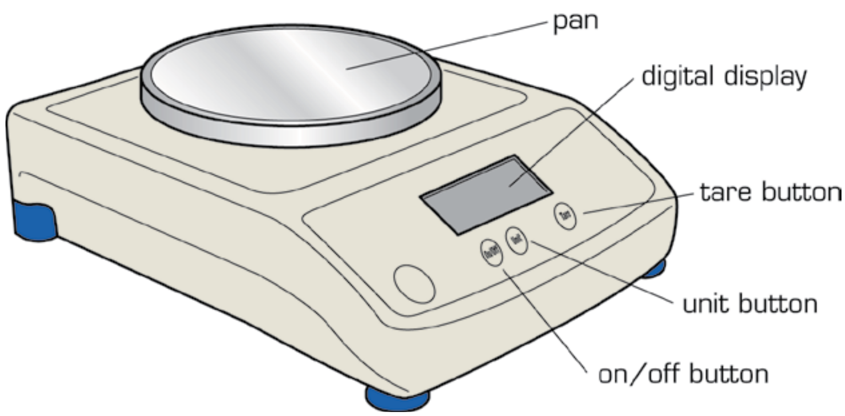


Subtracting the mass of the container from the mass of the substance and container will give you the mass of the substance alone.

When measuring mass using an electronic balance, you place the object you are measuring on the pan. Then you turn on the device and choose the unit of measurement. You read the measurement on the digital display. Some electronic balances have a tare button. This button lets you place a container on the balance and automatically subtract out the mass of the container. This saves you from having to take separate measurements and then subtract the mass of the container from the total mass.



Electronic Balance



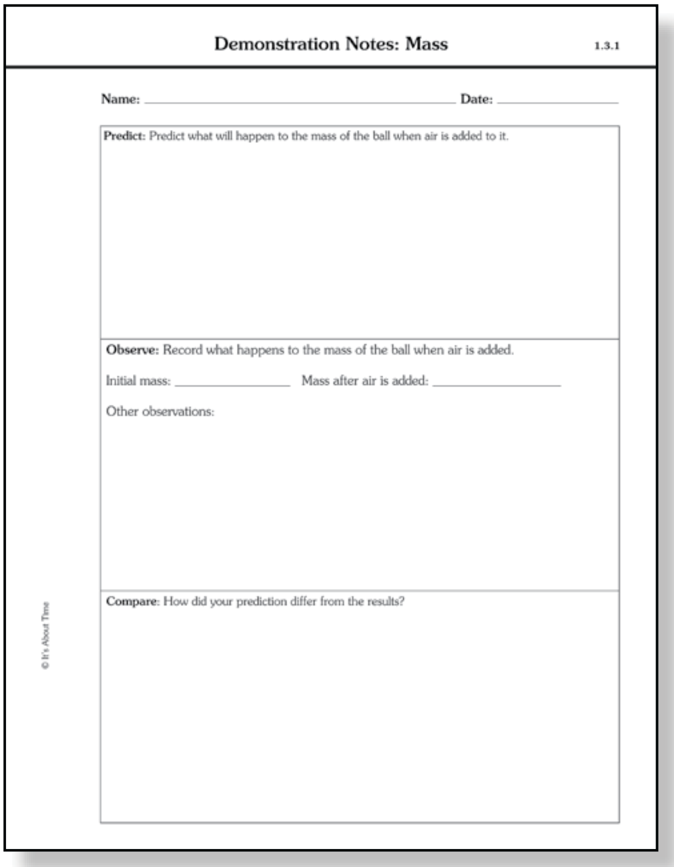
In this section, you are trying to determine if air, like other objects, has mass. Think about this as you are observing the demonstration.

Demonstration

In this demonstration, air will be added to a deflated ball. The process is similar to the one described for measuring the mass of objects in a container. First, a balance will be used to measure the mass of a deflated ball. Then, air will be added to the ball, and the mass of the ball will be measured again.

During the demonstration, as a class, you will be asked to predict, observe, and compare.

You will record all of your predictions, observations, and comparisons on a *Demonstration Notes: Mass* page.



Demonstration Notes: Mass 1.3.1

Name: ____________ Date: ____________

Predict: Predict what will happen to the mass of the ball when air is added to it.

Observe: Record what happens to the mass of the ball when air is added.

Initial mass: ____________ Mass after air is added: ____________

Other observations:

Compare: How did your prediction differ from the results?

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Predict—Predict what will happen to the mass of the deflated ball when air is added to it. Think about what the results should be if air has mass. After air is added, will the mass of the inflated ball be more, less, or the same as the mass of the deflated ball?

Observe—Record the mass of the deflated ball. Now observe what happens to the mass of the ball when air is added and the mass of the ball is measured again. Is the mass of the ball now more, less, or the same? If the mass has changed, how much did it increase or decrease?

Compare—How did the results of the demonstration compare with your prediction? Describe what happened to the ball when air was added. If your prediction differed from the actual results, record why you think the results were different.

Reflect

1. Come to a class agreement on the question for this section, *Does air have mass?*
2. How did the results of the demonstration help you determine if air has mass? Support your conclusion with evidence from the demonstration.

Matter

Anything that has both volume and mass is called **matter**. Matter is a term used to describe every substance that takes up space and has mass. Rocks, lemonade, and helium in a balloon are examples of matter because they have volume and mass.

matter: anything that has volume (takes up space) and has mass.

Properties of Matter

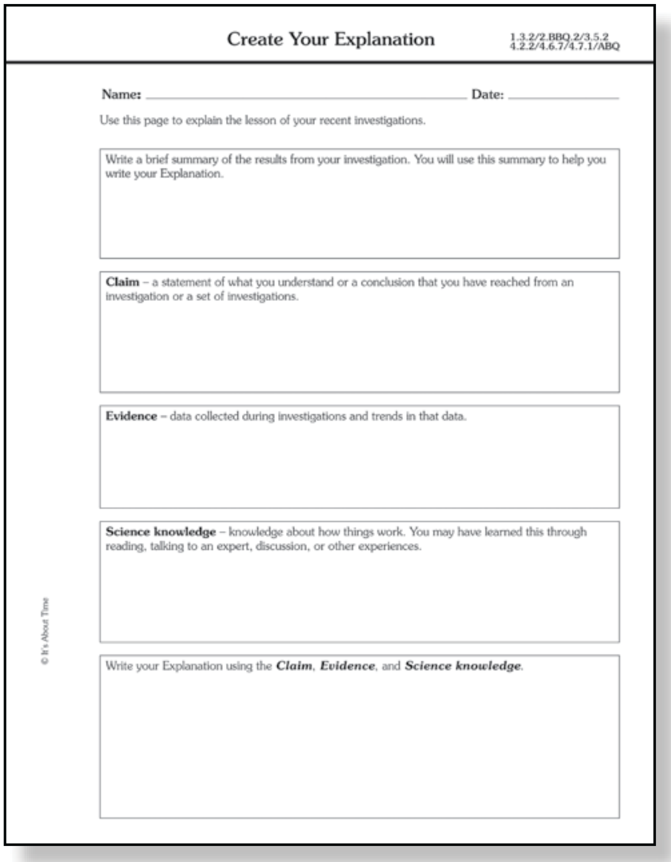
Volume and mass are two examples of physical properties of matter. A physical property of matter is a characteristic that you can observe without changing the nature, or composition, of the matter. Shape, color, odor, texture, and temperature are other physical properties of matter.

A train is matter. It has mass and volume.

Reflect

Think about all the demonstrations you have seen.

1. What evidence do you have that air has volume?
2. What evidence do you have that air has mass?
3. Now that you have learned what matter is, how can you use the evidence from the demonstrations to decide if air is matter?



Create Your Explanation 1.3.2/2.BBQ.2/3.5.2 4.2.2/4.6.7/4.7.1/ABQ

Name: Date:

Use this page to explain the lesson of your recent investigations.

Write a brief summary of the results from your investigation. You will use this summary to help you write your Explanation.

Claim – a statement of what you understand or a conclusion that you have reached from an investigation or a set of investigations.

Evidence – data collected during investigations and trends in that data.

Science knowledge – knowledge about how things work. You may have learned this through reading, talking to an expert, discussion, or other experiences.

Write your Explanation using the ***Claim***, ***Evidence***, and ***Science knowledge***.

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Explain

You have investigated whether air has mass. Earlier you investigated whether air has volume. Now use the evidence from your observations to make a claim about whether air is matter. Use a *Create Your Explanation* page to develop an explanation of your claim and support it with evidence. The results from the demonstrations are your evidence. You may have some science knowledge from your own experiences or from readings. Record all this information in the appropriate boxes. Then write a statement connecting your evidence and science knowledge to support your claim. This is your explanation. You do not know a lot of science knowledge to record yet. You will have a chance later, after you know more about air, to revise your claim and explanation.

Communicate

Share Your Explanation

Share your group's claim and explanation with the class. Share how you supported your claim with evidence and science knowledge. Pay special attention to how the other groups have supported their claims with science knowledge. Ask questions or make suggestions if you think a group's claim is not as accurate as it could be or if the group has not supported their claim well enough with evidence and science knowledge.

Reflect

1. Think back to the "empty" bottle at the beginning of this section. When your friend says the bottle is empty, you disagree. Using your explanation of air as matter, describe why the water bottle is not empty.

2. Describe a different way you might teach another student that air is matter.

3. Air has volume and mass. Air is matter. What is the relationship between air as matter and air quality? How does this change what you think about air quality?

Update the *Project Board*

In the demonstrations, you explored the volume and mass of air. You also made a claim about the properties of air. Add to the *What are we learning?* column of the *Project Board* what you now know about the relationship between volume, mass, and matter. Use the results from the demonstrations as supporting evidence in the *What is our evidence?* column. You may have ideas about investigations to find out more about what air is. Record your questions and ideas for investigations in the *What do we need to investigate?* column.

How can you improve air quality in your community?

What do we think we know?	What do we need to investigate?	What are we learning?	What is our evidence?	What does it mean for the challenge or question?

What's the Point?

Matter is defined as anything that has volume and mass. In the previous section, you found that air has volume. In this section, you investigated whether air has mass. When air was added to a deflated ball, the mass of the ball increased. Because only air was added to the ball, the change in mass must have come from the air. Therefore, air has mass. Because air has volume and mass, air is matter.

1.4 Investigate

What State of Matter Is Air?

When you look around, everything you see is matter. Everything takes up space and has mass. You can sit in a chair. It is hard and always the same. It has mass and takes up space. You can fill a sink with water, and when you spill water on the floor, it forms a puddle. Whether in the sink or on the floor, the water has mass and takes up space. The air you breathe is also matter. But air is a very different type of matter than a chair or water. You cannot sit on air, and you cannot see it. It does not form puddles on the floor. Chairs, water in a puddle, and air are examples of different **states** of matter. These states differ in very specific ways.

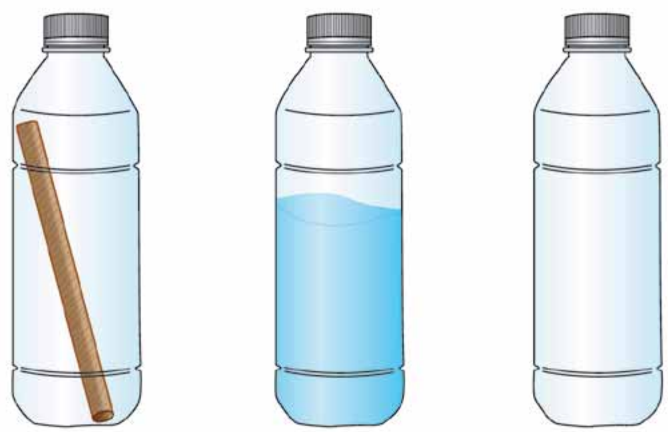
state: form, type, or kind.

Two characteristics of matter—volume and shape—can help you determine its state. Volume and shape are different for each state of matter. You may already have some ideas about the volume and shape of different states of matter. In this section, you will investigate these properties of states of matter.

Demonstration

How Can You Describe States of Matter?

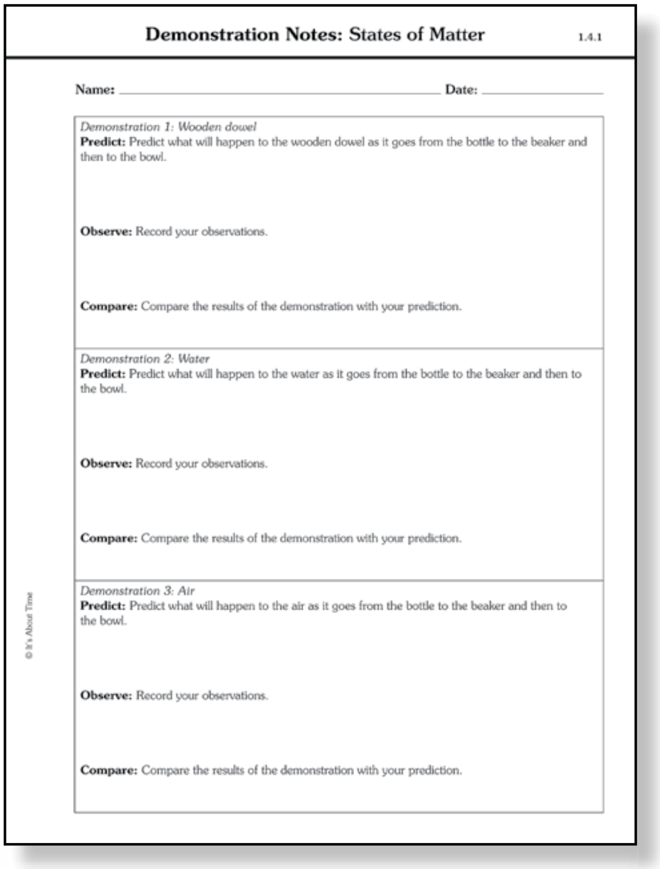
You will observe the contents of three bottles similar to the ones in the diagram below. Each bottle contains matter in a different state. One bottle contains a wooden dowel, one contains water from a faucet, and one contains air.



Each bottle contains matter in a different state.

Before observing the demonstration, discuss with your group the contents of each of the bottles.

- How do you know that each bottle contains matter? Support your answers using the results of the demonstrations in the previous sections.



Demonstration Notes: States of Matter 1.4.1

Name: ______ **Date:** ______

Demonstration 1: Wooden dowel
Predict: Predict what will happen to the wooden dowel as it goes from the bottle to the beaker and then to the bowl.

Observe: Record your observations.

Compare: Compare the results of the demonstration with your prediction.

Demonstration 2: Water
Predict: Predict what will happen to the water as it goes from the bottle to the beaker and then to the bowl.

Observe: Record your observations.

Compare: Compare the results of the demonstration with your prediction.

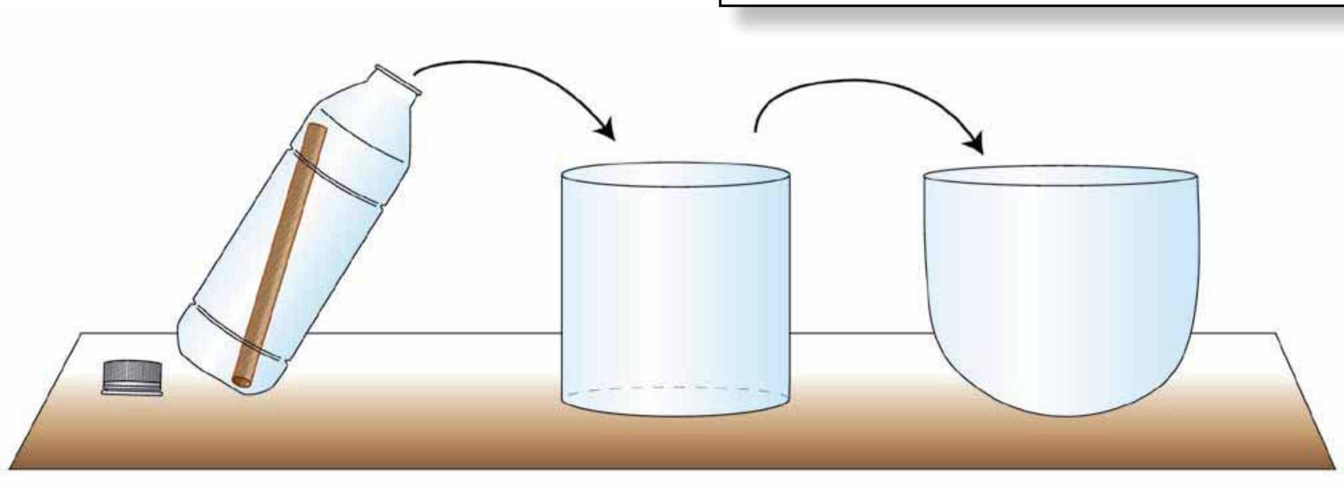
Demonstration 3: Air
Predict: Predict what will happen to the air as it goes from the bottle to the beaker and then to the bowl.

Observe: Record your observations.

Compare: Compare the results of the demonstration with your prediction.

You will be observing while the contents of each bottle are moved from the bottle to a beaker, and then, from the beaker to a bowl. As you observe this demonstration, pay close attention to what happens to the shape and volume of the matter in each bottle as it moves from one container to another. After observing the demonstration, you will decide how to describe a state of matter by its volume and shape.

During the demonstration, you will be asked to predict, observe, and compare.



Predict—Make three predictions.

- Make a prediction about the wooden dowel in the bottle. What do you think will happen to the wooden dowel when it is moved from the bottle to a beaker, and then to a bowl? How will the volume of the wooden dowel change? How will the shape of the wooden dowel change?

Include the reasons for what you think will happen. Record your predictions and reasoning on your *Demonstration Notes: States of Matter* page.

- Make a prediction about the water in the bottle. Predict what will happen to the water when it is moved from the bottle to a beaker, and then to a bowl. How will the volume of the water change? How will the shape of the water change? Include the reasons for what you think will happen. Record your predictions and reasoning on your *Demonstration Notes: States of Matter* page.

- Make a prediction about the air in the bottle. Predict what will happen to the air when it is moved from the bottle to a beaker, and then to a bowl. How will the volume of the air change? How will the shape of the air change? Include the reasons for what you think will happen. Record your predictions and reasoning on your *Demonstration Notes: States of Matter* page.

Observe—Record your observations of any changes in shape or volume as the wooden dowel is moved from the bottle to the beaker, and then to the bowl, on your *Demonstration Notes: States of Matter* page. Repeat your observations for the bottles of water and air.

Compare—Compare the results of the demonstration with your predictions.

Wooden dowel

- What happened to the volume of the wooden dowel as it was moved from one container to another? What happened to the shape of the wooden dowel as it was moved from one container to another? What conclusions can you make about this state of matter from your observations? How did the results of the demonstration compare with your prediction? If your prediction differed from the results, record why you think they were different.

Water

- What happened to the volume of the water as it was moved from one container to another? What happened to the shape of the water as it was moved from one container to another? What conclusions can you make about this state of matter from your observations?

How did the results of the demonstration compare with your prediction? If your prediction differed from the results, record why you think they where different.

Air

- What happened to the volume of the air as it was moved from one container to another? What happened to the shape of the air as it was moved from one container to another? What conclusions can you make about this state of matter from your observations? How did the results of the demonstration compare with your prediction? If your prediction differed from the results, record why you think they were different.

Communicate

With the class, discuss the results of the demonstration and your conclusions about the states of matter you observed.

- Come to an agreement about how the shape and volume of the different states of matter you observed changed because of the container.
- Develop a statement about how each state of matter can be described by its shape and volume.

How Is One State of Matter Different From Another?

The word **macroscopic** is used to describe observations that you can see with your unaided eye. In the demonstration, you observed the three states of matter.

The wooden dowel represented the **solid** state of matter. A solid maintains its shape and volume regardless of its container. Its shape and volume do not change whether it is in a bottle, a beaker, a bowl, or any other container.

Water from the faucet represented the **liquid** state of matter. A substance in the liquid state does not change its volume, but its shape can change. A liquid takes on the shape of its container. Whether in a bottle, a beaker, or a bowl, the water will have the same volume. However, its shape is the same as its container. This is true for all liquids.

macroscopic: a word used to describe an observation that can be seen by the unaided eye.

solid: matter that has a definite shape and volume and an organized arrangement of particles that remain very close together and vibrate slowly.

liquid: matter that has a definite volume but not a definite shape. A liquid takes the shape of its container. The particles remain close together and slide past each other in a fluid motion.

gas: a gas: matter that has no definite shape or volume. A gas takes the shape and volume of its container. The particles are far apart and move rapidly and randomly.

microscopic: things you cannot see with your unaided eyes.

atom: the basic building block of matter.

element: the simplest type of substance made up of identical atoms.

molecule: a combination of two or more atoms.

particle: atoms and molecules that make up substances.

thermal energy: the energy of motion of the particles of matter in a substance.

heat: the transfer of thermal energy from a warmer substance to a cooler one.

The air in the bottle represented the **gas** state of matter. Neither the volume nor the shape of a gas is constant. At first, the volume and shape of the air were determined by the bottle. A gas must be enclosed in some kind of closed container to have a measureable volume or a definite shape. When the bottle of air was emptied into the beaker, you could not see what happened to the air. The air took the volume and shape of its new container—the room, not the beaker. Some of it may have gone into the beaker, but you could not tell because you could not see the air.

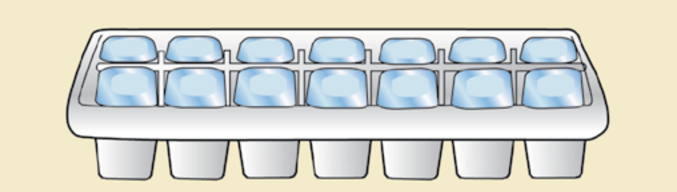
What is it that makes one state of matter different from another? The answer has to do with the structure of matter that you cannot see with your unaided eyes. Characteristics you cannot see with your unaided eye are called **microscopic** characteristics. All matter is made up of very small particles. The building blocks of matter are known as **atoms**. An atom is so small that trillions of atoms can fit on the head of a pin. You cannot see an atom.

The simplest type of substance made up of identical atoms is called an **element**. Hydrogen, oxygen, and helium are some elements with which you may be familiar. There are over 100 known elements.

Atoms of different elements can combine to form a variety of substances. A combination of at least two atoms can form a **molecule**. Substances such as water are made up of individual molecules. Each water molecule consists of two atoms of hydrogen and one atom of oxygen.

The atoms and molecules of substances are generally known as **particles** of matter. The particles within a substance are held together by forces of attraction. In other words, they are pulled together. The strength of the forces between them depends on the energy they have. Energy exists in many forms. Some objects have energy because they are moving. Other objects have stored energy in them. The energy of the motion of the particles in a sample of matter is known as **thermal energy**.

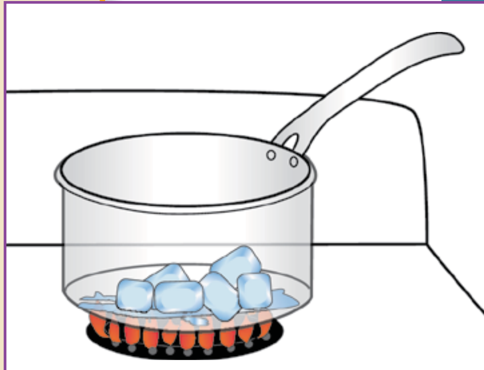
Thermal energy can be transferred from one sample of matter to another as **heat**. When you heat a sample, you increase the thermal energy of its particles. When a sample cools, the thermal energy of its particles decreases. How does this affect the state of matter? To figure it out, consider water as an example.



When the temperature of liquid water reaches the freezing temperature, it changes from liquid to a solid.

You may have made ice cubes in a freezer. The ice cubes are water's solid state. The particles in the ice cubes barely move. They can only vibrate in place. The force of attraction between the particles is strong, and they are held together. They retain a constant shape and volume.

Suppose you place the ice cubes in a pot on a stove. As you heat the ice, you transfer thermal energy to the water molecules. This causes the molecules to vibrate faster and faster. Their energy of motion increases. **Temperature** is a measure of the average speed of the molecules. The temperature of the ice cubes increases as they are heated.



When the temperature of ice reaches the melting point, ice changes from a solid to a liquid.

At a certain temperature, the molecules become so energetic that they overcome the forces of attraction between them. The solid ice becomes liquid water. The particles of the liquid are still strongly attracted to one another, but they are not held as tightly together as those in the solid. Now they are free to flow smoothly past one another.

The temperature at which a solid changes into a liquid is known as the **melting point** of a substance. The melting point of water is 0°C (32°F). The process of melting occurs at the melting point. Once a substance reaches the melting point, it continues to absorb energy. However, the temperature does not change. The increased energy is used to overcome the forces of attraction. Once the solid is completely changed into a liquid, any additional energy causes the temperature to start rising again.

If you continue to heat the liquid water, the molecules will move even faster. At a certain temperature, the molecules become so energetic that the forces of attraction can no longer hold the molecules together. The liquid changes into a gas. The gaseous state of water formed in this way is known as steam. The temperature at which a liquid changes into a gas is known as the **boiling point**. The boiling point of water is 100°C (212°F). The process of boiling occurs at the boiling point.

temperature: a measure of the averge speed of the particles of matter. Temperature changes as the particles move faster (warmer) or slower (colder).

melting point: the temperature at which a solid changes to a liquid.

boiling point: the temperature at which a liquid changes to a gas.

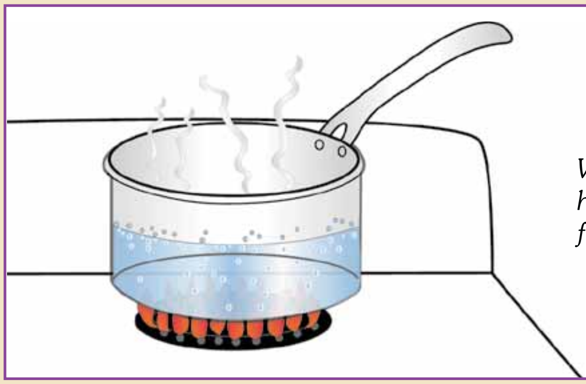
evaporation: a change from a liquid to a gas at a temperature that is lower than the boiling point.

condensation: the process in which a gas cools to form a liquid.

freezing: the process in which a liquid cools to form a solid.

freezing point: the temperature at which a liquid turns into a solid.

sublimation: the process of a substance changing directly from a solid to a gas.



When water becomes hot enough, it changes from a liquid to a gas.

You might know that a puddle of water can slowly disappear throughout the day. The water does not actually disappear, however. The liquid water in the puddle changes into a gas in the air without boiling.

A change from a liquid to a gas at a temperature that is lower than the boiling point is known as **evaporation**.

A change from one state of matter to another is known as a change of state. The changes of state can be reversed by cooling a substance. When a substance cools, thermal energy is transferred out of it. When a gas loses energy, the particles slow down and stay closer together. When the particles slow down enough so that the forces of attraction can hold them together, the gas changes into a liquid. The process in which a gas cools to form a liquid is known as **condensation**. The temperature at which a gas condenses is the same as the boiling point.

If the liquid cools, the particles slow down even further. When the particles slow down enough, the forces of attraction between them can hold them tightly enough to form a solid. The process in which a liquid cools to form a solid is known as **freezing**. The temperature at which a liquid freezes is the same as the temperature at which a solid changes into a liquid. This temperature is called the **freezing point**.

Generally, substances change from solid to liquid to gas, or they change from gas to liquid to solid. Some substances, however, can change directly from a solid to a gas in a process known as **sublimation**. The solid ice in a comet, for example, changes into a gas when the comet travels near the Sun. This sublimation forms a streak behind the comet that people on Earth can see.

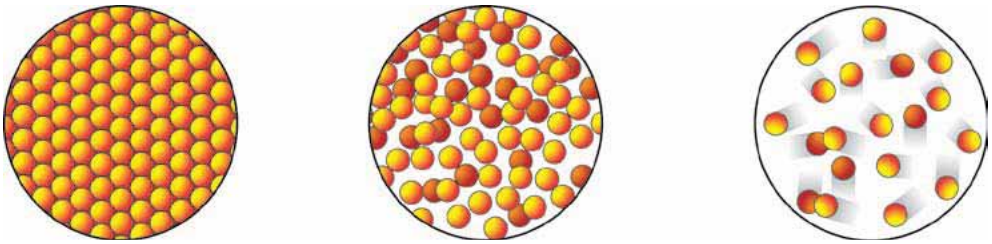
The tail of a comet is the sublimation of ice to gas.

Stop and Think

1. List three solids not discussed in this section. How do you know they are solids? Discuss the characteristics that indicate they are solids.
2. List three liquids not discussed in this section. How do you know they are liquids? Discuss the characteristics that indicate they are liquids.
3. List three gases not discussed in this section. How do you know they are gases? Discuss the characteristics that indicate they are gases.
4. List two characteristics that solids, liquids, and gases have in common.

Conference

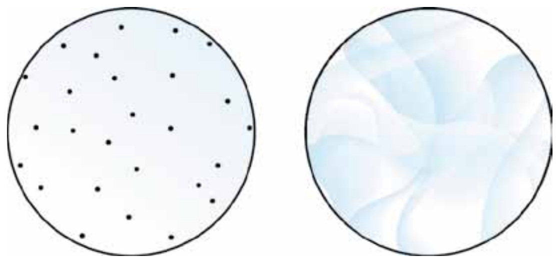
To understand the differences between the particles in solids, liquids, and gases, study the three diagrams below. In these diagrams, each small circle represents one particle. In general, matter can exist in three states: the solid state, the liquid state, and the gas state. Each of these diagrams represents one of these states of matter. Discuss the diagrams in your group and come to an agreement about which state of matter each diagram represents. Use evidence from the demonstrations and your reading.



You have read about particles of matter and the forces of attraction between them. You know some of the characteristics of states of matter. You should now have more of an idea of what air looks like. When you began this Unit, you sketched what you thought air looks like if seen through a powerful tool.

Most of your sketches were probably like one of these.

Now that you have more information about states of matter, discuss the pictures with your group. Which of the pictures do you think is more accurate, based on what you now know about air? Use evidence from the demonstrations and your reading.



How do you see air?

Reflect

1. When workers make gold bars, they must first melt the gold by heating it to a very high temperature. Describe what is happening to the particles that make up the gold when it is melted. In your answer, use the terms: states of matter and forces of attraction.

2. You put mothballs in a closet and leave them for a long time. Mothballs are made of a solid chemical substance called camphor and are used to keep moths out of clothing. They have a very strong smell. When you open the closet again, the mothballs are much smaller. You cannot find any evidence of liquid on the floor. What do you think happened to the mothballs? Why are they smaller?

What Is the Fourth State of Matter?

plasma: a state of matter that forms from gases at very high temperatures.

You have investigated three states of matter: solids, liquids, and gases. Almost all the matter on Earth is in a solid, liquid, or gas state. But scientists have studied the universe and found another type of matter that is rare on Earth. Scientists call this state of matter **plasma**. Plasma is closely related to gases and forms from gases only at very high temperatures. Ninety-nine percent of all the matter that can be observed in the universe is plasma. At extremely high temperatures, such as those on the Sun and other stars, matter exists as plasma. On Earth, plasma exists naturally only in the outer atmosphere and is responsible for the Aurora Borealis (Northern Lights) that can be seen in the sky in Earth's Northern Hemisphere. Through technology, scientists have developed "cool" plasma to make neon signs, fluorescent lights, and plasma (television and computer) displays.

The Aurora Borealis is an example of plasma, the fourth state of matter.

Model and Simulate

States of Matter

The demonstrations you observed and the reading you did provided information to help you describe the characteristics of states of matter. Now you will design and run a simulation to show how the molecules are arranged and move in solids, liquids, and gases. In your simulation, 12 students will use their bodies as model particles. They will simulate the arrangement and motion of particles in solids, liquids, and gases, and they will stay within a "container," a designated area on the floor.

Plan Your Simulations

1. Your goal is to arrange 12 classmates in a "container" and have them simulate the arrangement and motion of particles in solids, liquids, and gases. Agree about how you want to arrange and move your student "particles" for each state of matter—solid, liquid, and gas. The diagrams you analyzed, the demonstrations you observed, and your class discussions should help you as you plan.
2. With your group, write detailed instructions stating how the students should arrange themselves and how they will move when they simulate each state.

Run Your Simulation

When everyone has finished writing their simulation plans, 12 classmates will run each simulation. When it is your group's turn, read your instructions to the simulators. They will do what your instructions say.

When you observe the students running your simulation, pay attention to exactly how they are carrying out your directions. Note any differences in what you think you wrote and how the students are following your plan. Pay attention to what the students find simple and what they find more difficult. Also pay attention to how the simulation is similar to, or different from, the information you read earlier.

When it is time for your group to act as model particles in another group's simulation, follow the directions in their simulation plan as exactly as you can.

After the simulations are run, compare what you think you wrote in your simulation to what actually happened during the simulations. Compare the simulations run from your instructions to other simulations. Identify places where your simulation plan needs to be more specific or accurate.

Communicate

As a class, discuss the accuracy of the simulations. Use your notes to discuss how each simulation matched the information you read on particle arrangement and movement. How did each simulation differ from what you read and understood about characteristics of states of matter? How could you rewrite each simulation plan so that it is more accurate?

Together, write a simulation plan that accurately shows the arrangement and movement of particles in each of the states of matter you studied. Check to see that all the directions make sense. Come to an agreement about particle arrangement and movement for each of the states of matter.

Characteristics of the States of Matter

In class, you observed the characteristics of model particles in three different states of matter by observing a simulation of how the particles are arranged and how they behave.

When your classmates were simulating molecules in the solid state, they

- were lined up orderly;
- were closely packed together;
- moved a little bit, but very slowly (vibrated, rocked back and forth); and
- could not move to a different location in the container.

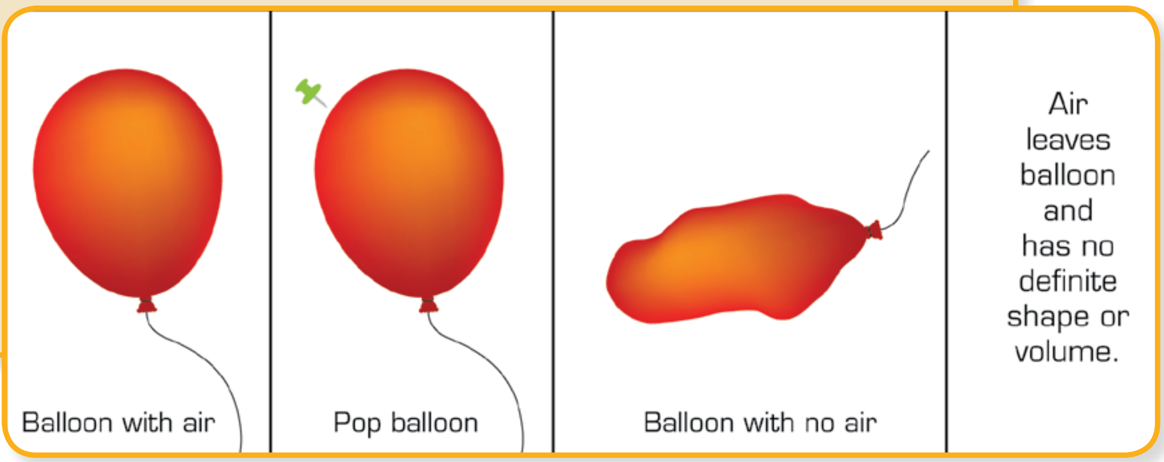
When your classmates simulated molecules in the liquid state, they

- were close together but randomly arranged;
- moved slowly but randomly about the “container”; and
- slid past one another.

When your classmates simulated molecules in the gas state, they

- were spread as far apart as possible within the container;
- were randomly arranged; and
- moved rapidly and randomly, bumping gently into one another.

Think about the air you investigated. Air is a gas. You are already familiar with the properties of some gases. When a balloon is filled with a gas such as helium, the balloon looks round. The gas inside the balloon takes the shape of its container. You could measure the balloon and determine the volume of gas inside. If you pop the balloon, the gas rushes out, and the balloon deflates. A gas cannot keep its shape without being in a container. When the balloon is popped and the gas is released, the gas particles move farther and farther apart until they are prevented from moving any farther apart by another container, such as the walls of a room, or until they reach a point where they are equally spread apart. When this happens, the gas particles continue to move quickly but will stay far apart.



Reflect

You now know how the particles of a solid, liquid, and gas are arranged and how they move. Use what you know about these states of matter to answer the following questions. Discuss the answers to the questions in class.

1. A factory located 16 km (about 10 miles) out of town releases gases into the air through its smokestack. What happens to these gases?
2. A truck on the highway 16 km (about 10 miles) out of town spills a liquid pollutant onto the roadway. This liquid changes to a gas at 26.6°C (80°F). What happens to this pollutant if the temperature outside is 7.2°C (45°F)? 32.2°C (90°F)?

3. Another truck on the same highway carries garbage. This waste releases pollutants into the air when it is burned. The truck runs off the road, spills its cargo into a ditch, and catches on fire. What happens to the particles in the garbage?

Update the *Project Board*

In this section, you explored the characteristics of solids, liquids, and gases. Use what you learned about how particles of matter are arranged and move to update the *What are we learning?* column of your *Project Board.* The demonstration, reading, and simulation are your evidence. Be sure to add this evidence to the *What is our evidence?* column. You should be coming to a better understanding of what air is, but you probably still have some questions and investigations you would like to carry out. Enter these in the *What do we need to investigate?* column.

What's the Point?

Matter commonly exists in three states on Earth: solid, liquid, and gas. Solids have a definite volume and definite shape that does not depend on the container. Liquids have a definite volume but not a definite shape. Liquids take on the shape of their container. Gases have no definite volume or shape. They take on the volume and shape of any container.

The arrangement and movement of particles of matter are different for different states of matter. In solids, the particles are organized, tightly packed, and vibrate slowly. The particles of a liquid are less organized than in solids and slightly farther apart. The particles can move about and slide past one another instead of just vibrating in place. In a gas, the particles have no organization and move rapidly, collide with one another, and expand to fill the available space.

The particles of matter in a substance are held together by forces of attraction. As a sample of matter gains or loses energy, the particles are held more tightly together or more loosely. As a result, the sample can change from one state to another. Matter can change from a solid to a liquid to a gas by gaining energy through heating. Matter can change from a gas to a liquid to a solid by losing energy through cooling.

More to Learn

Investigate Changes in State

A change in thermal energy can cause matter to change state. Increasing the amount of energy of the particles of matter can make a solid change to a liquid or make a liquid change to a gas. In this investigation, you will heat ice cubes on a hot plate and record the changes in temperature and make observations about the changes in state. Record all your data in the data table on a *Changes in State* page.

Before you get started, set up your equipment like the equipment in the picture. Be sure you attach the clamp firmly to your thermometer, and attach the clamp to the ringstand.

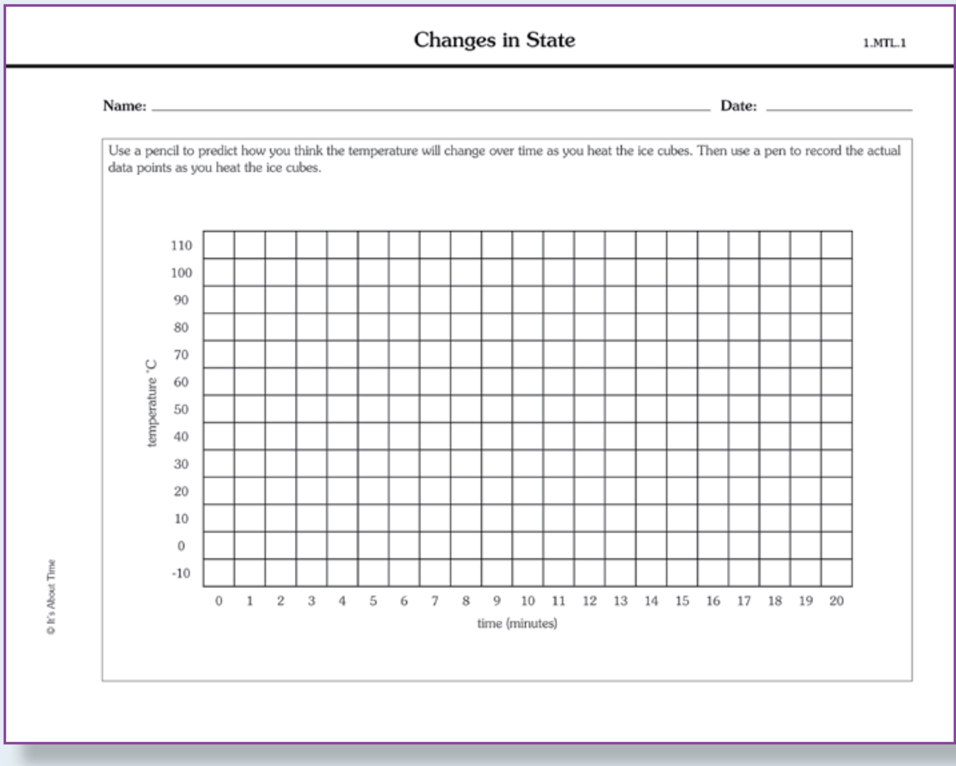
Get Started

1. Place five ice cubes in a beaker. Set the beaker on the hot plate. Insert a thermometer in the ice cubes.
2. Stir the ice cubes with the stirring rod and record the temperature on your *Changes in State* page in the box for 0 min Time.

Materials

- 5 ice cubes
- 250-mL beaker
- hot plate
- ringstand with thermometer clamp
- thermometer
- stirring rod
- access to power
- graph paper
- pencil
- pen
- stopwatch
- safety glasses

Be sure to wear your safety glasses. After turning on the hot plate, do not touch the hot plate or the outside of the beaker with your fingers. When stirring the ice cubes with the stirring rod, be careful that you do not break the thermometer. Leave the thermometer attached to the rod, as shown in the picture.


Changes in State 1.MTL.1

Name: ______________________ **Date:** __________

Use a pencil to predict how you think the temperature will change over time as you heat the ice cubes. Then use a pen to record the actual data points as you heat the ice cubes.

3. Look carefully at the graph on your *Changes in State* page. This graph will show the changes in temperature compared to the time that the ice in the beaker is on the hot plate. Make an X on the graph at time 0 min for the temperature you recorded.

4. Using a pencil, predict the shape of the graph over the time the beaker is on the hot plate. Sketch the shape you think the graph will be.

Do not touch the hot plate or the beaker with your fingers.

Increase the Energy

1. Turn the hot plate on medium heat.

2. While stirring the ice cubes with the stirring rod, record measurements of temperature and changes in shape or volume in the data table.Record the temperature every minute and record changes as they appear.

3. Continue heating and recording until the matter in the beaker reaches a temperature of 100°C (212°F).

Analyze Your Data

One way to analyze data is to create a graph. Put a dot on your graph for the temperature at each time (0 min, 1 min, 2 min, and so on). Using a pen, connect the dots with one line, beginning at time 0 until 20 min. Place an X on the line in each place where the direction of the line changes. Then answer the following questions.

1. How does the shape of your temperature line compare to your prediction?
2. What about the two lines was the same? What was different?
3. What was the temperature at the points where you placed an X? What observations did you make about the state of matter in the beaker at each of the X's?
4. How do the points where you put the X's match up to the melting and boiling points of water?

Reflect

Discuss with your group the data you graphed.

1. What happened when the temperature began to change the first time? What do you think scientists call that point?
2. What happened when the temperature stopped changing the second time? What do you think scientists call that second point?
3. How many state changes did you observe?
4. The temperature and your observations indicate what is happening at the macroscopic level. What do you think is happening to the ice at the microscopic level? That's is, what do you think is happening to the particles of matter? Describe the motion of the molecules of water at each place where you put an X on your graph.

Communicate

Share your group's graph of the temperature data. Also share your ideas about the X points and what you think is happening to the water molecules.

Reflect

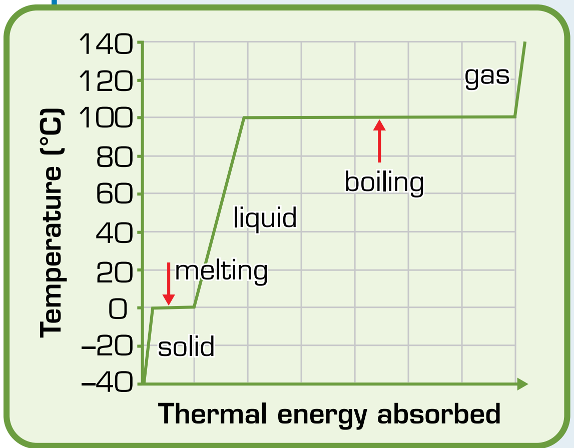
1. Some parts of the world are much warmer than others. Some days or times of the year are warmer than others. How do you think air temperature might affect air pollution?

2. How do you think heating or cooling could be used to remove pollutant gases from a factory's exhaust before that smoke leaves the smokestack? What would happen to the pollutants?

3. Scientists have found pollutants even in the ice of Antarctica. How might a warming of Earth's climate affect air pollution?

Heating Curve of Water

A type of a graph known as a heating curve can be used to trace changes of state for a specific substance. The graph below shows the heating curve of water. You can see that temperature is plotted along the vertical axis, or *y*-axis. Thermal energy is plotted along the horizontal axis, or *x*-axis. As thermal energy is added to solid ice, its temperature increases until it reaches 0°C—water's melting point. At this temperature, the graph becomes a flat line. The line shows that the temperature does not change, even though thermal energy is being absorbed. You read earlier that this thermal energy acts to overcome the forces of attraction between the water molecules. When the graph is flat at 0°C, water is changing from a solid to a liquid as thermal energy increases.



Once the sample of water is a liquid, the temperature rises again as it absorbs thermal energy. The temperature rises until it reaches 100°C—water's boiling point. Again, the graph becomes flat because the temperature stays the same, even though more thermal energy is absorbed. At this temperature, the thermal energy acts to overcome the forces of attraction holding the molecules in the liquid state. The liquid changes to a gas. Once the sample is in the gas state, the temperature rises again as it absorbs thermal energy.

You can trace the heating curve in the opposite direction to find out what happens as gaseous water loses thermal energy to become a liquid, and liquid water loses thermal energy to become a solid.

Learning Set 1

Back to the Big Question

How can you improve air quality in your community?

To understand air quality, you must first understand that air is matter and that samples of matter can be described by their physical properties. Matter is one of the many words that have a specific meaning in science. A person may say that a bottle of soda is empty or that a bus is empty. Even though the bottle does not have any soda in it or the bus has no passengers in it, neither object is "empty" in a scientific sense—they still contain air.

When you investigated whether air has volume, you started with a cup that looked empty. From your investigations, you determined that the cup was not really empty; it contained air. Then, when water entered the cup, it pushed out the air and occupied the space the air had initially taken. In this way, you were able to conclude that air has volume.

Everything on Earth is matter—air, water, soil, and all living things.

Then you observed a demonstration with a deflated ball. When air was added to the ball, the total mass of the ball increased. After observing that, you were able to conclude that air has mass.

Because air has volume and mass, air is matter. You read about matter being made up of particles. These particles may be packed tightly together or spread far apart. Because air is matter, air is also made up of particles. Air can be described as a gas because of the arrangement and motion of its particles. The motion and arrangement of the particles of matter determines the state of matter.

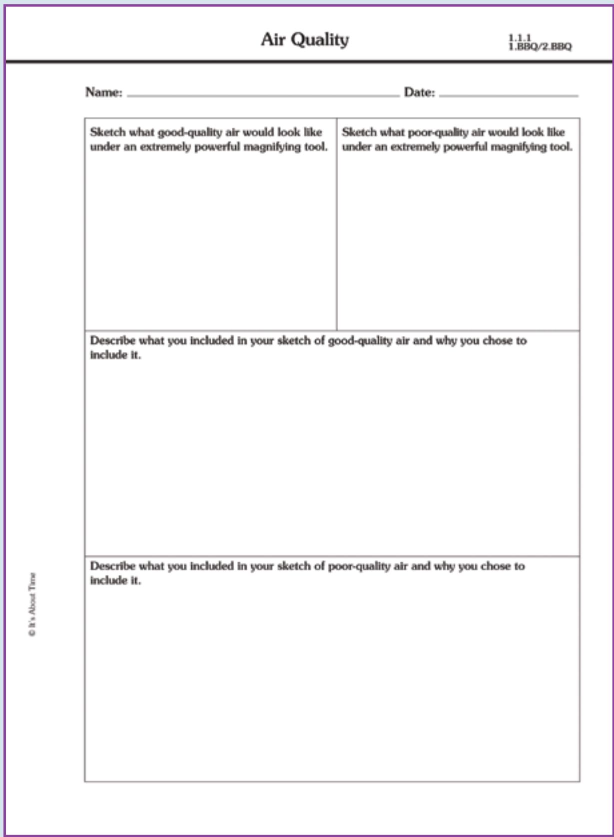
Update Your Sketch

What Does Air Look Like?

In your first sketch of good-quality air, you may have sketched air as an empty space because you cannot see air. After your investigations and readings, how would you now sketch good air?

Again, imagine you had a very powerful tool and that you could use it to look at samples of air. What do you now think good-quality air would look like?

Using what you know about air, update your sketch of good-quality air. Sketch your picture using as much detail as you can. Use a new *Air Quality* page for your sketch. Be prepared to describe what you included in your sketch and why you chose to include those specific details.


Air Quality

1.1.1
1.BBQ/2.BBQ

Name: ______ Date: ______

Sketch what good-quality air would look like under an extremely powerful magnifying tool.	Sketch what poor-quality air would look like under an extremely powerful magnifying tool.

Describe what you included in your sketch of good-quality air and why you chose to include it.

Describe what you included in your sketch of poor-quality air and why you chose to include it.

© It's About Time

Conference

In your group, discuss what you now think good-quality air looks like. Share and discuss your sketch and the descriptions of what you included in your sketch. Compare your new sketch with the first one you completed earlier in the Unit. How do they differ? What things does your new sketch include that your first sketch did not include?

Communicate

Share your sketches of air with the class. Compare them to the sketches of others in the class. As a class, come to an agreement about what good-quality air would look like under an extremely powerful magnifying tool.

Revise Your Explanation

As a class, revise your claim and explanation of air as matter. Be specific about the type of matter air is. Make your claim based on the results of the investigations and demonstration, your class's previous explanations about whether air has volume and mass, and other class discussions. Then identify the evidence and science knowledge that support your claim. The results from investigations and demonstrations are your evidence. Then, as a class, develop a new statement that connects the evidence and science knowledge to your claim. This is your explanation.

Communicate

Share Your Explanations

When everyone is finished, you will share your explanations with the class. As each group shares theirs, record the explanation. You might also create a poster for the classroom that has a full set of explanations on it.

Revise Your Explanation

As a class, develop a class claim. Be sure to identify the supporting evidence and science knowledge. The results from investigations and demonstrations and your class discussions are your evidence. Then develop an explanation statement that connects the evidence and science knowledge to the claim in a way that convinces others that the claim is correct.

Reflect

Work with your group to answer the following questions. Be prepared to share your answers with the class.

1. Look back at the pictures from the beginning of this *Learning Set.* You now know that air is matter in the gas state. Use what you know to critique your decisions about which pictures represent sources that improve air quality. Which of your decisions would you now change? Support your answer with evidence.

2. Use what you know to critique your decisions about which pictures represent sources that worsen air quality. Which of your decisions would you now change? Support your answer with evidence.

3. Which of the pictures remind you of scenes in your community? Why?
4. What new questions do you have about air now that you know it is matter in the gas state?
5. Think about air as matter with volume and mass. What new questions do you have about air pollution?
6. Think about the characteristics of the different states of matter and how they are affected by temperature. What new ideas and questions do you have about managing air pollution in your community?

Update the *Project Board*

In this *Learning Set,* you investigated air to determine if it is matter. You looked at two characteristics of matter—volume and mass. You also investigated three different states of matter, how the particles in them move, and how the states of matter are related. Now it is time to update the *Project Board.* Add to the *What are we learning?* column what you have learned about air. Be sure to add your evidence to the *What is our evidence?* column to support your new knowledge. Record in the *What do we think we know?* column anything you now think you know about air pollution and about air pollution in your community. Record questions you have about air, about air quality in your community, and about managing air quality in your community in the *What do we need to investigate?* column.

What items in this picture have volume and mass?